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BUILDINGS AND ARCHITECTURE
#1

ARCHITECTURAL MORPHOLOGY AND USER BEHAVIOR RELATIONSHIP IN SHOPPING MALLS:
A Comparative Case Study on Forum Shopping Centers in Istanbul through Syntactic Analysis

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ABSTRACT

In this study, the impacts of configuration and tenant types on user movement in shopping malls are examined using space syntax techniques focusing on natural movement theory. One of the main statements of space syntax methodology is the “natural movement theory” where human movement is effected by the configuration of space (Hillier et al., 1993). It is also set forth that spatial behavior is dependent upon individual evaluation and relative assessment of spaces (Downs, 1970). In this context, the study is examined as a comparative case study in two frequently visited shopping malls of Istanbul independently but with the same methodology depending on the observation of users and data collection methods. The selected malls have similar approaches in terms of user interfaces, configuration, and the brand distribution that have independent display spaces within the mall. Furthermore, they are built and managed by the same company and have similar architectural and management layouts at different locations of Istanbul. In that sense, how plan configuration and shop types affect users’ behaviors is investigated by space syntax methodology through the awareness of visual perception, shopping behavior, integration of spaces, the order in circulation areas, and the level of interaction between the spaces as well as the people that are visiting these malls. The goal is to examine whether the spatial layout or the content is affecting individuals’ decisions, and what kind of dominant effects they have on user movement at these shopping malls. According to some results in this study, spatial configuration is more dominant on users’ movements where it has a strong syntactic value such as connectivity or integration, however content is dominant where syntactic value is not very strong. The further discussion is how these findings may affect the future of shopping malls in terms of architectural design and spatial configuration in connection with the interior design decisions.

KEYWORDS

Shopping behavior, spatial configuration, integration, shopping mall, movement
1. INTRODUCTION AND THEORY

Shopping malls, in spite of their rapidly emerging existence in the recent decades, have been overspreading expeditiously and become an important part of urban life in Turkey. As well as providing one of the most basic activities like marketing, they are also new centers of social interaction and attraction, serving as public spaces of its kind. Victor Gruen (1976), the architect of the first modern shopping mall, claims that in order to provide a healthy urban social life, it is needed to create public spaces isolated from urban problems where people get in social interaction out of work or house. Likewise, today shopping malls are urban spaces where people come together, socialize and engage in socio-cultural and recreational activities besides many opportunities for shopping needs in a comfortable and safe space. In accordance with the sense of safety and comfort, many environmental factors are under control such as car traffic, security, air conditions, odor, pollution and noise. Hence, their architectural structures are vital because of being a key component of physical environment that have crucial impacts on visitors (White & Sutton, 2001; Erkip, 2003; Fong, 2003; Kurubayashi & Kishimoto, 2009; Kim et al. 2012). One of the foremost aims of shopping malls is attracting people to shops and supporting activity spaces as much as possible and it is expected that architectural design and spatial configuration should also motivate people for spending more time in these spaces, wander around and shop as much as possible. In this context, as Hillier et al. (1993) note in Diagram 1, beyond the relationship between visitor frequency and the configuration of the space in shopping settings, depending on the morphology of convex spaces as a whole, while attractors and movement may be mutually influential, the other two relationships are asymmetrical. The configuration may influence the location of attractors, but the location of attractors cannot influence configuration. Likewise, the configuration may influence movement, but movement cannot influence configuration. If strong correlations are found between movement and both configuration and attractors, the only logically possible lines of influence are from the configuration to both movement and attractors, with the latter two factors influencing each other. In this study, the relationship between visitor frequency and configuration is analyzed in detail; the attractors, namely, the shops or displays, are also considered in this relationship through certain critical semantic contributions within the overall space.

Diagram 1 - Attraction, configuration and movement (Hillier, et. all., 1993).

In regard to these circumstances, there are many researches, but we believe that there is much to do as further studies on spatial configuration and visitor behavior in shopping malls. Further studies are crucial for understanding the cultural differences of users and also differences at architectural approaches as well as management decisions in different malls. In that sense, our study intends to examine shopping behavior in shopping centers, as it is defined as shopping malls in the title of our study, of Istanbul through a comparative case study. The case study has been conducted in Istanbul by comparing two shopping centers, Marmara Forum Shopping Center (Marmara Forum SC) and Forum Istanbul Shopping Center (Forum Istanbul SC), which were built by the same business management. In this study, it is hypothesized that distribution
of shop types and the spatial configuration have significant affects on visitors’ frequency and their movement at shopping malls. For this study, syntactic analyses of spatial layout and observations of the users in the selected malls were made in order to make a comparison and examination of the spatial configuration’s traces. Distribution of shop types in relation with movement of visitors by using space syntax theory and methodology are also examined. Syntactic measures coming from such analysis of integration, connectivity, circularity, etc. are crucial for the comparison in this study. Through these measures “circularity” was a measure that reflects the relation with the geometry of space and has a tendency to decrease in a structure in which the interconnecting convex spaces among all spaces are tightened, narrowed and concentrated on a single field with a high mean integration. A decrease in the value is an indicator of gradual differentiation throughout the plan of the general averages of the mean 2D geometrical dimensions. Briefly, this value is accepted as an indicator of dimensional tightening of the convex spaces. Circularity value acts inversely with the compactness value. It could be inferred from the circularity value that the differences among the lengths of the plan morphologies in the second dimension (i.e., the increasing differentiation of width and length values in a convex space) begin to increase as this value increases and that the plan center began to shift towards the perimeters as this value increases. Alternatively, the convex spaces with different integration values throughout the plan begin to overlap in a single narrow field with a high integration value and visitors may be forced to use this field as a connection field due to tightening of the interconnecting areas among the convex spaces. The circularity value has the tendency to increase in these interconnecting, tightening spaces. The results coming from circularity should be interpreted and discussed particularly around the “integration” and “connectivity” values since connectivity values reflect the local shallowness or deepness within the configurational system where integration reflects a more global set of values.

In this study, perception and movement related issues should also be grasped in order to understand the morphology of shopping layouts through their syntactic and semantic dimensions. Kuipers et al.’s (2003) study on the cognitive maps of movement of the people describes how visual perception and cognition plays a key role in the processes of navigation, movement, and wayfinding. In relation with the shopping settings, visual perception and accessibility of the spaces also play a significant role in movement and wayfinding. Dalton’s (Zimring & Dalton, 2003) approach to decisions of people in terms of visual perception of the space that is similar to Kuipers et al.’s (2003) approach, Zimring & Dalton (2003) was interested in decisions that people head to during their navigation and in route choice decisions that are made at path junctions. "She created an environment in which participants were presented with a variety of different junction types and then noted the sequence of decisions.‖ (Zimring & Dalton, 2003). Dalton (Zimring & Dalton, 2003) found that “Angles that deviated least from a continuous straight heading were preferable to sharp turns..” Another interesting finding was “a strong evidence that participants tended to select routes that approximated a straight line and avoided routes that were particularly convoluted or meandering.” (Zimring & Dalton, 2003).

2. DATASETS AND METHODS

Shopping centers have become an important part of urban life by offering a sense of order, safety and comfort through the spaces while matching users’ demands for shopping and spending leisure time. Upon these demands, researchers have focused on their spatial dynamics, spatial use and social structure that lead people and also generated by people. Likewise, there are many factors that attract people to a shopping center such as plenty of shopping opportunities, physical conditions, variety of social and entertainment activities, and need for a secure space. All these factors may also affect the use of shopping centers (Goss, 1993; Akinci, 2013). Besides, there are many factors that affect the preference of users for a visit to a shopping center. According to some studies, preference is connected with travel time and size of the shopping center, where these important factors also increase frequencies of visitors in shopping centers (Shiffman, 1983; Bloch et al. 1994; Salcedo, 2003; Erkip, 2003). In addition to distance, factors like travel time, easy accessibility, being on the way home and so on, people also prefer the shopping mall according to their personal demands (Erkip, 2003; Akinci, 2013). For instance,
Forum Istanbul SC is a shopping mall, which is on an easy access point with many shopping advantages; however, consumers who live close to Marmara Forum SC are inclined to prefer Marmara Forum SC as the closer shopping center according to these findings. On the other hand, in case of a target product, consumers prefer shopping centers with more distance in order to provide their need as allegedly that a human takes the action after mostly personal impulse or a specific purpose (Penn, 2003; Garip & Ünlü 2009). Preferences inside of shopping centers are as important issue as preferences of shopping centers in urban context. Intervening variables like attractors or product placement in supermarkets partially divert movement flows within buildings (Salier, 2007; Gil et al, 2009; Garip & Ünlü, 2009).

Besides all, recent studies also have focused on spatial use of shopping malls and examined spatial configuration and its impacts on use (Fong, 2003; Erkip, 2003, 2010; Kurubayashi & Kishimoto, 2009; Kim et. al. 2008). Likewise, the theory of space syntax argues that buildings act fundamentally in relation with the movement, how it is generated and controlled (Hillier, 1996; Hillier, et. al., 1993). There are many findings that spatial structure led the movement in space. For example, in terms of syntactic factors, it is found that more integrated spaces were more vivid and haunted by more visitors while more segregated spaces were less crowded (Penn & Sailor, 2010). As well, people tended to center upon the places with high connectivity while low connected places tended to be less used (Nubani & Wineman, 2005). Through this phenomenon, environmental aspects in the context of spatial hierarchy within a building complex or in an exterior environment like a public square or a park influencing the common flows of movement is defined with “Natural Movement Theory” (Hillier et al., 1993; Hillier and Iida, 2005). In this context, we may argue that people move under the effects of environmental aspects, and spatial configuration drives movement flows in building space in accordance with their configurations and spatial order within the spaces. In this context, our study compares the effects of content and physical structure in terms of natural movement theory by observing users in two shopping malls.

2.1 COMPARISON OF LOCATIONS AND ARCHITECTURE OF FORUM ISTANBUL AND MARMARA FORUM SHOPPING CENTERS

Istanbul is a crowded city with lots of outdoor and indoor public spaces such as squares, parks, cultural centers, and theaters where people find opportunities to social interaction and engage in various social, cultural, entertainment activities. Anyhow, shopping centers are still favored by citizens even though having limited indoor area, limited opportunities and limited variety of activities and shopping centers became public spaces that people with any profile come to spend their leisure time and have fun (Erkip, 2003, 2005; Akinci, 2013). The selected shopping centers, Forum Istanbul SC and Marmara Forum SC are also amongst the most visited shopping malls in Istanbul. These two shopping malls are two of 117 shopping centers in this city in different locations and also built and managed by the same company. Therefore it is thought that they are built on common expectations and architectural views basically. Thus, it is found reasonable to examine and compare these shopping malls and get further information about how spatial morphology affects users in shopping centers.

First of them, Forum Istanbul SC, with a total construction area of 495,000 square meters in Bayrampaşa, is the biggest shopping center of Istanbul and one of the biggest shopping center of Turkey, also of Europe. This center hosts nearly 300 national and international brands providing almost any kind of shopping needs; retail, technology, sport brands, jewelry brands, kid stores, food and any goods. Besides that, it also hosts entertainment areas on many different concepts as attractive factors in order to offer a public place inviting visitors without shopping motives. Moreover, it has an easy accessibility for both cars and public transportation, as it is being located at the junction of E5 and TEM highways, and directly connected with the metro lines. Easy accessibility influences the preferences about which shopping mall to go and how much time will be spent in there (Bloch et al. 1994; Saucedo 2003).

Forum Istanbul SC is located at Bayrampaşa neighborhood, which is a new urban area having an expeditious development in recent years. Bayrampaşa has a dynamic economy standing on trade and industry and growing with its high population density and good social, educational
and health services. Similar to atmosphere of Bayrampaşa, the main design idea of Forum Istanbul SC is creating an atmosphere of a vivid city; its interior has an architecture based on a shopping district life with squares and streets along with the general view of vernacular architecture with a combination of various identities. In other words, Forum Istanbul SC gives an outside atmosphere inside the building with secure and controlled spaces within the spatial configuration of the building.

The other shopping center of this comparative study, Marmara Forum SC comprises 135,000 square meters of rental space located in Merter with an access from any point of Istanbul, providing almost any kind of shopping needs same as Forum Istanbul SC, with nearly 300 national and international brands. Marmara Forum SC also has entertainment areas for temporary events to get attention as similar to Forum Istanbul. Besides, its location is close to E5 highways as well and close to one of the main transportation nodes of Istanbul where almost all types of public transportation come together such as metrobus, metro lines, tram, minibus, bus, etc. Yet, the must-to-walk way after public transportation is long and unattractive and accessibility is laborious as compared with Forum Istanbul SC. In these circumstances, it can be said that Marmara Forum SC is less attractive than Forum Istanbul SC.
Figure 1 - Marmara Forum Shopping Center (below) and Forum Istanbul Shopping Center (above) in relation to their location (middle) in Istanbul.
Additionally, Merter, a district of Bakırköy, is one of the centers of textile industry and trading in Istanbul, also has many transportation opportunities, thus, it has a vivid urban life. Yet, Merter has a lack of cultural activities as unusual for a district in Bakırköy which is one of the most developed regions of Istanbul and hosts many central buildings of banks and cultural activities. In comparison, Marmara Forum SC has one to third smaller site than Forum Istanbul SC, however their contents are similar to each other and both have different advantages in accordance to their various functions that are creating alternative activities. For instance; even though they host almost same brands, Forum Istanbul SC offers more options in terms of goods. On the other hand, Marmara Forum SC has a bigger food court with more options than Forum Istanbul SC and most of the others. In addition, interior design concepts of two shopping malls are similar to each other, where they offer a shopping district with squares and streets, but they do not leave the same impression because of differences at scale, color, material, architectural structure and spatial configuration inside. On the other hand, beyond that Forum Istanbul SC is located closer to the center of the city on a more accessible point; there are other public facilities that attract people surrounding the Forum Istanbul SC and give more opportunities to people for coming and spending time here. Nevertheless, because of easy accessibility, people live near Marmara Forum SC are expected to prefer Marmara Forum SC too.

3. RESULTS OF OBSERVATIONS AND SYNTACTIC ANALYSIS OF FORUM ISTANBUL AND MARMARA FORUM SHOPPING CENTERS

Marmara Forum SC is a complex building comprised four floors and four entrances; two of the entrances are at the ground floor and the other two are at the first floor, which is selected for the study. The investigation process was operated at the selected floor as told above in three steps. The first step is collecting data by observing users’ behaviors in the shopping mall, making syntactic analyses of the floor plan, and categorizing tenant types; second step is making out correlations of spatial configuration that is depending to the syntactic measures and users’ movements that is depending on the frequency of visitors by using SPSS. SPSS gave us "Regression Analysis" results that are symbolized with "R" value in tables, where "p" value is also related with the degree of its significance at regression analysis. Last step is interpreting the results of these input and output data.

In Marmara Forum SC, circularity is the most effective morphological characteristic on users’ behavior (Table 2): It is found that the strongest correlation is between circularity and frequency ratio at the most used time period that is weekend day 2, 14:00 hours. On the other hand, the impacts of the circularity were weaker in the weekday evenings where it was reported that people used more connected and integrated spaces at the edges rather than the centrally positioned convex spaces in this time period. As a matter of fact, it is known that people prefer well-integrated and well-connected spaces for presenting further vision in comparison with segregated ones (Kim et al., 2008; Dalton, 2012). Besides that, the spaces with high circularity have the most directed routes at this floor in this shopping center.
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Figure 2 - Counting points/Gates and convex spaces of Marmara Forum Shopping Center.

Figure 3 - Integration (left) and connectivity (right) of Marmara Forum Shopping Center.
Figure 4 - Circularity (left) and mean depth (right) of Marmara Forum Shopping Center.

Figure 5 - Compactness (left) and distribution of types (right) at Marmara Forum Shopping Center.
### Syntactic Values

<table>
<thead>
<tr>
<th>Counting Points</th>
<th>FREQUENCY AVERAGE</th>
<th>COMPACTNESS</th>
<th>CIRCULARITY</th>
<th>CONNECTIVITY</th>
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Table 1 - Frequency average and syntactic values of Marmara Forum SC.
In addition to circularity, integration and connectivity were other syntactic measures that showed effects on users' movements in Marmara Forum SC such as mean depth and compactness. In such a way, the convex spaces that were crowded at most of the time, had also high compactness, integration, connectivity and integration values and low mean depth value. In contrary, the convex spaces, which were less used, also had low integration, compactness and connectivity values and high mean depth value. The observations disclosed that users mainly flow through the spaces that were at the same direction with their walking route, and they did not tend to deviate to corridors out of their directions whereas this situation was ascertained with last studies, people tend to walk straight and not to turn at the edges (Dalton, 2001). Additionally, these spaces had also higher syntactic values than the spaces at the other directions. These circumstances connote that syntactic values are determinant factors in this shopping center and have strong impacts on users’ movements such as observed ones like users’ flow and frequency in a space.

Table 2 - Frequency and convex space correlations Marmara Forum SC (significant findings are shaded)

<table>
<thead>
<tr>
<th>TIME PERIODS</th>
<th>COMPACTNESS R</th>
<th>p</th>
<th>CIRCULARITY R</th>
<th>p</th>
<th>CONNECTIVITY R</th>
<th>p</th>
<th>MEAN DEPTH R</th>
<th>p</th>
<th>INTEGRATION R</th>
<th>p</th>
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<td>0.374</td>
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<td>0.553</td>
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<td>0.256</td>
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<td>0.443</td>
<td>0.251</td>
<td>0.301</td>
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<tr>
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<td>0.597</td>
<td>0.510</td>
<td>0.026</td>
<td>0.298</td>
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<td>0.386</td>
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<td>0.450</td>
<td>0.053</td>
<td>-0.264</td>
<td>0.275</td>
<td>0.235</td>
<td>0.322</td>
<td>-0.250</td>
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<td>0.301</td>
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Table 3 - Frequency and gate counting correlations Marmara Forum SC (significant findings are shaded)

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<tr>
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<th>COMPACTNESS R</th>
<th>p</th>
<th>CIRCULARITY R</th>
<th>p</th>
<th>CONNECTIVITY R</th>
<th>p</th>
<th>MEAN DEPTH R</th>
<th>p</th>
<th>INTEGRATION R</th>
<th>p</th>
</tr>
</thead>
<tbody>
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<td>0.855</td>
<td>0.033</td>
<td>0.901</td>
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</tr>
<tr>
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<td>-0.009</td>
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<td>0.901</td>
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Lastly, there are a few types of shops and they are distributed almost a homogenous arrangement, apart from food shops which are located at disintegrated spaces on this floor of Marmara Forum SC. For the reason that there was no tenant type zoning clearly, it could not detected that whether shop type had a determinant role or not at users’ movements with only observations. However, it was also observed that when a space had an extra-ordinary activity as a short-time attractor, the space turned into the most used space at those time periods. Likewise, it is ascertained with previous studies that users’ movements in shopping centers are affected by spatial attractors along with spatial configuration; and also movement is not determined by only the urban grid as Hillier said, but the specific attractors such as product, activity and so on (Hillier, 1993; Fong, 2003; Yiu et al., 2008; Garip & Ünlü, 2009). All in all, it was not appointed that how shop types affected the visitors in Marmara Forum SC overtly, but it was distinguished that there were other attractors besides spatial configuration that affected use of space.

The same research process was conducted in Forum Istanbul SC. Forum Istanbul SC has four floors and four entrances whereas two of the entrances are at the ground floor and the other two are at the first floor which is selected for the study, just like Marmara Forum SC. Here, analyses and observations showed that the connectivity and integration of spaces had stronger impacts on users’ frequency and circulation behaviors similar to Marmara Forum SC, although the effects of spatial structure were hardly readable most of the time only with the data that collected with observations. Findings pointed that users tended to use more connected and integrated spaces more often and move through more connected and integrated spaces from less connected and integrated spaces. It was also observed that the most integrated and connected spaces were also the most crowded spaces at most of the time because of the users’ tendency to be able to gather more information about environment through the exterior or interior spaces by having wide perspective and act delicately (Dalton, 2001; 2012). Here, the most connected and integrated spaces are also the spaces, which provide vertical circulation and passage between entrances to shopping streets. Thus it can be thought that people use these areas for circulation and translocate in the floor and between floors there. On the other hand, compactness also showed effects on users in addition to connectivity and integration; users tended to use more compact spaces especially at early hours in weekdays. Whereas, the observations on weekend middays showed that compactness, connectivity and integration of spaces had impacts on users’ movement. Considering the circulation behaviors, even though it was ascertained that compactness, integration and connectivity of spaces affected users’ movements, it is thought that other factors such as types and numerousness of shops had more dominant effects on users than the spatial structure. It was also observed that people tended to move from the entrances to direct orientations at the junctions through the spaces containing retail as a tenant type, otherwise, they changed their direction in order to reach retail tenants. Local attractors have impacts on users’ movements flow in shopping centers and provoke unexpected space use (Fong, 2003; Garip & Ünlü, 2009).
ARCHITECTURAL MORPHOLOGY AND USER BEHAVIOR RELATIONSHIP IN SHOPPING MALLS: 
A Comparative Case Study on Forum Shopping Centers in Istanbul through Syntactic Analysis
ARCHITECTURAL MORPHOLOGY AND USER BEHAVIOR RELATIONSHIP IN SHOPPING MALLS: A Comparative Case Study on Forum Shopping Centers in Istanbul through Syntactic Analysis
## Table 4 - Frequency and gate counting correlations Forum İstanbul SC (significant findings are shaded).

<table>
<thead>
<tr>
<th>Counting Points</th>
<th>FREQUENCY</th>
<th>AVERAGE</th>
<th>COMPACTNESS</th>
<th>CIRCULARITY</th>
<th>CONNECTIVITY</th>
<th>MEAN DEPTH</th>
<th>INTEGRATION</th>
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<td>3.08</td>
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</table>
In sum, the spatial use in Forum Istanbul SC in relation with the users are mainly affected by spatial morphology as it is especially seen with the values of integration, connectivity, compactness and mean depth. These values showed distinguishable effects in some spaces, however it is still undeniable that there are other factors that may be influential more than spatial configuration. Considering the correlations depending on observations and syntactic analyses, it was obvious that syntactic values of space do not show strong effects on users’ flow and movement. In these circumstances, we may argue that tenant types and other attractors were more effective on users’ flow than spatial configuration in relation with the morphology of space.
4. CONCLUSION

In conclusion, this study compares the impacts of building morphology and content by examining their impacts on users' circulations and spontaneous gatherings in two shopping malls of Istanbul. Systematic observations of users were made in both shopping centers at definite time periods in weekdays and weekends in order to detect the impacts accurately. Correlations between syntactic analyses and users' gate counts and convex space frequencies show that there are certain impacts of each factor. It is attested that building morphology clearly affects observed user behavior in these shopping centers. The users’ behavior may definitely be affected by the configuration, but this is not always in accordance with the syntactic values. Other factors like types and quantity of stores, a temporary activity, having a target product that is making an attraction etc. could sometimes be more effective than spatial configuration. At one of the shopping centers, Marmara Forum SC, shops types are distributed almost homogeneously while at the other one, Forum Istanbul SC shop types are zoned partially on the selected floor. In these circumstances, it is ascertained that long axial paths (we may also call these paths as main orientation path or main movement path) of this character has distinguishable effects on users' movements besides other syntactic values at both of the shopping centers. Natural Movement Theory suggests that people incline to well-integrated and well-connected spaces because they collect information about space better for further movements in these kind of spaces (Hillier et al. 1993; Hillier & Iida, 2005; Sailer & Penn, 2010). In addition, it is also reported that visitors tend to the spaces with long lines as having high connectivity in both shopping centers. Likewise, it was alleged that direct links in shopping arcade have positive effects for the reason that continuing the shopping activity without interruption inclining with Natural Movement Theory (Teklenburg et. al. 1994; Fong, 2003). On the other hand, there were observed certain effects of spatial attractors and shop types in spite of morphological structure. Even though general physical configuration was supportive on natural movement of users in shopping malls, content was more dominant on users' decisions of spatial use as we have seen in this comparison. In other words, “the product is the key” (Yiu et al., 2008; Garip & Ünlü 2009). People move in the space not only according to spatial structure but also their personal assessments of space (Downs, 1970).

Although syntactic measures such as circularity, connectivity, integration all have some significant correlations with frequency of people depending on the time periods that they are counted and analyzed, the attraction factor of displays, shops, various activities such as entertainment areas and food courts usually influence the correlations. In this context as we seen from the table 6, there may be no correlations between the movement and frequency in gate counts in relation to syntactic values.

It is also significantly seen that in comparison of the two shopping malls, the comparatively small one (Marmara Forum SC) is giving very significant and strong correlations between the integration and gate counts as well as connectivity measures and gate counts. The reason for such a result is the more compact and visually increased orientation of the mall with the functions. The bigger mall (Istanbul Forum SC) is creating no correlation in that sense, which has the similar setting and the functions as well as the brands within the mall. As Dalton (Zimring & Dalton, 2003) found that “Angles that deviated least from a continuous straight heading were preferable to sharp turns” and also found that “a strong evidence that participants tended to select routes that approximated a straight line and avoided routes that were particularly convoluted or meandering” (Zimring & Dalton, 2003). In that sense, the difference in the morphology of main orientation path or main movement path between the two compared shopping malls created these significant results about the gate counts-frequency correlation. Marmara Forum SC that is serving with two main paths in comparison to a more complex axial or path system in Istanbul Forum SC due to its increasing total area has become a disadvantage in terms of visitor-user experience of the mall.
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#2

JAPANESE NURSING HOME COMMON SPACE SPATIAL LAYOUT CHANGES IN THE PAST 35 YEARS

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ABSTRACT
This article analyses changes of common space spatial characteristics in Japanese nursing homes in the past 35 years, aims to provide a reference for future nursing home common space design.

The analysis is done by using DepthMap tool. Totally 62 nursing homes from Japanese architecture publications are selected and analysed. The spatial integration metric for community space, physical training room, service station, and dining room is calculated and averaged to depict the transition of common space from classic large scale care nursing homes to modern unit care nursing homes in Japan in the past 35 years.

The findings point out:
(1) Community space has been allocated with increased spatial integration in recent years. This actually reflects a culture of connect to great community in modern Japanese nursing homes, that is, to make community space easily accessed and gathered by nursing home residents and visitors. (2) The integration of physical training room shows a little bit increase, which may indicate the need to design club house, fitness to a place with easier access in modern Japanese nursing homes. (3) Service station was positioned with high spatial integration place in classic nursing homes for the convenient to provide care service to large group of residents, but it has been changed in modern small unit care nursing homes. (4) The spatial layout of dining room is flexible in both classic and modern Japanese nursing homes, though its overall spatial integration in the past 35 years was in downtrend.

KEYWORDS
DepthMap, Common Space, Nursing Home, Convex Map, Space Syntax

1. INTRODUCTION
Along with the development of modern Japanese economy, nursing home in Japan has also been evolved. In 1963 when the 1st welfare law for the elderly was issued, Japan was experiencing high economic growth, urbanization, and women’s social advancement. The household functions was remodelling as well at that time, making it difficult for elderly to take care of themselves at home, which led to high market needs of senior facilities. Consequently, lots of large-scale nursing homes with big shared room for more than 10 residents were built up. This solved the problem of senior facility shortage, but the collective living in such a large scale care nursing home also brought residents the difficulty in receiving care service. With the improvement of
living standards, slightly smaller group living type nursing home came out in 1980s. Unlike the big shared room living, a smaller group of 4~6 people sharing living room became the main living style, but the nursing care was still provided collectively although the scale was a little smaller than before. Later, by the influence of realizing home alike living style and having individual care service, nursing home with private living room and unit care living space appeared in 1996, this is so-called modern unit care nursing home. This kind of nursing home was quickly spread out in all country, and is now the main senior facilities in Japan (Murakami, 2003).

By the transition of nursing home from large scale nursing care to unit care, the common space structure has been changed, too, as shown in figure 1. In large scale care nursing home, the common space is mainly concentrated in one location, where eating, recreation, and rehabilitation etc. day activities are taken place. On the other hand, with the conversion to unit care style, the dining room and day activity are gradually separated, a living space is designed and shared by several private rooms for day activities, and it further connects to place with higher publicity.

![Figure 1 - Large scale care and unit care nursing home](image)

Toyama (2002) investigated the effectiveness of social and care service by introducing private room and small scale care unit in Japanese nursing home, concluded that it brought residents the formation of personalized space, the improvement of QOL (quality of life) and ADL (activities of daily living), the increase in social participation and abundant interpersonal relationship.

On the other hand, what does this transition imply to changes of spatial characteristics for other common facilities, like community space, physical training room, service station, and dining room? In particular, in terms of space syntax metrics, how they were affected by this progression? Figuring out these changes would help the designing of common space in future Japanese nursing homes.

In this paper, 62 nursing homes which were built in the year from 1978 to 2014 are selected from Japanese architecture publications, with which the spatial characteristics of common facilities including community space, physical training room, care service station, and dining room are analysed to develop an understanding of how common space layout has been transformed, and what are the inherent spatial difference between large scale care nursing homes and unit care nursing homes, so as to provide a reference for future common space design in Japanese nursing homes.

2. LITERATURE REVIEW

Common space is a study of concern in Japanese nursing homes. So far, there are a number of researches done on the impact of common space on residents’ social activity. These studies focus on the effectiveness and importance of deploying common spaces by observing or counting resident’s stay time, behaviours, and frequency of use of common space. The typical examples are Kato’s research on factors to improve residents living quality based on environmental behaviour observation for over 50 residents in 3 nursing homes (Kato, 2007),
and Mori’s study on common space decentralization in nursing home based on the situation that some of the functions which should originally be performed outside the private room were packed into private living room (Mori, 2004). In addition, Kozuma (2015) proposed a living space layout rearrangement in nursing home by observing residents’ stay and routines of movement in common space, Inoue (1990) put forward the topic of the necessity of having common facilities such as handicraft rooms, lounges, multipurpose rooms, play rooms and heated pool in nursing home by analysing the actual utilization status. Besides, Kan (2012) conducted a spatial analysis on four Japanese elderly facilities by means of space syntax isovist theory, concluded to widen facility hall and front room hall to secure communication within residents.

However, many of these studies focused on the relation with residents’ social tie. The comprehensive investigation and analysis about common space characteristics such as spatial integration and accessibility is not seen in the reports. Although Kan applied space syntax theory to develop space visibility in nursing homes, his study itself focused on isovist visibility, no systematic spatial metric data was given on nursing home common space.

3. METHODOLOGY

3.1 METHOD AND METRICS

Space syntax theory is applied in this study. As Hillier pointed out “socially and culturally determined patterns are embedded in these configurations and social relations and processes express themselves in space through configurations” (Hillier 1984), the spatial integration is taken as the main metric to describe the space characteristics in this article.

UCL DepthMap tool provides different approaches to devise and analyse the spatial maps (Varoudis, 2013). The convex map approach utilizes vertical boundaries to convert 3-D space to a number of “fattest” or largest 2-D convex polygon (Peponis 2002), and establishes connection based on the availability of direct access (Klarqvist 1993). Due to this “fat” nature of the convex shape, it is said that this method is best suited for defining spaces such as building interiors (Daniel 2013), so this approach is applied in this article for spatial metrics calculation.

Floor plan of each selected nursing homes is scanned and converted to AutoCAD file, which is then imported to DepthMap tool to create convex maps. Based on space functionality, each space unit is presented by one or multiple convex maps but to use least possible number of convex map to cover all the spaces. The wall, any kind of partition which separates spaces is taken as boundary while doors and openings are considered as connection points. For multi-story buildings, according to the layout of common facilities, elevators and staircases are regarded as connection points.

3.2 COMMON SPACE AND EVALUATION

Japanese social welfare act provides general regulation on necessary common facilities in nursing home. In these facilities, community space is primarily designed for nursing home residents and local people gathered for social activities, the service and care station is to provide care services, these two facilities together with dining room and physical training room such as rehabilitee room, fitness and club house are four main facilities. The spatial layout of these four facilities is focused in analysis in this article.

The selection of nursing homes is evaluated in two groups based on the scale of nursing care performed, large scale care group and unit care group. The former is classic nursing home where 2-10 residents share living room while the latter is modern type where nursing care is conducted in small group unit.
4. FINDINGS AND DISCUSSION

4.1 LARGE SCALE CARE NURSING HOME

4.1.1 Spatial layout characteristics

Usually large scale nursing homes were designed to have a long corridor, along which housing and service facilities were built. In some cases, they were also designed into different functional areas connected by connection corridors. The typical floor plan of this two type large scale care nursing homes, created convex maps and integration result is presented in figure 2. In this figure, the integration is coloured based on its value, high value of well integrated location to poor is represented from red, yellow, to green, and dark blue.

The 1st example in figure 2 is a two-story nursing home of 92 residents built in 1982. There are 27 living rooms in total, of which 21 are four beds, 2 are double beds, and 4 are private. Besides, a dining room and service station are provided in each floor and physical training room is in the 2nd. There is a long corridor passes through each floor and these facilities are distributed on both sides of the corridor. The service station is situated in the middle of corridor, from here nursing staffs provide care service to all residents.

The DepthMap calculation demonstrates it is the long corridor which owns the highest spatial integration as shown in the upper part of figure 2.

The 2nd example is a nursing home for 80 residents built in 1996 with 11 four-bed rooms, 11 double bed rooms and 14 private rooms, all of them are concentrated in living area. The community space, physical training room, and dining room are situated in service area which is slightly away from living area while service station is sited in middle of living area. Again, the DepthMap calculation confirms the long corridor in living area and connection corridor between two areas are the high spatial integration place (figure 2).

Figure 2 - Typical large scale care nursing home floor plan(left) and integration result(right)
For all nursing homes in this group, the result of most and least integration place is listed in table 1 and table 2. The number in the table is amount of nursing homes where the particular location is the highest or least integration place. Location of others in the table include physical training room, staircase in table 1, laundry, locker room, terrace, dressing room etc. in table 2.

Same results as the two examples, table 1 tells for more than half of the large scale care nursing homes studied, the most integrated place is the main corridor or the connect corridor, which accounts for 22 and 3 in the total of 40 investigated. And, the high average integration value of 1.7219 in long corridor and 2.1805 in connect corridor also discloses the corridor is the most easy place where people to meet and gather together.

On the other hand, table 2 makes it clear that the least integration places in large scale care nursing homes are living room, warehouse and staff rooms. An interesting phenomenon is there are 5 nursing homes where the staff room is the least integration place, this could be a Japanese consideration to have customer oriented facilities be placed in easier access place with priority.

<table>
<thead>
<tr>
<th>Location</th>
<th>Long corridor</th>
<th>Connect corridor</th>
<th>Lobby</th>
<th>EV hall</th>
<th>Community space</th>
<th>Service station</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of</td>
<td>22</td>
<td>3</td>
<td>8</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>40</td>
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<td>Ave. Intgration</td>
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<td>2.1805</td>
<td>1.5198</td>
<td>1.2993</td>
<td>1.3329</td>
<td>1.1546</td>
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</tr>
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</table>

Table 1 - Most integrated place in large scale care nursing home

<table>
<thead>
<tr>
<th>Location</th>
<th>Living room</th>
<th>Warehouse</th>
<th>Staff room</th>
<th>Bath room</th>
<th>Stairs</th>
<th>Cooking room</th>
<th>Others</th>
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<td>Number of</td>
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<td>5</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>15</td>
<td>40</td>
</tr>
<tr>
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<td>0.4297</td>
<td>0.6460</td>
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</table>

Table 2 - Least integrated place in large scale care nursing home

4.1.2 Common facilities

The integration value for the four common facilities and nursing home all space average is summarized in table 3. The order of integration from high to low is included in the table as well.

4.1.2.1. Service station

As the two examples in figure 2, because the care service was conducted in large scale by limited staffs, the service station was positioned in the middle of living area as much as possible to reduce the moving distance for taking care service. This idea is verified in integration result. In table 3, in 29 of 40 surveyed nursing homes the service station is the highest integration place among the four common facilities. The overall average for all 40 nursing homes also confirms this result, that is, service station is most easily accessed place in the four common facilities.

4.1.2.2. Community space

The provision of community space in early Japanese nursing home was not popular. There were only 17 nursing homes in the total of 40 investigated where the community space was implemented, and in the implemented nursing homes, most of the community spaces were designed in a place away from living or central area as in figure 2, which basically causes its lower spatial integration and hard access. This result is confirmed in table 3 where there are 5
<table>
<thead>
<tr>
<th>No.</th>
<th>Build year</th>
<th>Nursing Home ave.</th>
<th>Community space</th>
<th>Physical train. room</th>
<th>Service station</th>
<th>Dining room</th>
<th>Order*</th>
</tr>
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<td>1</td>
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<td>1.0103</td>
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<td>1979</td>
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<tr>
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<td>1.3278</td>
<td>SS&gt;NH&gt;DR&gt;PT</td>
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<tr>
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<td>1983</td>
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<td>1.3593</td>
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<td>0.9405</td>
<td>1.2178</td>
<td>1.0358</td>
<td>SS&gt;DR&gt;NH&gt;CS&gt;PT</td>
</tr>
</tbody>
</table>

*Note: NH – Nursing home, CS – Community space, PT – Physical training room, SS – Service station, DR – Dining room.

Table 3 - Common facility integration result of large scale care nursing homes
nursing homes within which the community space is the lowest integration place among four common facilities, and its overall average accessibility is worse than service station and dining room.

This result might reflect the consideration in early Japanese nursing home planning to accommodate as more elderly as possible, the planning of a place for social activity did not get sufficient attention.

4.1.2.3. Physical training room

The overall average of spatial integration in table 3 exhibits physical training room is the least integrated place in the four common facilities. And, specific to each nursing home studied, the number of nursing homes where the physical training room is least spatial integration place in the four common facilities is 12, it is more than any other common facilities. Same as community space, this result reflects the planning of physical training room for easy access in early large scale care nursing homes was low priority.

4.1.2.4. Dining room

The dining room in table 3 exhibits dynamic changes in spatial integration, it is the least spatial integrated common facility in 5 nursing homes, and is the most integrated common facility in 8. This result might remind the flexibility in dining room spatial allocation in large scale care nursing homes.

4.2 UNIT CARE NURSING HOME

4.2.1 Spatial layout characteristics

Generally the unit care nursing home is constituted by multiple care units, each offers accommodation for about ten residents where nursing care is performed by exclusive staffs in accordance with resident individuality and the rhythm of life. By this concept, a common living space is designed in each unit where the light meal, nursing care and mutual activities are conducted. Besides, dedicated dining room, physical training room, and community space may also be supplied in some of them.

Figure 3 is a typical floor plan of unit care nursing home and spatial integration result. This example nursing home was built in 2005 in Okinawa for 112 residents, a two-story building with 5–6 care units in each floor. The care units are situated in 3 areas with each contains 1–2 units. In addition, a physical training room, a dedicated dining room are located in service area, and a community space with audio and visual techniques equipped hall is built in adjacent. The different functional areas are linked by connection corridors, and links between care units is done via open space(hall, lobby etc.) or short corridors, as shown in figure 3.

The calculation result demonstrates the connection corridor is the highest spatial integration place(right side of figure 3, number is order from high integration to low).

The detail result for common facilities and living spaces is listed in table 4. It can be found that living spaces in unit A1(#48), B(#41), C1(#39), C2(#40), and connection space in unit A(#28), C(#49) do not own high spatial integration. The reason might be the living space is spatially distributed across all floor.
### Table 4 - Integration result of unit care nursing home example

<table>
<thead>
<tr>
<th>Order(position #)</th>
<th>Location</th>
<th>Integration</th>
<th>Mean depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Connection corridor</td>
<td>1.2961</td>
<td>3.8611</td>
</tr>
<tr>
<td>2</td>
<td>Connection corridor</td>
<td>1.2654</td>
<td>3.9305</td>
</tr>
<tr>
<td>3</td>
<td>Entrance hall</td>
<td>1.1079</td>
<td>4.3472</td>
</tr>
<tr>
<td>4</td>
<td>Connection corridor</td>
<td>1.0988</td>
<td>4.3750</td>
</tr>
<tr>
<td>5</td>
<td>Short corridor</td>
<td>1.0766</td>
<td>4.4444</td>
</tr>
<tr>
<td>15</td>
<td>Service station</td>
<td>0.9207</td>
<td>5.0278</td>
</tr>
<tr>
<td>16</td>
<td>Community space</td>
<td>0.9144</td>
<td>5.056</td>
</tr>
<tr>
<td>58</td>
<td>Dining room</td>
<td>0.5842</td>
<td>7.3472</td>
</tr>
<tr>
<td>58</td>
<td>Physical training room</td>
<td>0.5842</td>
<td>7.3472</td>
</tr>
<tr>
<td>48</td>
<td>Unit A1 living space</td>
<td>0.6465</td>
<td>6.7361</td>
</tr>
<tr>
<td>17</td>
<td>Unit A2 living space</td>
<td>0.9051</td>
<td>5.0972</td>
</tr>
<tr>
<td>28</td>
<td>Unit A1,A2 connection space</td>
<td>0.7542</td>
<td>5.9167</td>
</tr>
<tr>
<td>41</td>
<td>Unit B living space</td>
<td>0.6881</td>
<td>6.3889</td>
</tr>
<tr>
<td>15</td>
<td>Unit B living space</td>
<td>0.9207</td>
<td>5.0278</td>
</tr>
<tr>
<td>25</td>
<td>Unit B connection space</td>
<td>0.7830</td>
<td>5.7361</td>
</tr>
<tr>
<td>39</td>
<td>Unit C1 living space</td>
<td>0.7064</td>
<td>6.2500</td>
</tr>
<tr>
<td>40</td>
<td>Unit C2 living space</td>
<td>0.6953</td>
<td>6.333</td>
</tr>
<tr>
<td>49</td>
<td>Unit C1,C2 connection space</td>
<td>0.6109</td>
<td>7.0694</td>
</tr>
<tr>
<td>Ave. of N.H.</td>
<td></td>
<td>0.7815</td>
<td>6.0894</td>
</tr>
</tbody>
</table>

Figure 3 - Typical unit care nursing home floor plan(left) and integration(right).
For all unit care nursing homes surveyed, the most and least integration place is summarized in table 5 and table 6.

In table 5, there are 9 nursing homes where the most integrated place is connection corridor, which accounts for 40% in 22 investigated. Except the example in figure 2, the integration and convex map result of these nursing homes are presented in figure 4. It’s clear from figure 4 that connection corridors which link different function areas is the highest integration place in Japanese unit care nursing homes.

Additionally, table 5 tells there are 2 nursing homes where the community space is the highest integration place. This reminds us that community space has been taken as an important place in spatial layout design in modern Japanese unit care nursing homes.

On the other hand, the least integration place is mainly private room (table 6), it accounts for 11 in 22 examined. This result may suggest us the consideration of putting high priority to secure private space for residents in Japanese unit care nursing homes.

<table>
<thead>
<tr>
<th>Location</th>
<th>Connect Kori</th>
<th>Lobby</th>
<th>EV hall</th>
<th>Community space</th>
<th>Service station</th>
<th>Physical</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>9</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>22</td>
<td>40</td>
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<td>Ave. Integration</td>
<td>1.7285</td>
<td>1.6709</td>
<td>1.6948</td>
<td>1.4314</td>
<td>1.4291</td>
<td>1.3030</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5 - Most integrated place in unit care nursing home

<table>
<thead>
<tr>
<th>Location</th>
<th>Living room</th>
<th>Warehouse</th>
<th>Staff room</th>
<th>Bath room</th>
<th>Stairs</th>
<th>Cooking room</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>11</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>22</td>
</tr>
<tr>
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<td>0.7700</td>
<td>0.5011</td>
<td>0.6358</td>
<td>0.5690</td>
<td>0.5671</td>
<td>0.5960</td>
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</tr>
</tbody>
</table>

Table 6 - Least integrated place in unit care nursing home
### Convex map and integration result

<table>
<thead>
<tr>
<th>Year</th>
<th>Capacity</th>
<th>Unit number in one floor</th>
<th>Highest integration</th>
<th>Remark</th>
</tr>
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<td>2003</td>
<td>100</td>
<td>6</td>
<td>1.4766</td>
<td>Built year: 2003</td>
</tr>
<tr>
<td>2005</td>
<td>100</td>
<td>3-6</td>
<td>1.7216</td>
<td>Built year: 2005</td>
</tr>
<tr>
<td>2005</td>
<td>80</td>
<td>~4</td>
<td>1.6667</td>
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</tr>
<tr>
<td>2012</td>
<td>54</td>
<td>~4</td>
<td>1.8958</td>
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<td>2013</td>
<td>80</td>
<td>2</td>
<td>1.4807</td>
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</tr>
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<td>2014</td>
<td>39</td>
<td>4</td>
<td>1.9778</td>
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<tr>
<td>2015</td>
<td>96</td>
<td>~10</td>
<td>1.7289</td>
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<tr>
<td>1997</td>
<td>70</td>
<td>~4</td>
<td>2.3123</td>
<td>Built year: 1997</td>
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</table>

Figure 4 - Unit care nursing home with connection corridor is high integration place.
4.2.2 Common facilities in unit care nursing home

The result is in table 7. In the table, the number of nursing homes where service station is the highest spatial integration common facility is 10, and it is 7 for community space, 2 for physical training room, 1 for dining room. And the overall average reveals community space is the highest integration place in the four common facilities. Both the results represent the fact that community space has been taken as a high spatial integration with easy access common facility in Japanese modern unit care nursing homes.

<table>
<thead>
<tr>
<th>No.</th>
<th>Build year</th>
<th>Nursing Home ave.</th>
<th>Community space</th>
<th>Physical train. room</th>
<th>Service station</th>
<th>Dining room</th>
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</tr>
</tbody>
</table>

*Ave Note: NH – Nursing home, CS – Community space, PT – Physical training room, SS – Service station, DR – Dining room.

Table 7 - Common facility integration result of unit care nursing homes
4.3 COMPARISON BETWEEN LARGE SCALE AND UNIT CARE NURSING HOME

The average integration for four common facilities in large scale care nursing home and unit care nursing home is presented in figure 5.

![Figure 5 - Unit care nursing home with connection corridor as most integrated](image)

It can be seen from this figure that compared with large scale care nursing home, integration of community space is increased by about 15% from 0.9558 to 1.0998, physical training room is increased slightly, about 2% from 0.9405 to 0.9608. On the other hand, service station and dining room are reduced about 10% and 13%, from 1.2178 to 1.0990 and 1.0358 to 0.8979 respectively.

Once more, in large scale care nursing home, limited staffs provide nursing care to large group of residents, the service station was placed to central living area as far as possible to reduce staffs moving distance, which led its higher spatial integration. On the other hand, by the influence of paying more attention to social activity, and providing nursing care in small distributed unit, the community space has been allocated to place with easy access and easy for people to gather together in modern Japanese unit care nursing homes.

4.4 OVERALL CHANGES OF COMMON SPACE IN PAST 35 YEARS

The overall transition of community space, physical training room, service station, and dining room in past 35 years is presented in figure 6. The result for large scale care nursing home is expressed in blue diamond shape, and red square is for unit care nursing home, the red line is trend line for past 35 years.

Again, the community space shows uptrend in spatial integration in the whole period.

The trend line of physical training room is slightly in uptrend, this result is in accordance with average comparison between large scale and unit care nursing homes. The result itself may indicate alteration has occurred to allocate physical training room includes rehabilitee room, club house, fitness room to a place of easier access in modern Japanese nursing homes.

On the other hand, the trend lines for both service station and dining room are in down tendency in the past 35 years. The decline in service station reflects the layout transformation from centralization in large scale care nursing home to diversity in unit care nursing home.
Figure 6 - Common space integration overall changes in past 35 years (CS: community space, PT: physical training room, SS: service station, DR: dining room)
5. CONCLUSIONS

The spatial characteristics and common space in particular for 62 Japanese nursing homes built in the year from 1978 to 2014 are analysed by using of DepthMap tool. The result tells in classic large scale care nursing homes, the corridor along which living rooms and service facilities are distributed is the highest spatial integration place. Besides, service station in general is also located in high spatial integration place in this type of nursing homes. Moreover, in modern unit care nursing homes, the corridors link different functional areas usually is the highest integration place, and community space appears to be situated in high spatial integration place as well.

The comparison between large scale care and unit care nursing homes reveals that the spatial integration of community space is increased about 15%, but service station and dining room are reduced about 10% and 13%, this indicates the changes has happened in allocating community space to higher spatial integration place with easy access and easy for people to gather together in modern Japanese unit care nursing homes.

The overall transition of common space in Japanese nursing homes in the past 35 years also confirms the uptrend of community space in spatial integration, and downtrend of service station and dining rooms. This transition may reflect a culture of connect to great community in modern Japanese nursing home design, that is, to make community space easily accessed and gathered by nursing home residents and local people.
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ANALYSIS OF BEHAVIOURAL PATTERNS OF CHILDREN AND THEIR COMPANIONS IN A PAEDIATRIC HEALTHCARE ENVIRONMENT
Searching the Association Between Behaviour Maps and Space Syntax

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ABSTRACT

The relationship between human psychology and space is studied through an ecological approach by Barker (1968) concerning that the harmony between human behaviours and physical and social attributes of space is dependent on the synomorphy of the place offering individuals a balanced amount of basic psychological needs of human beings; privacy and publicity. He puts forward the notions of ritual, display and surveillance as the dominating factors of space and develops the discourse called behaviour setting; stating that spaces have an impact on imposing individuals to behave in certain manners. Within this discourse, each space has a certain structure of behaviour setting so that individuals initially observe the behaviour patterns of others and later on follow the same social norms and behaviours when they first participate into a specific space. According to Barker, this kind of interaction of the individual with the environment has an effect on diminishing environmental stress arisen from the environment and enhancing adaptation of the individual.

In this manner, this paper focuses on the correspondent interaction between physical and social attributes of paediatric healthcare spaces where children are treated. Although paediatric spaces are supposed to be designed through a holistic approach respecting children’s physical, cognitive, social and psychological needs, these spaces are nonetheless stressful settings especially for inpatient children to get accustomed to various physical attributes together with social attributes that are decision makers on the patient’s physical integrity. For that reason, during the child’s treatment period, the accompaniment of a parent is a necessity within a paediatric healthcare environment for the well-being of children to ensure them to require physical and psychological support. Accordingly, children and their companions who have diverse physical and social needs, simultaneously share the spaces of the paediatric healthcare environment displaying certain kinds of behaviour patterns.

The main aim of the article is to search for the relationship between various sociobehavioural patterns of two social groups (paediatric inpatients and their companions) and physical attributes of an existing paediatric healthcare environment through a methodology of behaviour maps and space syntax. Within the context of case study, behavioural frequency data of paediatric inpatients and companions is gathered, correlated by the syntactic values of the actual spatial structure and evaluated to search for any significant outcomes by regression analyses. The investigation is conducted by the participation of 30 children and 30 companions in a Paediatric Haematology and Oncology Service in Istanbul Cerrahpasa University.
KEYWORDS
Behaviour Maps, Behaviour Setting, Paediatric Healthcare Spaces, Space Syntax, Spatial Perception

1. INTRODUCTION

The interaction of the individual through the environment is studied through a multidimensional approach within environment and behaviour theories, regarding psychology, sociology, anthropology and architecture. Within this framework, this research area focuses on the examination of building design program through a holistic approach bringing forward the values, norms, needs and preferences of the users of a specific space. According to Moore (1979), decently designed buildings should support the spatial needs of the users by eliminating environmental stress, enhancing the existence of the individuals and enabling them to behave more free and competent. Within this approach environment is not only a configuration composed of physical attributes perceived by senses, but rather a concept which is affected by social circumstances. While the perceptual processes of the individuals tend to change imposing them to behave in certain manners under the stimuli triggered by the environment, the environment on the other hand tends to be affected by the acts caused by the individuals.

1.1 ECOLOGICAL APPROACH WITHIN ENVIRONMENT AND BEHAVIOUR THEORIES

Ecological approach within environment and behaviour theories is mainly developed by the studies of Barker and Gibson (Kaminski, 1989). Despite some significant differences between their attitudes, both researchers analyse perceptual processes of the individuals through the ones’ physiological and biological presence regarding their adapted environment as an inseparable concept from their well-being. According to Gibson, analysing the perceptual process of the one is not possible without analysing the environment that the one has been adapted. Following this argument, it can be asserted that personal experiences of the individual is strongly engaged with the perception of the individual within that specific environment. Furthermore, Barker puts forward a grounded theory called as behaviour setting concept analysing the environment through the existence of the being since he mentions that the environment becomes existent with the aggregation of natural, spontaneous, temporary actions of the being himself (Kaminski, 1989).

Barker discusses the concept of space having a synomorphy whether there is a harmony between the individuals’ behaviours with the physical and social attributes of the setting and argues the coherence of space through the concepts of community and privacy as the vital psychological needs of the humans. He puts forward the notions of ritual, display and surveillance in order to debate over building programs with various typologies. He asserts that such buildings like churches yield people to carry out some specific social rituals; such buildings like museums yield people to display themselves within a certain part of the society besides the display of objects; such buildings like libraries, prisons and hospitals yield people to be kept in surveillance by others. While display-oriented spaces do not include adequate amount of privacy, spaces designed through a public priority prevent the one’s personal space to be sufficiently organised. In addition to that, Barker emphasises that spaces impose people to follow a specific kind of behaviour setting proper to that space; for instance, people tend to follow a certain type of behaviour setting in the theatres, airports, schools and even in laundries. In other words, an individual who has never been in a specific space experiencing a significant amount of environmental stress because of the one’s first involvement, observes the others inside and follows out the same social norms and behavioural patterns so that this process helps to decrease the environmental stress and results as the adaptation of the being (Lawson, 2001).

According to Scott (2005), the strength of Barker’s behaviour setting theory compared to other theories in psychology depends on the dominating effect of the concept of space free from the statue and different characteristics of individuals together with the concept of time; despite the temporariness of the individuals as beings in space, behaviour setting is permanent. Furthermore, according to Studer (1970), the key method to examine the interaction between
the individuals and the space can be attained through analysing the social organisation and through focusing on the actual experiences of them since the space created by the individual is a social phenomenon. For that reason, experiences of the individual should be systematically observed and recorded through behaviour maps in order to reveal behavioural patterns as a matter of fact.

In modern societies, the individuals are used to proceed a daily routine between their homes, schools and offices where they pursue some specific behavioural patterns. This case is not intrinsically different for children since from their early ages; they are also involved into such daily cycles where they eventually adopt specific kind of behaviour patterns. However, there are some periods interrupting that regular process such as illness periods throughout which the children may need to spend some time in a paediatric healthcare setting including unfamiliar physical and social attributes causing a significant amount of environmental stress. In relation to this discussion, Lawton and Nahemow (1973) assert that individuals who are highly stressed because of their illnesses, have more difficulty in fighting with the negative stimuli arisen from the environment.

Within this debate, it could be stated that children are regarded as more fragile beings compared to adults in terms of competing with environmental stress therefore they tend to react in fear and behave in unusual manners since their perceptual process are effected by their first-time experiences. Additionally, illness period of the child as an inpatient for a significant amount of time is also a stress generating time for the child’s companion- an essential person fulfilling child’s needs- because the daily routine of the companion is also harmed. For that reason, together with inpatient children, their companions’ behavioural patterns are also deemed worthy to be examined as secondary social actors of this study.

The aim of this paper focuses on the interaction between the abruptly changed perceptual processes by behavioural patterns of children who are inpatients of a paediatric healthcare setting together with their companions, and existing physical characteristics of that setting. Through such an interdisciplinary approach using behaviour maps and space syntax, the study searches for statistically significant outcomes between the frequencies in behaviour maps and values gathered from syntactic analyses in order to discuss the social potentials of paediatric healthcare spaces in terms of sociopedal and sociofugal space. The notions of sociopedal and sociofugal space concepts are firstly put forward by Osmond (Lawson, 2001) in order to examine in what degree spaces are influential on the social interaction of the individuals; while sociopedal space tends to make an influence on individuals to socialize, sociofugal space tends to make an influence on individuals to become distant from each other, dependent on the configurational characteristics in both circumstances.

1.2 METHODOLOGY

The quantitative dataset of the behavioural patterns of both inpatient children and their companions revealed by behaviour maps are statistically correlated by the quantitative dataset of existing physical characteristics of the healthcare setting revealed by syntactic analyses. Data gathering process is conducted in two phases. In the first phase, each inpatient and his/her companion are separately observed for one hour to find out (1) behavioural frequency of each single space regarding inpatients (2) behavioural frequency of each single space regarding companions and in the second phase, the existing layout of the healthcare setting is analysed by Syntax 2D to find out the integration, isovist area, isovist perimeter, compactness, circularity, occlusivity, connectivity and mean depth values of each single space. Generated values are correlated by regression analyses through SPSS to search for significant outcomes.

Case study is implemented with the participation of 30 children between the ages of 7-18 and their companions. Selected space is in the Paediatric Haematology and Oncology Service of Medical Faculty of Cerrahpasa Hospital, Istanbul which accommodates a child-centred design facility. While the children participated into the study consist of 15 boys and 15 girls, all of the companions are women; 28 of whom are mothers and 2 of them are sisters of the inpatients.
The paediatric healthcare setting consists of a linear configuration that inpatients wards and other administrative spaces are lined up through each side of a long corridor (Figure 1). Inpatient wards are designed to accommodate a child with his/her companion including a bathroom inside. A transparent window visually connects the interior of each ward with the corridor so that a group of specialists may track the course of disease as a daily routine without entering inside because of the risk of an infection. The setting consists of 12 inpatient wards, a linear common balcony that can be reached through 10 of the wards, a nurse station with its dressing room and bathroom, medication room, specialist room, meeting room for the specialists, microscope room, medical intervention space, shared bathroom area for the companions, laundry, two storage rooms, common kitchen space for the companions to cook extra food, hospital school for the children to pursue their ongoing education and a playroom including various handicraft tools to spend their spare times.

In order to obtain mathematical data to reveal behavioural patterns of the participants, the paediatric healthcare setting had been visited for 20 days from 10:00 am to 18:00 pm observing and recording each participant for one hour. The participants were chosen from the ones between the ages of 7-18 who is staying in the healthcare setting five days in minimum. Behavioural patterns of the selected participants were recorded without disturbing them by eye contact so that they would not be aware that they are tracked. Together with recording who is visiting which space for how long, observed behaviour setting of noteworthy spaces is also revealed regarding each group of participants (Table 1).

Figure 1. Plan of the layout.
<table>
<thead>
<tr>
<th>Setting</th>
<th>Observed Behaviour Setting Regarding Inpatients (Children)</th>
<th>Observed Behaviour Setting Regarding Companions</th>
</tr>
</thead>
<tbody>
<tr>
<td>In the ward</td>
<td>relaxing, sleeping, watching TV, playing with tablet, having conversation with their companions, nurses and other inpatients, watching sea from the window.</td>
<td>having conversation with their children, talking on the phone, handicraft activities like knitting, keeping medical track of their children, watching TV, cleaning the floors, changing the bedclothes, perform the ritual prayers of Islam.</td>
</tr>
<tr>
<td>In the play room</td>
<td>drawing, painting, having conversation with other companions, playing with a game console, playing with toys, doing a handicraft activity with a volunteered instructor, watching theatre, eating, watching others.</td>
<td>doing recreational activities, having conversation with other companions, doing a handicraft activity with a volunteered instructor, watching theatre, feeding their children, watching others, celebrating special occasions such as religious festivals and national holidays.</td>
</tr>
<tr>
<td>In the Hospital School</td>
<td>doing homework, learn something with the instruction of a teacher.</td>
<td>do not attend</td>
</tr>
<tr>
<td>In the Kitchen</td>
<td>are not allowed to enter.</td>
<td>preparing food on the table, cooking, accompanying others who are preparing food, drinking beverages, washing the dishes, having conversation with other companions.</td>
</tr>
<tr>
<td>In the Corridor</td>
<td>walking back and forth with the serum hanger, having conversation with the nurses, companions and other inpatients, riding with a three-wheeled bicycle.</td>
<td>Having conversation with other companions, exchange information with the medical specialists, walking back and forth with their children, talking on the phone, taking raw food to prepare or to cook.</td>
</tr>
<tr>
<td>Laundry, Common Bathroom, Specialists Room</td>
<td>are not allowed to enter</td>
<td>Washing the laundry, talking to nurses and other medical specialists in their rooms, having a bath.</td>
</tr>
</tbody>
</table>

Table 1 - Observed behaviour setting dependent on some noteworthy spatial components of the paediatric healthcare setting.

2. DATASETS AND METHODS

2.1 WITHIN THE ACCUMULATION PROCESS OF BEHAVIOUR MAPS,

1. A grid representation of the layout is initially prepared for each inpatient and companion. Depending on the actual observation of an inpatient and his/her companion for 60 minutes, the time spent in space is highlighted – blue for the inpatients, magenta for the companions- in the units of minutes, as 1 minute equals to 1 pixel in the grid, recorded as the behavioural frequency of each single space (Figure 2).
2. In order to display the movement patterns of participants, another distinctive type of behavioural representation is implemented to indicate each participant’s behaviour as an uninterrupted and continuous action so that every action of the being could be displayed in such a way that how the being ‘weaves’ the space. Whether the participant remain unchanged in one space, the action of the self is represented by a fixed dot in the map. Through the accumulated representation of behaviour patterns belonging to each group separately, it became possible to discover how the inpatients and companions weave the identical space through a unique way of movement (Figure 3).

3. By the time the observation process of all the participants is accomplished, a single representation of behaviour maps belonging to all 30 inpatients and 30 companions is arranged showing each group in total, on one separate representation (Figure 4).

4. Besides, the number of the change between spaces of each participant is also recorded to obtain every participant’s behavioural frequency so that the mobility of each group is revealed as a quantitative data.

![Figure 2 - Examples of behaviour maps of a child (left, with blue) and a companion (right, with magenta) through a pixel representation on a grid system of the plan.](image)

![Figure 3 - Examples of behaviour maps of a child (left with blue) and a companion (right with magenta) through weaved space representation.](image)

![Figure 4 - Behaviour maps of all participants represented with pixels and weaved space regarding the inpatients on the left, companions on the right.](image)
Regarding the spatial usage frequency of each group, it is revealed that while the average spatial usage frequency of children is 4.03 and the average spatial usage frequency of the companions is 17.63, together with the two representational expressions within the behaviour maps (Figure 4), this result shows that the mobility of the companions is significantly higher than the mobility of inpatients, and the companions travel back and forth between spaces very frequently.

3. RESULTS

3.1 RESULTS REGARDING THE BEHAVIOUR MAPS OF THE INPATIENTS

While the lowest behavioural frequency of children is identified as “1” regarding 11 children, the highest behavioural frequency of children is identified as “18” regarding only one child which means the children do not show an enthusiasm to change their spaces frequently. Regarding the fact that the wards (total spatial usage frequency of 12 wards: 1275) and the playroom (spatial usage frequency: 326) are the most visited spaces, the concepts of personal space and privacy become as prominent as the concept of social interaction. In this context, it could be stated that children had to spend a significant amount of time in their wards since they feel tired and exhausted because of their fragile circumstances but still prefer accompanying other children in the play room even with their serum hangers and masks on their faces, when they feel well. For that reason, play room can be evaluated as a sociopedal space regarding children’s behaviour maps. On the other hand, corridor (spatial usage frequency: 106) is mostly used as an exercise axis to go back and forth since they are not allowed spending time at outdoors in case of an infection risk.

3.2 RESULTS REGARDING THE BEHAVIOUR MAPS OF THE COMPANIONS

While the lowest behavioural frequency of companions is identified as “1” regarding only one companion, the highest behavioural frequency of companions is identified as “32” regarding two of them. Compared to the children’s behavioural frequency, it could be stated that the companions bear tremendous amount of responsibility since they have a heavy day routine supporting both the physical and psychological circumstances of their children.

The highest spatial usage frequency is the kitchen (spatial usage frequency: 280) as a space not only for cooking but also to adopt a new daily routine. Second highest frequency belongs to the ward number 9 (spatial usage frequency: 280) which is actually a coincidental case since the participants of the study were chosen unintentionally from this ward. Third highest frequency belongs to the corridor (spatial usage frequency: 199) as can be discovered from the high number of pixels and thickening lines (Figure 4) in the two behavioural representations. This result shows that corridor is not only used as a space to travel back and forth between spaces, but rather used to exchange information with the medical specialists, have a communication with others, welcome visitors on feet, have conversations on phone or burst into tears without showing themselves to their children.

3.3 RESULTS REGARDING THE SYNTACTIC ATTRIBUTES OF THE HEALTHCARE ENVIRONMENT

Through the accessibility graph which is structured to display walkable areas of the layout, the values of integration, compactness, circularity, occlusivity, connectivity and mean depth are obtained from the entrance fields of every space. Regarding this (Figure 5), while the highest integration value is revealed on the thresholds of the wards, the lowest integration value is revealed on the bathroom spaces within the wards. Secondary highest integration value is revealed at the common balcony that can be reached from 10 of the wards. Nonetheless, this spatial component is actually the least visited space because of the infection risk of the inpatients. Kitchen which is revealed as the most visited space by the companions in the behaviour maps, is syntactically exposed as a relatively deep space. However, in the actual condition, this space is far beyond its function providing solidarity between the companions in the service. The play room which is also a significant space having an average integration value is a significant space in the behaviour maps.
The *isovist* graph which is structured to display visual connections between spaces present that windows providing visual contact both between wards-corridor and play room-corridor and make the total layout to be comprehended in a different manner (Figure 6). The highest visibility is displayed in a part of the corridor adjacent to the play room. The visibility of the play room may explain the sociopedal characteristic of that space as it is exposed in the behaviour maps, due to an assumption that children tend to spend significant amount of time in the playroom since they can be observed visually from the corridor and feel safe.

The compactness and circularity graphs are structured to display the spatial components related to the time spent in spaces; as the compactness value increases, time spent in that space increases, as the circularity value increases, that space tends to become a transferring area which is passed by quickly (Figure 7). For that reason, these two values should be evaluated together; while the compactness value is the highest in the play room providing inclusiveness, safety and joy in the compactness graph, circularity value is high in the corridor. However, corridor as exposed in the behaviour maps, is not actually a *passed by* component but rather a *sociopedal space* providing social interaction between the shared actors of the healthcare setting.
According to Benedikt, in order to acquire a significant quantitative data of the total configuration regarding the interaction of the individual with the environment, more than one isovist input should be obtained and the relationship between these inputs should be examined (Batty, 2001). *Occlusivity* is identified by Benedikt (1979) as the “length of occluding boundaries within the isovist” (Batty, 2001; p.127) stating that *occlusivity* fields of a layout demonstrate the obstructed isovist spots so that *occlusivity* value might guide in redesigning of an environment.

Within this context, in the *occlusivity* graph, some specific areas in the play room, hospital school and nurse station appeared to be the most occlusive spaces (Figure 8). As shown in the isovist and compactness graphs, playroom has a high value in terms of visibility and compactness so that it might be assumed that the *occlusivity* of this space impose children positively to spend time within this setting. Despite the high *occlusivity* value in the hospital school, it is hard to make any comments since the classroom is only opened and used in control when the teacher comes to the healthcare environment. Additionally, it is also hard to make any comment about the *occlusivity* in the nurse station since this part is dominantly used by the nurses who are not in the scope of this study.

![Figure 8 - Occlusivity graph of the paediatric health care setting.](image)

In the *connectivity* graph which is structured to display the most associated and connected portions, some parts in the corridor connecting the doors opposing each other have high connectivity values (Figure 9). However, because of the fact that the wards are not welcoming spaces for the outsiders due to the risk of an infection, this syntactic value has no effect on the behavioural patterns of the participants.

![Figure 9 - Connectivity graph of the paediatric health care setting.](image)

In the *mean* graph (Figure 10), while the corridor is the shallowest component, the deepest parts of the setting are demonstrated as the bathrooms inside the wards number 11 and 12. However, these wards are not used in a different manner compared to the other wards, so this syntactic value has no effect on the behavioural patterns of the participants. On the other hand, mean depth value of the play room nearly shows the same value as the bathrooms. Nevertheless, the play room is a frequently visited space both regarding inpatients and the companions as revealed in the behaviour maps. For that reason, this syntactic value also does not seem to have any impact on the behaviour patterns of the participants.
3.4 CORRELATIONS

Considering the correlations between the spatial frequencies regarding the inpatients and the syntactic values of the spaces, behavioural patterns of children are not significantly correlated with any of the syntactic values.

The integration value of the layout does not affect the behavioural patterns since the inpatients do not have the option to move freely and actively because of their illnesses. Isovist area and perimeter values do not have any impact on the behavioural usage of spaces since children choose to either stay in their wards in an uninterrupted position keeping themselves in their personal spaces or spend time with some leisure activities in the play room in order to get into social interaction. Although the children tend to spend a lot of time in the play room, behavioural frequency of this space is not significantly correlated by its syntactic value since the highest amount of time is spent in the wards compared to the playroom. Corridor with the highest value in terms of circularity does not affect the behavioural frequency of inpatients since children actually use the corridor for a reason beyond its function; they pace back and forth to make some exercise even with their serum hangers since it is suggested to do so by medical staff. Connectivity value also does not affect the behavioural frequency of the inpatients since most of the spaces is restricted to be used by others. Mean depth value, with the highest degrees in the bathrooms of the wards, also does not have an impact on the behavioural frequency of the inpatients.

In summary, insignificant correlations regarding children, demonstrate that their fragile conditions caused by their serious illnesses concerned with oncology retain them to act freely so that they spend a significant amount of time in the wards in a relaxed position. But still, during the limited times when they feel relatively better, they prefer to visit the playroom even with their serum hangers, masks on their faces, or in wheel chairs and they spend plenty of time with other inpatients. Another reason of the playroom having high frequency in the behaviour maps of children is due to the fact that this setting is such a long-awaited spatial component resembling their schools where they were accustomed to gather with friends, play games and learn something. In other words, play room represents their previous daily routines they were bounded up.

Considering the correlations between the spatial frequencies regarding the companions and the syntactic values of the spaces (Table 2), behavioural patterns of companions are significantly correlated with isovist area and isovist perimeter, circularity, occlusivity and mean depth and not significantly correlated with integration, compactness and connectivity values. In other words, the behavioural patterns of the companions, as the mobile actors in the setting carrying tremendous physical and psychological responsibility, are correlated with the visible, shallow, circular and occlusive characteristics of spaces. Some comments regarding these results could be stated as follows;

1. The highest integration value of the corridor as exposed in the accessibility graph does not have a significant impact on the behavioural frequency of companions. This result shows that although the companions use the corridor for numerous reasons, they use the corridor for small amount of intervals but rather prefer to spend higher amount of time where they get into an extensive social interaction with others.
2. Compactness value also does not affect the behavioural frequency of the companions because they only visit the spaces with the highest compactness value – the playroom where their children are there. Otherwise, they prefer spending time in the kitchen where they come across with their peers.

3. Shallowness regarding the significant results in the mean depth value and circularity values regarding the corridor, have a significant effect on the high frequency of the behaviour patterns of the companions. Companions use the corridor very frequently both to keep up their daily routines in the service and search for social interaction due to the lack of a gathering space for them.

4. Isovist perimeter and isovist area values regarding the playroom have a significant effect on the high frequency of the behaviour patterns of the companions. Children feel safe in this setting because of the reason that they do recreational activities, and they also feel safe due to the visibility value of this space. Since the companions go along with their children all the time during the day, they also share this space with other children and their companions, so that playroom turns into a space for solidarity for everyone in the health care setting.

<table>
<thead>
<tr>
<th>Behavioural frequency of spaces regarding companions; integration value of spaces</th>
<th>$r^2$</th>
<th>$p$</th>
<th>significance</th>
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<th>$p$</th>
<th>significance</th>
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<td>0.22</td>
<td>0.161 &gt; 0.05</td>
<td>insignificant</td>
</tr>
</tbody>
</table>

<table>
<thead>
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<th>Behavioural frequency of spaces regarding companions; mean depth value of spaces</th>
<th>$r^2$</th>
<th>$p$</th>
<th>significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-0.308</td>
<td>0.048 &lt; 0.05</td>
<td>significant</td>
</tr>
</tbody>
</table>

Table 2 - Linear regression correlations between the frequencies of companions and the syntactic values of the layout.
4. CONCLUSIONS

The daily routine which the children are accustomed to pursue through specific kinds of behaviour patterns, is occasionally interrupted due to an illness that might force them to be treated within a paediatric healthcare setting as inpatients. Such an unfamiliar kind of setting generates a significant amount of environmental stress on children imposing them to behave in different manners. Due to this fact, paediatric healthcare settings are used to be designed through a child-centred approach presenting an effective layout including both sociofugal spaces to have some privacy, and sociopedal spaces to have social contact with other inpatients. However, other social attributes of paediatric healthcare environments, especially the inpatients’ companions in the scope of this study, also need equivalent kind of physical and psychological desires since they are the active team mates dealing one-to-one with the ongoing illness period and fulfilling their children’s necessities. This study examines how an actual healthcare layout effects the behavioural patterns of the participants -both inpatients and the companions- by using an interdisciplinary analysing method; space syntax and behaviour maps.

Inpatients are treated in a paediatric haematology and oncology healthcare setting within such circumstances that outdoor environments are kept in minimum due to a risk of an infection. So, configurational design quality of the layout gains significant importance in order to present the children a satisfying environment sustaining their well-being and keeping them within a learning environment together with their peers. The wards where they spend plenty of time and keep their privacy can be arranged in such a way allowing them to add some kind of personalization enhancing their place attachments.

Within this context, regarding the sociofugal spaces in which companions can have an adequate amount of personal space and privacy, the syntactic configuration of a healthcare setting should allow companions where they can dress up, store some personal belongings, talk on the phone privately, watch TV and etc. Such kind of an arrangement could be facilitated through an open plan within the ward area. Additionally, regarding the sociopedal spaces in which companions can have an adequate amount of social interaction, the syntactic configuration can be organised in such a way that additional spaces for the companions can be organised where they welcome visitors and get into social interaction with their peers. Furthermore, during the periods when they accompany their children in the playroom, flexible arrangements could be organised allowing companions to learn something new and developing themselves during this mandatory period. All types of attempts associated with additional setting for the companions should be organised through a design attitude providing adequate amount of transparency to keep their children in sight so that they could pursue their daily routines without neglecting their children.

In conclusion, significant results exposed in this study verified that the spatial layout of the paediatric healthcare settings should be evaluated enabling such spatial components maintaining the personal space, privacy and social interaction requirements through a holistic approach regarding all of the social actors; mainly the companions right along with enhancing the spatial conditions of the inpatients. It can be concluded that while a child-centred design approach within a paediatric health care environment supports the well-being of the inpatient both physically and psychologically, the design program and spatial characteristics of these settings should also facilitate such spaces supporting the companions’ needs, focusing both their privacy and social interaction.
REFERENCES


#4
THE OUTDOOR SPACES OF THE CONTEMPORARY GREEK CYPRIOΤ DETACHED HOUSE

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ABSTRACT
A planning law passed during the British colonial rule of Cyprus still has a strong impact on the character of towns and villages alike. This law requires that ‘no part of the main building or alteration or addition to any existing main building shall be less than 10 feet from any boundary of the plot on which it stands’. The impact was enormous, with the continuous street front of the vernacular villages and the older city centers abruptly replaced by rows of detached buildings. The paper focuses on the change the law brought upon the Greek-Cypriot house and more specifically, regarding the role the resulting outdoor spaces now play in the spatial configuration of the house and their visual relationship with the interior of the house and the public space of the front street. Through the study, a discussion is undertaken regarding the significance the regulations have on the kind of community and domestic architecture it promotes through clauses regarding the height of the boundary walls, the heights and use of auxiliary buildings and the parking, all located within the required 3m setback.

KEYWORDS
detached house, courtyard house, spatial characteristics, building regulations

1. INTRODUCTION
"No part of the main building or alteration or addition to any existing main building shall be less than 10 feet from any boundary of the plot on which it stands, except that in cases where the building is used for trade or industry the appropriate authority may sanction such lesser or greater distances as it may in each case consider necessary or appropriate."
(published in THE CYPRUS GAZETTE, 30th MAY, 1946.)

The above planning law, passed during the British colonial rule of Cyprus, played an important role in the transition from the traditional Cypriot house to the contemporary detached Greek-Cypriot house. And while the reasons behind this Law are not to protect thatched roofs from gunpowder sparks, as it was the case in Lagos, the impact was similarly strong. The loss of the
large amount of consolidated outdoor space forming the courtyard (see Figure 1) and the breaking up of the continuous street fronts, contributed greatly in the formation of new character for neighborhoods in villages and towns in Cyprus.

The contemporary neighborhood, as a result of the above planning rule, is composed of rows of independent detached houses that no longer generate space but rather, occupy it. As houses contract and move away from one another to satisfy this new law, there is an increase in privately owned, leftover space between them. The social role of this resulting free space around the building is of particular interest, since it raises questions regarding the relationship between the exterior and the interior, the public and the private, the domestic life of the family and how it relates to its spatial and social context.

The first sections that follow, present brief descriptions of both the vernacular Cypriot house and the contemporary detached house, a result of the building regulations. The main part of the paper focuses on the comparison between a sample of four award winning contemporary Greek Cypriot houses and a sample of four typical vernacular courtyard houses.

Admittedly, the Cypriot family and its relationship with its domestic environment have undergone great changes, many of which are not directly linked to the building regulations under investigation. Still, the proposed comparison can highlight the changes that ensued from the vernacular to the contemporary, in terms of the relationship the outdoor spaces have with the interior of the house and the adjacent spaces, be it other neighbouring private houses or the street.

2. THE TRADITIONAL COURTYARD HOUSE

The long Ottoman Rule of Cyprus (1571-1877), deterred industrialization and restricted urban modernization resulting in a rather similar development in urban and rural areas, until the early decades of the British colonial period (1878 - 1960). Historically, traditional housing in Cyprus, found in rural and urban areas, adopted a courtyard typology within a dense building fabric and a continuous facade. These houses had no space between them. The tightly knit nature of living within such a neighborhood, meant that the families were interdependent upon one another and through this co-operation, the community's "system of social control" was also
strengthened. (Markides, 1978, p.81) Additionally, the lack of physical space between each home resulted in a greater consolidation of outdoor space in each house. This compact massing provided shading to the traditional narrow streets, from one and two storey buildings on either side rendering this space, together with the absence of vehicular traffic, a public living-room.

In its elemental form, each home was characterized by a makrinari, a central room opening to an internal courtyard or facing a street. This central room developed into the dichoron by adding a second makrinari and further additional rooms were created due to growing families and social influences. Through these spatial ramifications, the traditional house began to evolve into more complex spatial configurations. These walls were composed of stones at their base and then supplemented using plinthari, mud mixed with straw, otherwise known as abode construction. The walls shared between two households reduced heat losses and gains as they were protected from the natural environment. There are two primary forms of traditional housing, one type facing the street with a yard at the back and the other with the yard facing the street and the house behind it. The form of the house adapted, depended on its orientation, with the makrinari facing north and the courtyard always facing south. (Papacharalampous, 2001)

The courtyard is an architectural feature which was established in prehistoric and historic architecture in Cyprus. The closed and semi-open rooms were arranged around the courtyard, with a consideration of their orientations, inter-relations and communications. This arrangement was vital as it formed the dwelling’s layout. The courtyard developed a comfortable microclimate for the house using cross and stack ventilation to cool the dwelling. (Philokyprou, 2011)

Semi-open spaces such as the iliakoi (entrances), porches and galleries were located on the south side of the courtyards, (Papacharalampous, 2001) in order to prevent direct sun rays from entering the house.

Traditional dwellings in Cyprus, developed over time, through the evolution of society, respond to their environment and context and acknowledge the necessities of the locals. (Heal, Paradise, & Forster, 2006) As emphasized by Rapoport, the traditional house is constructed through traditional construction methods using local materials while its spaces are defined by several social and cultural notions. Thus, both its construction as well as its spatial configuration is in response to its physical and social environment.

3. THE MODERN DETACHED HOUSE

In the 20th Century, administrative stability under the British Rule, brought a “modern” planning system to the island, covering construction, road network and sanitation. The new planning regulations abolished the formal spatial arrangement of the traditional Cypriot dwelling and its most important feature, the courtyard. This was the birth of the modern detached house.

The modern house in Cyprus eventually left behind fundamentally all of the characteristics of its predecessor. The mass of the building moved to the center while the outdoor space, from a unified central courtyard became a perimetrical 3 meter wide space around the house. The salotrapezaria (the formal living/dining room) replaced the dichoron as a central element of the household and served the purpose of hosting the xenos (the honored guest). The modern house introduced the aspect of further separate rooms, especially bedrooms. (Markides, 1978) There is also an increase in permanent separations leading to a loss of multifunctional spaces which was a characteristic of the traditional house.

Furthermore, the spatial form of the modern house, with its interior and exterior spaces having various orientations, does not allow potential passive energy to cool and heat the house. Moreover, the lack of homogeneity, regarding the heights of adjacent dwellings, result in reduced privacy. Without being solely responsible for the changes taking place, the new proximity regulations established by the British Rule, have greatly contributed in the disintegration of the traditional neighborhood.

Modern architecture called for clarity, light and the investigation of the relationship between the interior and the exterior. (Jaschke, 2009) In the early twentieth century, German Jewish
philosopher, Walter Benjamin, with his description of the over-furnished and over-crowded “bourgeois interior,” set a negative reference to which the concept of modern living was generated against. (Benjamin & Demetz, 1986) Modern architects began to design new residential interiors open to the exterior world. Yet, these new architectures, Ebenezer Howard’s Garden City, Le Corbusier’s Ville Contemporaine and Frank Lloyd Wright’s Prairie Houses were open to nature, rather than the city. Subsequently, modern architects and planners avoided undertaking the matter of contention; the individual dwelling’s relation with public space, offering potential for “encounter, exchange and spectacle.” Modern architecture’s failure to relate the “domestic” with the urban has been linked to the strict and rather professional division between urban and architectural planning. In the 1950s, a young group of architects calling themselves Team 10, arose from the international platform for modern architects CIAM, and began to question the division of architecture and urbanism. They also re-evaluated the relationship between interior and exterior space. They focused in identifying the counterpart of “private, domestic interior” as the urban realm, not nature. Furthermore, they re-examined the manner in which the connection between interior and exterior should be made, not only through spatial and visual continuity but “through meaningful, psychologically effective transitions.” (Jaschke, 2009, p.175) The Dutch architect Aldo van Eyck, a member of Team 10, expressed this issue as an urban question with existentialist and psychological overtones:

“We are not only breathing in, nor are we exclusively breathing out. This is why it would be so beneficial if the relation of interior space and exterior space, between individual and common space inside and outside, between open and closed (directed towards the inside and outside) could be the built mirror of human nature, so that a man can identify with it. These are formal realities because they are mental realities. Moreover they are not polar but ambivalent realities. The dwelling and its extension into the exterior, the city and its extension into the interior, that’s what we have to achieve” (van Eyck, 1956)

Perhaps the rationale supporting the regulations imposed by the British in Cyprus did not have the above aims in mind. Still, in this case as well, the main idea was to improve the living conditions of the inhabitants. The regulations in effect today, which are in a sense an evolvement of those initial regulations related to the massing of the house and its relationship with the plot boundaries are:

• the distance between the main house and any boundary of the plot is a minimum of 3 meters.

• within the 3m setback, buildings supporting the main building may be built as long as they meet the height and size requirements. Any auxiliary building area must be less than 25% of the main building and less than 10% of the building plot. Furthermore, it must be located a minimum of 1.5m away from the main building with a maximum height of 3.5m. If it is a mechanical room it could be in contact with the main building but in such a case it must be 1.8m away from the plot boundary.

• a covered parking space touching the main building as well as the plot boundary is allowed as long as the parking space is open on two sides. A small auxiliary building can also be part of this arrangement.

• the auxiliary building’s contact along the outer plot boundary can be maximum 35% of the boundary dimension it can be increased to 40% when the auxiliary buildings of the neighboring house meets with the common border as well. Auxiliary buildings are not allowed in contact with the road boundary or a public green space which may be adjacent to the plot.

• the maximum height of the boundary walls is 2.1m when it is a boundary between two plots. When the boundary meets the road, the boundary wall must be less than 1.2m. (Ministry of Interior, Department of Building and Housing, 2011)

Yet, most architects and users alike, seem to doubt the effectiveness of these regulations and especially regarding the creation of a peripheral zone of outdoor space on each plot. While admittedly the planning regulations enforced by the British were not solely responsible, the
rather abrupt and forced shift from the traditional house to the modern detached house in Cyprus has clearly generated a noticeable reduction in the social interaction between the families living in a neighborhood. The resulting, privately owned leftover space around the house, rather than offering opportunities for social activity, is often neglected and underused and in many cases it becomes the cause of problems between neighbors. Popular ways of deviating from the law reveal the degree of discrepancy between the desired and the permitted. In perhaps most of the cases, auxiliary buildings which are shown as a storage space or a laundry room are used as proper living space for the house-help or an older parent, the height of the front and side wall is increased by thick bushes or a ‘non-permanent’ wooden or metal construction, while the garage which can touch both the main house as well as the plot boundary only if it is open on two of its sides is often sealed by a construction that can be considered by the planning authorities as ‘impermanent’.

These observations reflect the gap between the lifestyle proposed or assumed by the residential design which is influenced greatly by the regulations enforced by town planners, and the actual lifestyle of the users. The section that follows takes a closer look at four award winning houses, analyzing their spatial characteristics and listening to what the architects as well as the homeowners themselves have to say about the designs. The comparison of these houses with four typical vernacular courtyard houses allows for an evaluation of the shifting role played by the outdoor spaces then and now.

5. A COMPARISON BETWEEN THE CONTEMPORARY AWARD WINNING DETACHED GREEK-CYPRIOT HOUSE AND ITS VERNACULAR ANCESTOR

Four award-winning detached houses are compared to four vernacular courtyard houses in an attempt to see how the specific regulations have influenced the design of the house and sequentially, the manner in which the house relates to its outdoor spaces and its urban context. The fact that the award winning houses have been distinguished by the evaluation committee as exemplary pieces of domestic architecture could be taken as representative of the views of the local architectural culture in general. Before examining the houses themselves, brief accounts of the remarks or comments by the architects in their statements accompanying their entry to the competition, and the homeowners expressed in semi-structured interviews conducted for the sake of the present research, are presented.

5.1 COMMENTS BY THE ARCHITECTS AND THE USERS REGARDING ASPECTS OF THE DESIGNS INFLUENCED BY THE PLANNING REGULATIONS

5.1.1 COMMENTS BY THE ARCHITECTS

The architects, in the report submitted along the other materials requested for the evaluation, give some form of explaining regarding the way they went about designing the exterior space: ‘The form of the house was strongly influenced by the shape of the plot, its orientation and the surrounding space. The open plan interior wraps around the courtyard which is related to the surrounding nature’ (architect of House 1); ‘The clients’ request was for an introverted house with a central private outdoor space’ (architect for House 2); ‘the design investigates the relationship between the private domestic space and the public space of the neighbourhood street through the creation of degrees of privatization which, with the use of in-between spaces and controlled visual connections with the street and the public walkway, protects the interior of the house. What is sought after is an organic connection between the interior and the exterior spaces. The large areas for planting allow for low and high vegetation which will contribute in the creation of a favourable living environment’ (architect for House 3); ‘the public and semi-public spaces, (kitchen/dining room and living room), are arranged around the patio facing south with views into the private garden and to the Troodos mountains at the back’ (architect for House 4)

It is clear that the stated intentions of the architects are greatly related to desired relationship between the main outdoor space and the interior of the house. And while three of the houses
aim at creating a private outdoor space, only the fourth house (House 3) tries to create degrees of privatization between the public street and the private interior.

5.1.2 COMMENTS BY THE HOMEOWNERS

The homeowners of house 1 are the parents of the architect. They find that the sheltered courtyard creates the right spatial connection between the interior and the exterior. Similarly, the homeowner of house 2 is quite satisfied with the rather introverted design which presents high walls to the exterior.

The homeowner of house 3 explained that he has a very close relationship with his architect and that through their friendship the architect knew well the family’s desire to have large and varied outdoor spaces. The homeowner says that they practically use all the outdoor areas designed by the architect, depending on the season and the time of day. When the climate is cool they sit in an area where there is no wind and when it is hot they sit in a space where there is a cool breeze. There are also spaces which are more private for intimate social gatherings and spaces where they can watch the children play. He is happy with the variety of spaces but he believes that he would be just as content with half the spaces provided. When asked about privacy, the homeowner explained that privacy is not one of his priorities but it is for his wife. If he could alter the height of the front boundary wall he would make it higher to increase the privacy of the outdoor areas.

Being also the architect, the inhabitant and owner of house 4 explains how the 3m setback on the east and west sides of his plot were incorporated in the garden while the south (garden) and north (garage) sides are spaces which are wider than 3m. He argues that the front and back spaces are not wasted as they are indeed used by the family. He finds that the 3m setback rule should be revised or replaced and finds that it is perhaps more important to have substantial distances between the windows in adjacent properties.

Here too, as with the comments by the architects, it is clear that privacy in the use of the outdoor spaces of the house is valued by the users.

5.2 QUANTITATIVE ANALYSES

A more quantitative attitude is adopted in this part of the paper, with the first section looking at the relationship the outdoor spaces in the two sub-groups have with the interior as well as with the public domain (the street), and the second section looking at the syntactic characteristics of the designs using tools offered by the space syntax methodology.

5.2.1 THE OUTDOOR SPACES, THE INTERIOR AND THE PUBLIC DOMAIN (THE STREET)

The analysis in this section is based on a space break-up of the outdoor spaces around the house, and looks at the use allocated to these spaces, and at the visual relationships between the interior, the outdoor spaces and the street.(see Figures 2-5)

Concentrating on the outdoor space itself, a number of comparisons and observations can be made based on the information presented in tabular form regarding the allocation of use in the outdoor space and the visual connections created by the design. One first observation is that Detached House 3 tends to be an exception regarding all the aspects examined in the Detached Houses.
<table>
<thead>
<tr>
<th>HOUSES</th>
<th>TOTAL OUTSIDE AREA</th>
<th>SOCIAL AMENITIES</th>
<th>TRANSITION</th>
<th>NOT FOR SPECIFIC USE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
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<td></td>
<td></td>
<td></td>
</tr>
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</tr>
<tr>
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<td>21.15%</td>
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<tr>
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<td>VS&amp;VI</td>
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<tr>
<td></td>
<td>Percentage</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

VS=Visible from Street  
VI=Visible from Interior  
VS&VI=Visible from Interior & Street  
NV=Not visible from either Interior or Street

4.7
Figure 3 - Outside area in four award winning detached Houses in Cyprus. By Author, 2017
**Table presenting data for outside area for the four courtyard Houses in Cyprus.**

<table>
<thead>
<tr>
<th>HOUSES</th>
<th>TOTAL OUTSIDE AREA</th>
<th>SOCIAL AMENITIES</th>
<th>TRANSITION</th>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Area</td>
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<td>2.95</td>
<td></td>
</tr>
<tr>
<td>Percentage</td>
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<td>0.05%</td>
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</tr>
<tr>
<td>VS</td>
<td>1.91</td>
<td>VI</td>
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<td></td>
</tr>
<tr>
<td>Total Area Sub-C Percentage</td>
<td>-</td>
<td>-</td>
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<td></td>
</tr>
<tr>
<td>Courtyard House 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area</td>
<td>411.71</td>
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<td>Courtyard House 3</td>
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<td>Courtyard House 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area</td>
<td>121.62</td>
<td></td>
<td>5.99</td>
<td></td>
</tr>
<tr>
<td>Percentage</td>
<td>100.00%</td>
<td></td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td>VS</td>
<td>0.91</td>
<td>VI</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td>Total Area Sub-Category</td>
<td>-</td>
<td>-</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td>Total Area Sub-C Percentage</td>
<td>-</td>
<td>-</td>
<td>0.00%</td>
<td></td>
</tr>
</tbody>
</table>

**Legend:**

- **VS** = Visible from Street
- **VI** = Visible from Interior
- **VS&VI** = Visible from Interior & Street

**Author:** 2017

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**Figure 4:** The Outdoor Spaces of the Contemporary Greek Cypriot Detached House.
Figure 5 - Outside area for the four courtyard Houses in Cyprus. By Author, 2017
5.2.1.1 OUTDOOR SPACE AND ALLOCATION OF USE

Presumably due to the larger plot sizes, the total amount of outdoor area for the courtyard houses is less than that of the detached houses. Still, in the case of courtyard houses, the space is central whereas the outdoor spaces of the detached houses is broken up and found mainly on the perimeter of the house.

As Figure 2 shows, the largest percentage of outdoor space in the contemporary detached houses is not allocated to a specific use in all the houses except house 3. Furthermore, with the exception of house 3 and house 2, social uses tend to be allocated to the smallest percentage of outdoor space.

In the case of the Courtyard vernacular houses (Figure 4) the greatest percentage of outdoor space is not allocated a specific use but it is known that this space was used for social events as well as for activities related to farming and animal rearing.

5.2.1.2 VISUAL ACCESSIBILITY OF OUTDOOR SPACES

A general observation regarding the Detached Houses is that, with the exception of the introverted house 2, a large percentage of the outdoor space is visible from the street and a much smaller percentage is rendered visible from the interior. Under a different lens, looking only at the percentage of the outdoor space which is allocated to social use, a different reading can be made. Here, the largest part of the social spaces is mainly visible from the interior, except in the case of House 3 since most of the social outdoor spaces are visible more from the street than from the interior.

In the case of the Courtyard vernacular houses, with the exception of the courtyard house 2, a large percentage of the outdoor space is not visible from either the street or the interior. In the case of courtyard house 2, the amount of outdoor space visible from the interior is equal to the amount of outdoor space not visible from either street or interior. All the courtyard houses are generally more visible from the interior rather than the street. With courtyard houses outdoor space is mostly not visible, therefore creating a visual link from the interior or exterior is not dominant in this design.

Interestingly enough, flowerbeds and planters in the detached houses are mostly visible from the street (public) rather than the interior.

5.2.2 SPACE SYNTAX ANALYSIS

The spatial properties of the two groups of houses are investigated using space syntax analysis. The goal is to determine the degree and the manner in which outdoor space is integrated within the house's layout. For the analysis, all indoor and outdoor spaces are accounted for and DepthmapX is used to calculate the syntactic measures. Furthermore, using the convex map as a base, Justified Accessibility Graphs (J-Graphs) are created to examine how the spaces are related to each other.

5.2.2.1 INTEGRATION AND MEAN DEPTH VALUES (DEPTHMAPX)

According to the overall results, the average integration value of all convex spaces per detached house is lower than that of the courtyard houses. Quite telling are the rankings of the main spaces according to the integration values:

Detached House 1  MV > EH > IL > FD = ID > FL > B > K
Detached House 2  EH > IL > FL > MV > FD > ID > K > B
Detached House 3  EH > FD > L > K /ID > MV > B
Detached House 4  B > K > D > L > MV
Proceedings of the 11th Space Syntax Symposium

THE OUTDOOR SPACES OF THE CONTEMPORARY GREEK CYPRIOT DETACHED HOUSE

4.12

Courtyard House 1  
MC = P > MR = D > K = ASH

Courtyard House 2  
MC > MR > D > P > ER = K

Courtyard House 3  
MC > P = MR > ASH > K = ER > D

Courtyard House 4  
P > MR > MCER > D > ASH

In two detached houses, the most integrated space is the entrance hall and the staircase connecting the two floors, while in the other two cases the most integrated space is an outer transition space, which is located within the 3m setback and has no direct connection to the interior. The values for the main veranda show no clear trend, apart from the fact that this space tends to be segregated rather than integrated.

In contrast, the rankings for the courtyard houses show the most integrated space, in three of the four cases, to be the main courtyard and in one case, the iliakos, another primarily outdoor space. However, in terms of the depth values of their main outdoor spaces, the two types of dwellings are analogous. These spaces tend to be shallow spaces rather than deep, despite the fact that all the detached houses exhibit larger mean depth values in comparison to the courtyard houses.

5.2.2.2 JUSTIFIED GRAPHS

Each space in the justified graph can be classified according to the way it connects to its neighbours and beyond. Four types thus emerge: Type A is a terminal space; Type B is a transition space which is not part of a ring sequence; Type C is a space that is part of a ring sequence; Type D is a space which is part of two or more ring sequences, (Hanson, 1998, p.173).

All the detached houses, with the exception of one, have a very low percentage of TYPE A and TYPE B convex spaces (spaces that do not create rings). In fact, they exhibit a large proportion of TYPE C and TYPE D convex spaces. This results in large rings between the perimeter outdoor spaces of the houses and a large number of rings between the exterior and interior spaces.

The courtyard houses have predominantly TYPE A and TYPE B rather than TYPE C and TYPE D convex spaces implying the presence of significantly fewer rings. In two cases, there is a ring between the enclosed areas and the iliakos, whereas in one courtyard house there is a ring involving some of the outdoor areas and the main courtyard, and in the other courtyard house there is a ring between the interior and the main courtyard.

Convex Break Up and integration analysis using DepthmapX

Detached Houses
main veranda: MV
entrance hall: EH
informal living: IL
formal living: FL
single living space: S
informal dining: ID
formal dining: FD
single dining space: D
kitchen: K
bedroom: B

Courtyard Houses
main courtyard: MC
porch: P
main room: MR
animal shelter: ASH
kitchen: K
extra room: ER
depot: D

Figure 6 - Table showing Convex Break Up and integration analysis using DepthmapX. By Author, 2017
### Syntactic resulted data using DepthmapX

<table>
<thead>
<tr>
<th>Detached Houses</th>
<th>Integration (HH)</th>
<th>Mean Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
<td>Average</td>
</tr>
<tr>
<td>House 1</td>
<td>0.591825</td>
<td>1.00902</td>
</tr>
<tr>
<td>House 2</td>
<td>0.408273</td>
<td>0.824118</td>
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<tr>
<td>House 3</td>
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<tr>
<td>House 4</td>
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<td>0.708888</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Courtyard Houses</th>
<th>Integration (HH)</th>
<th>Mean Depth</th>
</tr>
</thead>
<tbody>
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<td>Minimum</td>
<td>Average</td>
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<td>House 2</td>
<td>0.746129</td>
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</tr>
<tr>
<td>House 3</td>
<td>0.6098</td>
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</tr>
<tr>
<td>House 4</td>
<td>0.472966</td>
<td>0.855004</td>
</tr>
</tbody>
</table>

Figure 7 - Table showing syntactic resulted data using DepthmapX. By Author, 2017.

### Justified Graphs using Jass

<table>
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<th>Detached Houses</th>
<th>Courtyard Houses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 8 - Table showing Justified Graphs using Jass. By Author, 2017.
6. CONCLUSIONS

A number of comments can now be made regarding the character of the outdoor spaces of the detached contemporary Greek-Cypriot house with the results of the analysis confirming that the impact the building regulations introduced by the British Rule in 1946 goes beyond the quite apparent break-up of the continuous street front of the vernacular neighbourhood.

The strongly integrated courtyard of the vernacular house as the main, and in many cases only, outdoor space is replaced by a main veranda or other outdoor space which, despite its connections with other outdoor spaces which run perimetrically around the building, remains rather segregated. The most integrated space of the unit now tends to be located inside the house. Even in cases when the most integrated space is an outdoor space, it is not the main outdoor space but a transition space somewhere in the perimeter of the building which is not that essential in the life of the family.

The above observation is also linked to the increase in the number of rings in the detached contemporary house but what needs to be pointed out, as mentioned above, is that many of these rings do not play a significant role in the lifestyle of the family since they involve the practically left-over space around the house.

Additionally, although the visual connection between the courtyard and the interior spaces of the vernacular house was much less than that of the main outdoor space and the interior of the contemporary house, the visual exposure of the contemporary house’s outdoor space to the street, means less privacy, a setup which does not seem to be desirable by most homeowners. With the wall separating the street from the outdoor spaces having a maximum height of 1.2 m, the imposed spatial relationship does not seem to reflect the way the family relates to the public space. This is also the case, with the 2.1m high wall which can be built where the plot meets a neighbouring plot. Unlike the interior spaces which were found around the courtyard of the vernacular house, these walls may break the visual but not the sound connectivity between adjacent houses.

It should therefore be no surprise that the architect during the design, and the homeowners after the house is completed, try to find ways to eliminate the negative effects these regulations have on the desired lifestyle of the family.
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ECOPSYCHOSOCIAL PARAMETERS AND MENTAL HEALTH: 
The complexities of the psychiatric ward

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ABSTRACT
Mental illness historically has followed an uneven path regarding the social integration and the therapeutic priorities of mentally ill people. This was reflected in the institutions that provided for mental illness, with emphasis shifting between custodial and somatic priorities. Gradually, mainly in North America and most European countries, big institutions have been replaced by networks of smaller facilities, known as community care, which introduced the psychosocial model prior to the pre-existing jurisdictional and medical models of treatment and care. These new environments display great variations in policy, service provision and care regimes, even in the same area. Architectural typologies for psychiatric facilities follow this experimental pattern. That hindered the creation of an established, evidence based methodology for psychiatric spaces. The gap was addressed with a patient-focused model, specifically designed for psychiatric facilities, the SCP model. It used methodologies of social medicine, corresponds to the 3 main care models of psychiatry and has been applied in several European contexts. It aids set a red line for medical planners and designers and the identification of areas for further research.

A key area identified by the application of SCP model on awarded psychiatric buildings was the lack of understanding on the influence of ward layout to patient wellbeing. Following that, this research aims to promote our understanding of psychiatric space and help us promote our understanding on the mechanisms of the built environment against total institutions and their institutional practices.

The locus comprised 2 acute psychiatric wards in London, belonging to different Mental Health Trusts, all part of the public healthcare sector. Each was evaluated using the SCP model, to identify the relation between policy, care regime and patient-focused built environment. Parallel, a syntactic analysis identified the social logic of the wards’ layout, in terms of hierarchies for the two main user-groups patients and staff, staff’s control of the ward in terms of supervision and patient privacy.

The juxtaposition of medical architecture and space syntax provided new insights on how psychiatric space is used, as the analysis of the area surrounding the nursing station indicates. The different approaches regarding the gathering of people outside the nursing station, from institutional (unstructured behaviours or unrest) as interpreted by medical architecture to an expected social interaction to the most integrated point from the syntactic perspective, indicated that there is a new potential from the combination of the two methodologies. From the paper, it occurs that Space syntax could unearth underlying issues of social interaction and then the medical architecture methodologies could interpret these issues in the context of the therapeutic regime. That way, we can reach a better understanding not only of how medical spaces operate but provide new insights on the therapeutic regimes.
KEYWORDS
Mental health architecture, Space Syntax, Health care buildings, psychiatric spaces, mental health facilities

1. BACKGROUND
The concept of mental illness in the west, historically, presents great complexity. It has been interconnected with the cultural, socio-political and religious values characterizing each era and even, in some cases, it has been influenced by the key economical drivers. Healthcare facilities have always been reproducing the system of care and represented a reflection of its values (Marcus, 1993). One of the formative elements of psychiatric architecture as a result of these social values has been the stigma associated with mental illness (Goffman, 1961; Foucault, 1964; Pevsner, 1976).

Stigma is a parenthesis in the history of mental illness as at the onset on western medicine (Chartocolis, 1981), somatic theories were the norm yet this parenthesis occupied the clear majority of the period starting from St Augustine (Chartocolis, 1981; Georgiou et al., 1993) to the age of Second confinement (Abatzoglou, 1995) leaving remnants that still create undercurrents in the psychosocial integration of the mentally ill even in the western context, as the process for the social reintegration of the institutionalised patient is about half a century old. These undercurrents might be present even inside the healthcare systems, create internal inequalities, influence policies and find pathways in all parts of a system including staff (Sartorius, 2007), with the building stock related to mental illness—which is the main subject of the paper -- proving no exception. For those reasons, it is very important to acknowledge their origins and presence and be aware of these potential undercurrents in any layer of psychiatric related research including this of the built environment.

In this uneven trail but consistent in the dominance of stigma, we could detect a shift from the initial somatic perception of the illness to more socio-political, which in fact was corresponding to a shift of power from the doctors, be it Hippocrates or Pinel (Georgiou et al., 1993; Vavyli 1992), to judges (Cavadino, 1989; Cayla 1992) and resulted in a custodial way of dealing with mental illness, which comprises the jurisdictional model of mental health provision. This duality between a disease and a threat became even more obvious after the establishment of psychiatry, where the religious assumptions connected to the illness started to disappear, yet important elements of the socio-political barriers and especially those related with the rights of the mentally ill in our society. For example, even in countries that considered pioneer in Community care, the police as opposed to the A&E department of the general hospital might still be the first point of contact with the health services including the police car instead of the ambulance being the transportation vehicle, and its projection as bare from any furniture seclusion rooms or padded cells inside the psychiatric wards (Care Community Commission, 2015), and the dynamics of the institutions (Mental Health Act, 1983; Department of Health, 2014; Born et al., 2014). In this paper, the field of medical architecture, salutogenic architecture or therapeutic architecture --a discipline of evidence based design linked closely to the concepts of physiology and perception of the disease in relation to space and place and in close methodological links with medical sociology—approaches space syntax as the theory that can provide insights on socio-spatial dynamics and possibly identifying undercurrents of stigma in the psychiatric establishments. Therefore, it is important to familiarise the reader who is not necessarily familiar with the psychiatric regime what is the experience that several patients might have through their individual journeys in mental health facilities.

The developments of psychiatry, gradually shifted powers from judges to doctors (Mental Health Act, 1959) and the foundation of the psychiatric hospitals (Vavyli, 2003) and correspond to the medical model of mental health provision. Yet, both professions are still involved in the decision-making related to mentally ill people, depending on context and dangerousness, i.e., a key term of psychiatry defined as the condition where a person is more likely to cause harm or self-harm (Chiswick and Cope, 1995). In fact, this balance between the medical and jurisdictional power reflects a fundamental reason for the existence mental health facilities.
Even in our times, society does not accept the responsibility to deal with the dangerousness associated with mental illness and shifts this responsibility inside the protected environments of psychiatric premises to manage or contain that risk. For example in England the patients who are detained in psychiatric facilities under a section of the 1983 Mental Health Act as amended in 2007, form approximately one half of the psychiatric patient population (Community and Mental Health Team NHS Digital, 2016). These, depending on the severity and the threat to oneself or to others could either belong to custodial services, or hospitals or in facilities in the community such as Community Mental Health Centres. A patient, could sometimes move between the three, depending on the individual course of illness, healthcare system or service availability. Yet, in all three contexts quality of life might be compromised and some institutional practices still prevail, several years after De-institutionalisation.

On his work on neurodegenerative diseases Zeisel (2010) stresses that the inadequacy of the pharmaceuticals and the medical aspects of care could be partially overcome by focusing on areas that we have already some results and specifically human resources and design of the premises. This could also be the case for mental health since medicine has not yet addressed key issues to allow patients have a fully functional life. In fact mental health conditions are among the diseases demonstrating some of the lowest diagnostic and interventional accuracies (Christensen et al., 2009) accentuates the need to develop non-pharmacological ways and more precisely through social and physical contexts, to alleviate patients’ burden and increase their quality of life, in the meantime. These are meant to act complementary to medical interventions, reducing the effects of the symptomatology for patients and staff and do not claim being a cure. Evidence base healthcare design has also been considered as a cost-effective means of improving care (Hastings centre report). This need of architecture to support the mental health provision has been frequently reported in medical journals and publications either from doctors and healthcare staff as a need for evidence base design informed healthcare facilities (Foley and Lacy, 1967; Cammock, 1972; Smith, 1973) or from mixed medical and healthcare architecture teams (From and Lundin, 2010; Chrysikou et al., 2016) as well as policymakers (Iowa State University, 1993; Stange, 2012). Most, the importance of architecture for psychiatrists is demonstrated by the fact that bricks and mortar have been regarded as one of the four essential components of psychiatric de-institutionalisation (Chow and Priebe, 2013) and according to World Health Organisation (WHO) investment on facilities is crucial for mental health provision (WHO, 2015).

Mental disorders account on 31% of years in life spent with disability per person and significant increase of mental illness is expected –depression alone to become the second burden among diseases globally, first in developed countries (WHO and WONCA, 2008). Taking to account the importance of the research of the psychiatric environment as a means to support mental health and the gravity of the social context to mental illness, Hillier and Hanson’s theory (1984) on the interrelation of space and social structures, makes the research of the physical environment of psychiatric space crucial for the understanding of mental health care itself. That happens because, in psychiatric spaces usual social norms are modified, either due to regimes or to undercurrents of institutionalization. Thus, understanding of socio-spatial relations might provide understanding of the actual mental health practices and regimes. To achieve this, the objectives are:

a) comprehend the background of psychiatric care
b) explore the main concepts for designing for mental health as they have influenced the psychiatric premises
c) understand the existing state of the art in mental health facilities design and
d) try to identify ways where space syntax could provide new insights.
1.1 MENTAL HEALTH CARE IN THE 20TH CENTURY: FROM INSTITUTIONS TO CARE IN THE COMMUNITY

Soon after the end of WWI in Europe we witness the first seeds of community care, especially in USSR (Madianos, 1980). Yet it was the second WW2 where there is a breakthrough with the development of the first tranquilisers that generated a new confidence on psychiatry and created hope for a potential cure for mental illness (Baldwin, 1993). This, resulted in the shift of the locus of treatment and care from the psychiatric hospital, which used to be a remote, large-scale institution surrounded by leafy grounds to the psychiatric ward of the general hospital, following the floor plan of the rest of the wards and situated usually at the top floor (Cavadino, 1989; Vavyli, 1992). This contributed to an unprecedented medicalisation of care and it was the first attempt against the stigma associated with the illness, as it was included among the less stigmatized conditions that are normally associated with the general hospital. Location-wise too, the general hospital tended to have a much better integration in the urban grid compared to the segregated psychiatric hospital. However, the mentally ill were confined on the top floor, with the ward corridor the only available space to move and they lacked access to open air. Soon became clear that the functional approach of the hospital tower, influenced by the circulation of medical gases and fluids among others, was not the optimum environment for the treatment of mental illness (MARU, 1991). The disillusionment regarding the effectiveness of pharmacological interventions, as there was a revolving door syndrome and patients needed frequent and lengthy re-admissions and the influence of the antipsychiatry movement led to the John F Kennedy legislation on an extensive de-institutionalisation and constituted the Community Mental Health Centre as the main provision for psychiatric care (Turner-Crowson, 1993). This was known as De-institutionalisation, Community Care, Care in the Community or in some contexts as Psychiatric Revolution and corresponds to a psychosocial model of care where multidisciplinary teams including psychologists, social workers, art therapists etc were involved in the care programmes. It was implemented in a different mode across the western world, presented a considerable degree of experimentation and local variation influenced by principles such as sectorisation, i.e. a decentralized approach of mental healthcare provision, and introduced new types of disciplines such as psychology and occupational therapy, arts and social work in the care of mentally ill patients (Vignet, 1999). Unevenly developed, broad networks of services, most of them experimental and presenting significant local variations, catered for the various needs of mentally ill people (Chrysikou, 2014).

1.2 MENTAL HEALTHCARE ARCHITECTURE

Facilities for mental health followed a similar pattern of experimentation and variety. However, as buildings tend to present a greater inertia to adaptations compared to services, and mental health buildings proved no exception. As a norm, mental health facilities did not reflect the revolutionary semiotics that accompanied care in the community. Although there was literature on the care aspects of the service provision, there was a dearth of Evidence base references to Facilities and Estates suggestions. There could be named several reasons for that:

- The lack of evidence based culture in architecture
- The limited exchange of knowledge between architecture and psychiatry, despite the fact that psychiatry considered buildings as an essential part of de-institutionalisation as explained earlier in the paper.
- The fact that in several contexts, psychiatric revolution meant that the mentally ill people would return in ordinary housing in the community, thus presenting limited interest for medical architecture, the discipline related to healthcare facilities planning and design.
- The complexity and plethora of the available options, such as day centres or night centres, crisis centres, day or night hospitals, half way homes, rehabilitation hostels, serviced apartments, protected apartments, foster homes, psychiatric wards, community centres, community cafes, occupational rehabilitation services, in terms of service provision, which made their research and the extraction of evidence even more challenging.
• Lack of knowledge of how psychiatric space operates. There was some knowledge from environmental psychology and psychiatric literature on institutional behaviors in asylums but this research was conducted mostly in the large psychiatric hospitals, which stop operating in most countries and the model of care has changed considerably since. Guidelines on psychiatric facilities by the WHO (Baker et al., 1960), were very far from evidence based models and were mostly reflecting psychiatric theories on how patients' behavior might be influenced by space. What is interesting though about these publications is that they indicated a clear interest on buildings which would support the therapeutic regime by the medical community, yet this need did not reach the architectural community.

For the NH in the UK, but also in other European countries such as the Netherlands, healthcare architecture kept a systemic role in the planning of the services as the provision for in-house, DoH based, hospital R&D architectural teams suggested and which continued to work closely with the NHS (HANSARD 1803-2005, 1982) even after it was renamed as Medical Architecture Research Unit (MARU) and relocated in the Polytechnic of North London. Yet, other areas of healthcare provision and planning received higher priority.

Mental health architecture, since the mid of the past century presented some very innovative concepts, mainly through the field of environmental psychology. Those involved small scale interventions, such as furniture arrangements or interior design modifications (Amiel, 1976; Ittelson et al., 1970; Sloan Devlin, 1992; Gutkowski et al., 1992) concluding that improvements in the environment of mental health facilities could have a therapeutic effect for patients. That was a very important finding considering the neglect that psychiatric facilities tended to present, but apart from this message that design matters, there was not an integrated theory on how to achieve that. Later, control, privacy and social interaction were identified by Halpern (1995) as elements that could influence mental health through the built environment in general but not specifically in health or mental health facilities.

A multi-disciplinary conceptual collaboration by Baker, Davies and Sivadon for WHO (1960) introduced a theoretical, stemming from psychiatric doctrines, integrated approach to design, with suggestions covering from the location, the scale and the layout of the psychiatric hospital to furniture details. Yet, the timing, just before hospitals started to close, did not allow that model to evolve and suggest a model for the design of community care buildings. The massive closure of psychiatric hospitals, generated unmet needs for the accommodation of the newly discharged patients that resulted in several heavily institutionalized people to experience homelessness. Subsequently, the need to house the old and new patients fast in the community occurred and there was no time to propose and research fit for purpose models.

The experimentation, variety and lack of a central theory of psychiatry or medical architecture on mental health facilities, generated a corresponding experimentation on the design of the community mental health facilities. This resulted occasionally in facilities hosting very severe incidents of anti-social behaviors that their buildings were deemed unsuitable and that had to be demolished shortly after opening (Elderfield, 2002; Chrysikou, 2015).

1.3 NORMALISATION, ITS CRITICISM AND THE SCP MODEL

Normalisation theory, which was developed for the neighbouring field of learning disabilities (Wolfensberger and Glenn, 1973) was introduced to the architecture for learning disabilities and from then to architecture for mental health architecture to cover the gap. It was a theory that was already in line with the UK policy regarding the closure of the asylums in the 60’s (Wainright, 1999). Initially it appeared as a match, introducing the concept of normal, as opposed to institutional, approaches of treating and accommodating patients. This sounded appealing after the closure of the psychiatric hospitals, as it opposed to stigma and promoted inclusion. Regarding the built environment, this attempt to eliminate stigma was achieved through a symbolic use of architecture via the polarity between normal vs institutional aesthetics (Robinson and Thompson, 1999). Nevertheless, the efficacy of these theoretical models, or the design guidelines and literature suggestions that derived from it had not been tested
through evidence based research. Additionally, there were significant differences between the symptomatology of learning disabilities and psychotic related illnesses, even though belong under the broader mental health umbrella. The main criticism of normalisation came from the practice of medical architecture, with Cullinam (Rush, 1982) and Davies (1988) suggesting that normalisation was disguising medical power and promoted an attitude of invisibility for mental illness and in fact was a reverse use of aesthetics than that of normalisation: instead of helping people to fit in, celebrated diversity and promoted pride through the environment. Both theories however, used physical form to influence the perception of the users of architecture.

Findings from environmental psychology related to healthcare design as well as policy change from more functionalistic models such as nucleus hospitals to patient focused care (Francis et al., 1999) and the influence of the USA consumer oriented healthcare and the Plane Tree hospital ethos, services and aesthetics (Malkin 2002, Frampton et al., 2008) started to affect the whole medical architecture sector. This change was further fuelled by the work in therapeutic landscapes mainly in Scandinavia (Lygum et al., 2012; Jiang and Verderber, 2015) and the USA as well as the introduction of the theory of Salutogenesis from medical sociology (Antonofsky, 1979; 1987) to medical architecture, that became known as salutogenic design (Dilani, 2008).

At the same time in Europe, psychiatric rehabilitation was implemented following various approaches, each differentiated by the place of the hospital in the system: from catering for the most acute spectrum of the disease in hospital settings, such as the case of Belgium who still kept the concept of psychiatric hospital campus and further developed specialised units inside or outside the premises (Fouqault, 1964) or France that retained the hospital but developed sectorised networks of community based associations (Vignet, 1999) that case to being replaced by Care in the Community as in the case of the UK (Griffiths,1988) or hybrids of the two approaches such as the case of Greece that developed community facilities either as satellites of the Psychiatric ward of the general hospital and former asylums, sometimes even in the premises of those, or as part of community based independent associations (Council of the European Union, 1984; Saradides,1995).

In the beginning of the new Millennium, a research was conducted at the Graduate School of the Bartlett, a synchronous and comparative study of the mental health facilities in the UK and France (Chrysikou, 2008). The research was informed of all these theories, i.e, environmental psychology, Care in the Community and Salutogenics as well as normalisation and its criticism (Chrysikou, 2014). After an initial sample of 200 mental health facilities that where visited, 10 --five wards in Community Mental Health Centres in the UK and five Foyer de Post Cure in France-- were selected for a detailed, user-inclusive study. It gathered the key themes and suggestions that appeared in medical, healthcare planning and medical architecture literature and juxtaposed them with patient and staff views on the subject. Methodology was based on medical sociology and comprised analysis of the plans according to use, a detailed architectural checklist of 212 points on the institutional elements of the buildings, based on a checklist for accommodation for learning disabilities (Robinson et al., 1984) evaluation of the physical environment according to salutogenic criteria and detailed patient and staff semi-structured interviews.

Data were classified according to three tiers of needs, from the basic (survival related) to those related to wellbeing. More analytically, physical needs related mostly to safety and security, i.e. the need to remain alive when there is dangerousness involved. Then patients’ competence to being able to take care of oneself, an ability that is compromised by mental illness is mostly related with the nurturing and care provided by staff. Finally, the restoration of the ability to act as an individual, i.e. personalization and choice, as opposed to the imposed uniformity of the institutions, can be achieved when the previous two have been met and is associated with the wellbeing. Moreover, the model corresponded to the three axes associated with mental health as it has been formatted over the centuries by the three main frameworks: the jurisdictional/ custodial (safety and security), which has been historically the longer influence, the medical (competence) and the psychosocial, the most recent that developed after psychiatric revolution (personalization and choice).
For example, forensic facilities present much stronger custodial elements, as opposed to assessment wards that have a stronger medical element or vocational rehabilitation services which are closer to the psychosocial. Nevertheless, all elements co-exist in all mental health systems and facilities, following different combinations of the three elements across each system. Thus, each facility can occupy a single point in a three-dimensional space described by the three axes. The model was named the SCP model, from the acronyms of the three parameters (Safety & Security, Competence and Personalisation & Choice) (Figure 1).

Figure 1 - Different types of accommodation, such as the forensic ward, the assessment ward, the protected apartment and private residence according to the SCP model. With the help of the model we can locate each facility in the 3D space that is formed by the three parameters of the model, each parameter serving as an axis. This place is ideally determined by the pathology and stage of the illness: for example, patients living in the protected apartments have much lower needs for an anti-ligature environment than the forensic patients and their competence is very close to independent living and they have much more freedom to personalise their environments and make choices.

The study produced a significant number of findings covering a broad area of service and building provision, with key finding the inadequacy of the normalization theory to cover the complex needs of mentally ill people, compromising all aspects of care. It is beyond the scope of this paper to go into detail regarding the findings. However, one very interesting finding resulted from comparing the buildings per their institutional features, and juxtaposing them with the inhabitant satisfaction from the ward or foyer premises.

There was a relationship between the number of institutional traits of the buildings and the replies of patients and staff, not necessarily related to the qualitative aspects that the architectural auditing provided. Awarded buildings included in the sample performed middle to low, corresponding to the Checklist score. These were relatively new, purpose built wards in Mental Health Centres, all built with the best of intentions, and awarded accordingly. Especially one of the two, even though had received all these architectural attention as an exemplar (Health Building Note 35, 1997) and was well maintained, performed comparably low to another unit presenting strong institutional characteristics including neglect and anti-social behaviours such as violence and prostitution, both traits that characterized asylums, what we could call a hybrid of an institution in the community. A first, explanation when compared to facilities that scored the lowest in terms of institutional characteristics and additionally presented a high degree of staff and patient satisfaction, was that the later had a significant user involvement, in the form of staff and patient input, from the very early stages of their planning and design. However, this could be the reason for the performance of the latter but not an adequate explanation of the performance of the former (the awarded).
One question generated from this finding related to the morphological characteristics of spatial configurations and if those might be able to provide any hints for that unexpected outcome, i.e., the difference between architectural good intentions and patient as well as staff satisfaction.

A second, smaller scale but higher complexity in terms of methodological approach, was conducted between 2015-2017 involving assessment mental health wards in London. These are still in the framework of Care in the Community, as the UK has closed its Psychiatric hospitals but very close to the acute spectrum of the disease, as patients are at the closest stage of an acute episode, when they need higher medical care as opposed to rehabilitation support and most patients are under significant restrictions of movement and under a section of the Mental Health Act, which is clear custodial element. Yet, this being under the umbrella of Care in the Community, psychosocial rehabilitation is embedded in all stages of the program.

2. METHODOLOGY

The research, which is continuation of the earlier research using the SCP model, uses all the methodological tools of the previous study and at the same time introduces the element of socio-spatial interaction. It bears methodological similarities to an earlier study on care homes for older people combining qualitative psychosocial data and spatial analysis, which found that the spatial analysis could provide insights on issues related to quality of life (Hanson and Zako, 2005). Here, the tools used for the evaluation of the wards with the SCP model, involved the relation of the physical environment to the therapeutic regime and to salutogenic elements, the physiology and the perception of the patients, it was a method to understand the fit for purpose of a facility in accordance to the therapeutic model and to patient-focused care. In short, it was a social medicine methodology applied in the field of medical architecture.

The research that Hanson and Zako were involved was the closest to the research conducted by space syntax in the broader sector of healthcare facilities to the current research, as it was interdisciplinary and used two main research teams, one of which worked on a quality of life matrix and the other introduced the spatial morphology methods. It should be mentioned here that there is a growing body literature on space syntax and building layouts in relation to nurse work stations, such as the work of Koch and Steen (2012), Sailer et al (2013) yet these are more related to staff interactions and information exchange, which differ from the salutogenic- (patient focused) framework of this research. The key structural difference stems from the fact that the physiology and the perception of the person is altered by a disease and this can affect preferences or actions in relation the physical environment (Vlček, 2011; Nanda,2012; Granovskaya et al., 2013).

For instance, in space syntax literature interactions are not necessarily related to the pathology nor are subject to interpretation as normative vs institutional induced behaviour (as in the case of standing and wandering (institutional behaviour) for example, in Hou & Marquardt 2016 which has received equal gravity to socialising (behaviour indicating improved mental health). Additionally there is a strong distinction between the culture, the policies and the principles between health hospitals and mental health facilities that is even so strong that in most countries they do not co-exist in the same Trusts (as in the case of the NHS that the health trusts are completely disconnected from the Mental Health Trusts), as well as the decreasing dependency of the mental health facilities from the medical profession and roles especially since the psychosocial model of mental health became the dominant model and we have examples of mental health provision that are so self-governed that the patients hire the staff including doctors (Farrell and Deeds, 1997). This has been an additional reason that we could not draw analogies from research on hospital environments, although the researcher is aware of it, including research in hospital settings conducted using space syntax methodology, as opposed to mental health architecture.

Data derived from building plans, the architectural, walk-through checklist of 212 points and qualitative data on the quality of life of patients and staff from the two semi-structured interviews, one for patients and one from staff, each involving a set of 30 topics. Qualitative methods aim to uncover relationship between the buildings and their features to the quality
of life of patients and staff. Then spatial analysis of the wards involves their morphological characteristics of spatial configurations. The research aimed to involve the least possible disruption to the life of the wards, so observations of patients was not advisable for their pathology, especially since at the assessment stage their mental state is very fragile and was avoided. Yet, as the researcher spent time in the ward for the rest of the data collection, there was a relatively good understanding of the actual use of space. Ethical approvals were sought and permissions were granted.

3. DISCUSSION

None of the wards was stand alone and both belonged in a larger mental health complex. Both were in London, Finsbury ward was in St Ann’s hospital, Barnet, Enfield and Haringey Mental Health NHS Trust. Initially it was built as fever hospital, yet for four decades it accommodates mentally ill patients. The campus reminds more of an asylum rather than a community mental health facility, as it is the size of several blocks and a tall brick wall separates the campus from the rest of the community. Yet, the campus entrance is not locked, contrary to the ward entrance. It is a place that with clear signs of wear and tear but there is the minimum possible maintenance on the basis that there is a plan to be replaced soon. Yet, this was also the case when the researcher first visited the ward in 2000, when there were already architectural plans of the “new” building. However, nothing has materialised since and patients are admitted in the ward. The ward is around two almost in-line double loaded corridors that are connected to each other through a common open area at the middle where the pool-table is (Figure 2, figure 3). There is also the nursing station, with direct view to the garden, the lounge and parts of the corridor (figure 4).

The ward presents several institutional elements, it is male only, with very limited privacy having a mixture of dormitories and single bedrooms, and all toilet and shower facilities are common. There is a secure garden, where patients are allowed on their own and where smoking is still permitted, yet there is not internal dining room so they have access to a dining room outside the ward at meal times only. The same room is shared by the female ward too but this happens at different ours and genders do not mix. Staff areas are scattered around the ward, with staff toilets near the entrance, nursing station at the middle, and a series of offices at the other end of the ward, in a part inaccessible to patients. Patients tend to stay in the dormitories (Figure 5), several engaged in passive behaviours in their beds which is a strong institutional trait, which opposed to the psychosocial model of care, some roaming around the corridor close to the nursing office, which is also considered as institutional behaviour, and the pool table, a bit less at the lounge which is arranged in a socio-fugal way and several are at the garden, chatting or smoking. The garden is the area where most social interaction occurs. There are very limited opportunities for therapeutic activities available in the ward and most staff are either in the staff area, so invisible and inaccessible to ward patients, or in the nursing station. The nursing station is occupied with at least two staff members most of the time, yet the furniture arrangement is such that staff is looking at the garden only. In general it was a building that could belong to the former models of care as a hybrid between the jurisdictional model –dormitories, shared toilet facilities, lack of therapeutic areas, socio-fugal furniture etc, with very few elements referring to the psychosocial model of care.
The second ward is Sapphire ward, at Highgate Mental Health Centre and is part of Camden and Islington NHS Foundation Trust. It is a building that was purpose built as a mental health facility, with several wards on the same floor and on the floors above. Sapphire (figure 6) is at the rear of the building, quite a long walk from the entrance and separated by a sequence of doors. It is on the ground floor viewing green spaces, yet with access only to a secure internal, fully enclosed courtyard. Contrary to Finsbury, smoking is not allowed in the premises and staff had to escort patients outside the premises for cigarettes. This created a lot of tension in the ward, which had been burned by a patient hiding a lighter earlier that year. The researcher visited the ward shortly after the renovation, as it remained closed for couple of months after the fire, and the condition was good. It presented more anti-ligature features than Finsbury and perceived sources of danger including the sheltered areas in the courtyard had been removed after a prior incident. The ward comprised three doubled loaded corridors (figure 7), meeting at the nursing station (figure 8). Office areas located at the entrance, occupied one of the tree corridors, one was the female only zone, including bedrooms and a female lounge and the rest were the male area, accessible to all genders (common areas and corridor). All rooms were single with en-suite facilities. The ward presented very strong anti-ligature features (jurisdictional model) but also had strong references to the rest of the models with medical offices being present in the ward plus the privacy of own bedrooms and en-suite facilities together with the presence of female only area (psychosocial model).
Regarding their layouts, the wards presented similarities. They were both single-storey, ground floor with access to a fully protected courtyard. In terms of the position of the nursing station and the common areas, the double loaded corridors, the existence of a secure courtyard, the central placement of the clinic which is the room where medication is administered each morning. Yet, offices at Finsbury where at the deepest end from the entrance and the opposite was happening for Sapphire. Sapphire appeared to be self-contained, with minimal need for patients to leave the ward provision-wise, contrary to Finsbury, which depended in parts outside the ward for areas that patients needed access regularly, such as the dining room or the family guest room, for patients they received visits from family, as children were not allowed in the ward. Yet, the policy, and in particular the smoking policy, had a key impact on the autonomy, the resources and the quality of life of the ward. One staff member had to leave the campus premises to escort one patient for a cigarette break and return after approximately 20 minutes to escort another patient. That was a frequent source of unrest in the ward, as there was not enough staff to escort patients, end patients waiting for staff availability could create an escalated tension outside the nursing station. This was a controversial policy for most of staff and patients, who would see the consequences of both the unrest, the fact that one member of staff had to leave the ward and the congestion it created outside the nursing station for sectioned patients waiting to receive escorted leave. Both staff and patients in the interviews disagreed with this policy. For both groups this was one of the most serious disruptors in the ward and one of the key sources of ward tension. It was even described by the ward manager as the reason behind the fire: that patients were tempted to hide lighters. The policy was imposed by the Trust on the principle that this is
a healthcare facility and smoking should not be permitted, even in the courtyards. This policy was not in action at Finsbury ward, so the queuing and the unrest was avoided as patients had full, unescorted access of the courtyard for that purpose. Having said that, queuing outside the nursing station is considered as an institutional situation, very frequently observed in asylums and even considered together with lying in bed as a key indicator of institutional behaviour. The smoking queue bears references to the institutional practice of the past that was known as cigarette distribution (Chrysikou, 2014; Hirshbein, 2015), where staff would distribute one cigarette at a time at patients, in regular intervals and times through the day, starting from a specific time and ending up at curfew. The practice would create one more reason for queuing outside staff office for patients asking for cigarettes. To see the full implication of this act of having to ask for a lighter and ask, beg or threaten, cause unrest or team up with other patients for added pressure, as all these were demonstrated as escalating behaviours when staff were not available, on patients’ self-esteem, a citation from Goffman on what would constitute a description of asylum incident back at the time of total institutions:

..“cannot realize the humiliation to anyone able bodied yet lacking authority to do the simplest offices for herself of having to beg repeatedly for even such small necessities as clean linen or a light for her cigarette from nurses who constantly brush her aside with, “I’ll give it to you in a minute, dear”, and go off leaving her.” Goffman (1961), p 41.

Looking at the semiology of this act to the culture of mental facilities this socio-spatial act outside the nursing station is very important point, indicating:

- One less institutional facility in terms of building features might present a strong institutional behavior because of policy/regime.
- Social unrest can be created by policies even if buildings have provided solutions: in this case, an enclosed courtyard.
- Policy/regime and buildings in mental health provision are interrelated. Yet, policies might change at any time during the building life-circle.
- Policy/regime might affect the spatial use of mental health facilities considerably. For example, in Finsbury ward patients spent a lot of time in bed, especially in dormitories, a very strong institutional passive behaviour. There are mental health facilities where patients must leave their beds and bedrooms lock after breakfast and patients must use common areas or participate in activities. The fact that policy or regime differ considerably even in wards that are geographically close, as in this case, makes policy a strong influence in spatial use. Knowledge and understanding of the institutional regime and policy framework at a broader scale than the case studies might be essential for the understanding of the impact of the ward phenomena and the influence of institutional practices in the wards.

Space Syntax gives a very interesting perspective in the argument. In both wards, the most integrated spaces appear to be the areas outside the nursing station (Figure 9). They are also areas of very good visibility (Figure 10). According to space syntax theory, the most integrated spaces are those that attract most people and social activity (Hillier and Hanson, 1984). In mental health literature ward corridors including the area outside the nursing station have been associated with relatively low expectation of harm and self-harm as a level two out of five (Hunt and Sine, 2009). Research looking at reports in one ward in the US would increase the level of security at these areas from two to four due to increased risk of violence, falls and elopement (Bayramzadeh, 2016). Yet, in both wards in our research staff felt safe in that area and did not perceived this area as dangerous neither for them nor for patients. This could be related to other findings of this research suggesting an increase in the anti-ligature and the security promoting elements of the current facilities compared to what was happening in the UK 15 years ago which is also a finding of De Almeida and Killaspy (2011).

To that we need to add that the area outside the nursing station, or in many wards that do not have the typical fishbowl nursing station it might be the nursing office -- and not the ward manager’s office or the administration, or even the psychiatrist’s office in the cases that there
is a medical office inside the ward—the area where patients tend to gather in total institutions. It is possibly the area where visibility from that point might have been a brief requirement, although in many psychiatric wards especially in those that develop in several floors, which might often be the case, or in clusters not necessarily directly connected to the nursing station as psychiatric wards influenced by normalisation might have a plethora of possible typologies opposite to hospital wards, the nursing station might have visibility only in a very small part of the ward and definitely of one floor only.

Also, the nursing station is not the area where most staff might be at a given time. For example, patients did not tend to gather outside the staff office during ward rounds, where most staff happen to be at Sapphire ward, neither outside the entrance connecting the ward corridor to the ward part where most staff areas lied in Finsbury ward. Patients tended to gather at the most central point. To what extend was that a demonstration of an institutional behaviour, especially in the case of Sapphire ward that the smoking policy bore references to the institutional policy of “cigarette distribution” or a human need of meeting people at the most integrated point of the ward, there can be no certainty. Both are possibilities, as the context of the psychiatric wards where free movement is compromised by a series of policies, which is also the case in these two wards. However, similar findings from other healthcare settings such as correlation between global integration and patients’ standing, wandering and socialising in day centres for dementia (Hou and Marquardt, 2016), yet without clarifying if that is a case of layout contribution or part of institutional behaviour.

Figure 9 - Integration of the Sapphire and Finsbury ward. The most integrated space in both cases is the area outside the nursing station

Figure 10 - Visibility from the nursing station at the Sapphire and Finsbury ward
Regarding the visibility from the nursing station, it is indeed the purpose of a nursing station to have a good control of the circulation areas of the wards. This is what appears in the point Isovists created by using Depthmap software (Turner, 1998). However, the visibility from windows from the nursing station to the corridor has been partially blocked by staff, as they wanted to increase privacy and their chairs face the wall or the courtyard and staff have their backs to the screen of the nursing station. So, they have still the most central position, to run towards an incident yet they do not have in practice a visual control of the corridor or the ward and they did not attempt to by rearranging the furniture for instance or they do not wish to as the action of covering the windows to achieve privacy in the office indicated. Apart from their need to increase privacy, which could be related to the fact that in both wards patients tend to gather outside the nursing station entrance and seek staff attention, either for cigarettes which was the case in Sapphire as otherwise patients were expressing their satisfaction with the attention they were getting from staff or without a specific purpose in Finsbury ward. This need to increase privacy was contradictory to findings regarding ward visibility by Bayramzadeh (2016) but this could be related to the increased violence of that ward at this point and could be related to several reasons, not necessarily spatial.

4. CONCLUSIONS

Mental health facilities present significant variations even at a local level. There can be significant differences in the resources available and facilities can be at the whole spectrum of being obsolete and neglected, to being equipped with the latest technologies in anti-ligature. In both cases, the wards present stronger references to the previous care models, the jurisdictional or custodial and the medical model rather than the current model of the psychosocial rehabilitations. This could be the result of both spatial and organisational reasons.

One of the most common indications of this has been the accumulation of patients outside the nursing station either in form of wandering or in form of expressing dissatisfaction. This was confirmed by the analysis of the spatial morphology of the wards (Table 1). However, in institutional contexts this could be for reasons deriving from the social fabric or the policy of the institution, i.e. typical institutional behaviour or a reaction to a practice that might restrict aspects of movement or personal freedom and generate phenomena related to total institutions and not necessarily part of a socio-spatial interaction. The restrictions to the smoking policy or limited staff and patient interaction due to the impermeability of the staff area by patients (locked doors) or lack of therapeutic activity program could be some of the reasons behind that, indicating the complexity of the problem.

Nursing stations in single storey wards tend to be in the most integrated part of the facility and in areas providing good visibility, yet this visibility is not necessarily among staff priorities. This is a very important finding on the revisiting of the centrality of the placement of the nursing station in terms of a briefing priority. A spatial analysis of wards that presented similar integration characteristics in the activity or the social areas, such as the common room or the activity room might increase the potential for social interaction. More research in that area is needed.

Spatial analysis could provide an insight to the use of the spaces in psychiatric facilities that a qualitative, medical architecture methodology might not have picked, and reveal ways that previous models of care prevail in the building stock. That way models closer to the current concept of care, i.e., the psychosocial model, could emerge. In that case space syntax could be used parallel to other tools at the planning stage of healthcare facilities, as other research in healthcare facilities indicated (Peponis et al., 1996). However, the insights from the medical sociology methodology, could provide an alternative understanding to the mechanisms of the institutions, compared to spatial analysis. The combinations of both methodologies could provide help develop more elaborate research tools both for medical architecture and architectural morphology, as research with comparative methodologies involving healthcare facilities are increasing, however, there is still potential, especially for research comparing methodologies (Haq and Luo, 2012).
The most important finding though is that research comparing mental health architecture and space syntax could increase our understanding not only for the psychiatric space but the dynamics of the psychiatric institutions in general. It could also challenge the way psychiatric facilities are designed, from the current observation led model to one closer to the psychiatric rehabilitation, as this might benefit more from psychosocial rehabilitation uses provided at points of higher integration. This does not mean that safety and security might be compromised, as there are several other ways that could provide the required levels of safety and security. This, would have immediate implications to the quality of life of mental health professionals, carers, family members and most of all for mentally ill people.

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**Table 1 - Syntactic resulted data of the two wards**: Integration analysis
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ECOPSYCHOSOCIAL PARAMETERS AND MENTAL HEALTH:
The complexities of the psychiatric ward

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RESPONDING TO USER CULTURAL NEEDS IN HOSPITALS WITH THE SUPPORT OF SPACE SYNTAX ANALYSIS

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ABSTRACT
As part of a research project about hospital humanization, this study applied Space Syntax analysis techniques to answer two key research questions:

• Is it possible to evaluate the experiential path of the user within a hospital by introducing configurational parameters that take into account the relationships between spaces?
• Can configurational parameters be used to understand how much hospital space meets specific cultural needs in order to develop spatial indicators which can satisfy immigrant user needs?

Space Syntax methodology deals with both questions. It interprets architecture as the essence of relationships and asserts that culture plays a fundamental role in the design of a building and in particular in the determination of its spatial forms (Hillier and Hanson, 1984; Hillier, 1999).

A distinction between general and immigrant users has been made due to the different needs of the two categories. Each user need has been associated with specific spatial requirements and environmental and configurational indicators. Environmental indicators refer to the presence or absence of environmental factors that can affect the user’s psychophysical well-being. Configurational indicators refer to the syntactic properties of the space for which the Space Syntax methodology tools were used.

The indicators identified were then applied to the spaces that form the outpatient path of a hospital/case study in Turin and a rating was assigned to each of the analysed areas according to the satisfaction level of the indicator. In this way feedback was obtained on the degree of humanization of the structure considered. This feedback can simplify the identification of areas which are most in need of improvement to meet user demands.

In this study, therefore, the measures and configurational analysis of Space Syntax were used as a response to spatial requirements arising from cultural needs, combining spatial analysis and quantitative measures with abstract socio-cultural constructs. The Space Syntax tools were then used as a link between the cultural features of the users and the configurational aspects of the spaces.

KEYWORDS
Cultural needs, Space Syntax analysis, hospital humanization.
1. INTRODUCTION

In order to improve the user’s well-being, in recent decades it has become necessary to rethink the hospital system and the physician-patient relationship with the focus shifting from the disease to the patient and his functional and psycho-emotional needs. In this context, it has become necessary to give increasing importance to the role that the physical environment plays on the user’s behaviour and well-being.

This interest in the health sector began to assume increasingly more importance with the birth of the environmental psychology discipline, whose research demonstrated that the environment deeply affects people’s behaviour, their ways of relating and their physical and psycho-sensory well-being, becoming one of the decisive factors for the quality of the service.

The environments designed therefore, are no longer called to meet only functional requirements, but they also have to take into account many aspects that affect the psychological and social sphere of the user. This is especially true for health care facilities, in the middle of a radical change that involves different disciplines (medicine, environmental psychology, ergonomics, proxemics, architecture, sociology, hospital hygiene) with the common goal of improving the welfare of patients and staff. This tendency towards hospital humanization is based on the need to add psychological criteria to the functional ones, in order to avoid a state of discomfort, and stimulate a responsive attitude towards the patient’s disease.

The above is made even more necessary by the evidence that, in the past, health facilities have focused only on aspects related to medical activity. They assumed spatial configurations, functional structures, logical fruition and organizational models that were totally indifferent to issues related to the needs of patients and health professionals. Despite the undeniable benefits achieved with the development of technology in hospitals, the efficiency and quality of medical care has not been sufficiently addressed.

The lack of attention towards the psycho-social dimension of the users leads to a negative and “inhuman” image of the hospital in the collective imagination. In fact, the idea of humanizing a hospital can appear a paradox as if it was “born as an expression of humanity and charity, it should have by definition a human vocation” (Catanati and Cambieri, 1990).

The increase of interest in psycho-sensorial needs finds its realization in a design approach called “user-centered design” (Gifford, 2002), which aims to design spaces taking into account existing or future users point of view and then putting them into the spotlight.

In literature there are many studies on the influence of the built environment on human health and the potential architectural and environmental aspects which may constitute stressors. Only few studies, however, cover the subject in a broader view, taking into account not only the necessary requirements for individual spaces, but also the relationships between them, thus providing a “comprehensive” response to the user experience within the structure, in a configurational perspective. In addition, among the users on which is usually placed more attention because considered “vulnerable”, a category with specific cultural needs such as that of immigrants, has not been given enough consideration, even though it is becoming increasingly important in the contemporary society. This increasingly presence puts the social-health services in a difficult position of responding to the demand for care of populations from different cultural universe, in order to promote their integration.

This research is based on the detailed-study of these two aspects with the aim of proposing an innovative methodology of analysis, based on the idea of spatial configuration and attentive to the needs of users with cultural diversity.

2. WHY IS IT IMPORTANT TO CONSIDER THE CULTURAL NEEDS OF IMMIGRANT USERS?

Dealing with the cultural needs of immigrant users is particularly important in the healthcare field for several reasons: on the one hand, the different ways of conceiving illness and care cause communication difficulties between physician and patient. On the other hand, the different
conception of space - which are culturally bound – can affect the appropriate use of services. These issues lead to the under-utilization of public services by immigrants.

The ethnic, linguistic and religious diversification that increasingly characterizes these users requires the introduction of specific solutions in the organizational and the spatial field in order to meet their needs.

If it is true that humanization extends the concept of health to the psychological and social dimensions of the user, emphasizing the relationship between health and the socio-cultural context, it also needs to take into account the needs derived from specific cultural characteristics.

In fact, in every human community, the representation of the body, how to deal with illness or conceive spaces, are strongly related to cultural characteristics and beliefs, which often differ from one society to another (Delle Fave and Massimini, 2001). The human being can in fact be considered the heir of genetic heritage but also of a culture: people receive from the cultural environment in which they are born and develop a number of behavioural instructions that they translate into daily actions. Culture, transmitted from generation to generation, provides the individual with a repertoire of behavioural patterns that affect the different ways of conceiving health and space. Cultural identity is the symbolic apparatus through which a subject is placed in a certain context characterized by time and space.

The way in which the physical body is perceived and cared for, is strongly influenced by the culture: the perception of the body is proper to each of us, and it is linked both to the subject's history and to her culture. The way in which personal space is articulated and how it is lived is coherent with the inner world of the person. It also depends on the context and socio-cultural values: deep cultural patterns involve different perceptive systems in different populations. Each culture then organizes space in its own way. For this reason, an inadequate knowledge of cultural differences in perception and space management could easily lead designers and architects to the mistake of building spaces in which a lack of attention to the needs and languages of the various ethnic groups could alienate many immigrant users. Meeting the demands of cultural diversity is not aimed at creating dedicated and exclusive solutions for immigrant users, but rather at paying more attention to their needs. This is an opportunity to improve the quality of services for all users in an inclusive way.

3. THE SPACE SYNTAX METHODOLOGY AS THE ANALYSIS TOOL

For its ability to link spatial and social issues, the Space Syntax methodology was considered a useful support tool to deal with the research topics identified.

In fact, it develops important theoretical aspects of the relationship between space and culture and proposes spatial analysis that are based on the concept of space configuration and the users' perception.

In particular, this methodology faces the two key themes of my research: on the one hand it defines the architecture as the essence of relations between space and society, and on the other it affirms that buildings are the bearers of culture, which plays a fundamental role in shaping space (Hillier and Hanson, 1984).

One of the key concepts of Space Syntax is to understand architecture as the essence of relations between space and society. The theoretical bases start from the hypothesis that space contains in itself psycho-social information that are able to be explained through the spatial configuration.

The spatial layout therefore has an important influence on human behaviour. The way in which the places are connected is directly related to the way in which people move and interact. The spaces' organisation inside a building is equivalent to the organisation of the relationships between people.

Although this analysis tool cannot replace the traditional functional analysis, it adds additional information not visible to the naked eye, by introducing a quantitative study of space and its
ability to influence human behaviour. The content of the configurational properties of space will then be integrated with the data that the designer obtains from further analysis, in relation to his research questions. The results obtained are never absolute, but they have to be carefully evaluated according to the set goals. The analysis made through Space Syntax contain the characteristics that refer to how people perceive space. Space Syntax in fact does not explain why people behave in a certain way, but how it is more likely that they will act. Therefore, all parameters contained within the analysis software used have been designed and developed according to these principles.

In addition to the theme of the relationship between space and its configurational properties, this methodology deals with another key topic of this research: the relationship between space and culture.

Specifically, Space Syntax argues that culture plays a fundamental role in the design of a building and it calls “genotype” the cultural structure that remains unchanged along the generations in the design process (Hillier et al., 1987).

Again, Hillier (1999) affirms that “spatial organisation through buildings and built environments becomes one of the principle ways in which culture is made real for us in the material world, and it is because this is so that buildings can, and normally do, carry social ideas within their spatial forms”. So, the society expresses its nature through the shape of the buildings.

The architecture is thus considered “social art” not only because the buildings are important visual symbols from the individual and collective point of view, but also because, thanks to the way they create and organise the space, we can recognise the society they refer to. Therefore, culture and social aspects, are considered key factors that can give shape to space.

Because of this dual role and ability to face both aspects related to the configuration of the spaces and the relationship between space and culture, the Space Syntax methodology was chosen to answer the main research questions:

- Is it possible to evaluate the experiential path of the user within a hospital by introducing configurational parameters that take into account the relationships between spaces?
- Can configurational parameters be used to understand how much hospital space meets specific cultural needs in order to develop spatial indicators which are able to satisfy the immigrant user needs?

4. DEVELOPMENT OF THE ANALYSIS METHODOLOGY

For the development of the proposed analysis, the experiential path that users take within the hospital is taken into account. From this point of view a hospital can be analysed according to different paths: emergency, hospitalization, outpatient etc.

This research focuses on the outpatient path as it is definitely the one in which the user has more autonomy of action and the most popular with the category of immigrant users on which the research makes a specific focus. Moreover, outpatient activities are currently at the focus of attention and redevelopment to lighten the other over-used services. The spaces analysed are those which correspond to the procedural steps that the users have to do during his experiential path within the hospital (Simoncini et al., 2013).

Usually, users, on their outpatient path, take the following steps: they enter into the structure, they go to reception, they wait for their turn in the waiting area, they relate with the operators at the acceptance area, they pay ticket for the service to be received, they wait their turn again, and finally they receive the required service. Within this research all the steps analysed are those that happen within the structure between the access and the provision of care, in places where the user can move freely without any special permit or need to be accompanied by the members of staff.

For this reason, the areas of the entrance and the visiting room are indicated but not analysed: the first one in fact has a relationship with the interior of the structure but above all with the
external environment, while the second one does not come into the spaces which the users can access without staff. The analysed spaces are therefore the reception, the acceptance and the waiting areas to which are added also the horizontal and vertical connections (corridors, stairs and lifts) that, although they cannot be considered steps, they deserve to be considered as elements of union of all the other steps.

All these spaces are analysed through the application of certain indicators which have been assigned a different weight depending on the category of users referred to. At the end, the weight of each indicator, divided by spaces, has been multiplied by the value of the judgment that has been attributed to them in order to obtain the final evaluations for each step of the path taken into account. Thanks to these evaluations it will be easier to identify the areas most in need of improvement interventions, and give attention to the most critical indicators.

5. DEFINITION OF THE REQUIREMENTS AND INDICATORS FOR THE DIFFERENT USERS CATEGORIES

The first step was to study the profiles of users who use the health facilities. Given that the objective of the research is to bring out how a hospital meets the specific needs of people with cultural diversity, users were divided into general and immigrant users. Regarding the latter, a further study was made analysing the Moroccan culture which is strongly rooted in Turin.

For each category specific needs were studied, in order to define spatial requirements linked to environmental and configurational indicators. The first relate to the presence or absence of environmental factors that may affect the user’s psycho-physical well-being (for example natural and artificial light); the latter refer to the syntactic properties of space that are not directly visible to the naked eye but which play an important role in conditioning the behaviour of users in space (e.g. the topological connections, visibility, permeability etc.). In order to develop the configurational indicators, the Space Syntax methodology was used, intended to study the configurational characteristics of the space and their influence on the movements of people.

5.1 GENERAL USERS

For general users three macro-needs were identified to which specific spatial requirements and indicator were linked.

<table>
<thead>
<tr>
<th>Needs</th>
<th>Spatial Requirements</th>
<th>Indicators</th>
<th>Type Of Indicator</th>
<th>Spaces Analysed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental well-being</td>
<td>Outside view</td>
<td>Visibility and quality of outdoor spaces</td>
<td>Configurational</td>
<td>Waiting area; Corridors, stairs lift</td>
</tr>
<tr>
<td></td>
<td>Restorative potential</td>
<td>Presence of restorative elements</td>
<td>Environmental</td>
<td>Reception; Acceptance area; Waiting area; Corridors</td>
</tr>
<tr>
<td></td>
<td>Restorative potential</td>
<td>Presence of facilities for the users</td>
<td>Environmental</td>
<td>Corridors; Waiting area</td>
</tr>
<tr>
<td></td>
<td>Colours and decorations that</td>
<td>Quality of the colours and decorations of finishes and furnishings</td>
<td>Environmental</td>
<td>Reception; Acceptance area; Waiting area; Corridors</td>
</tr>
<tr>
<td></td>
<td>contribute to psychological</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>and emotional well-being</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Natural lighting</td>
<td>Coefficient of natural lighting</td>
<td>Environmental</td>
<td>Reception; Acceptance area; Waiting area; Corridors</td>
</tr>
<tr>
<td></td>
<td>Artificial lighting</td>
<td>Artificial lighting features</td>
<td>Environmental</td>
<td>Reception; Acceptance area; Waiting area; Corridors</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Psycho and emotional</td>
<td>Usability in conditions of safety</td>
<td>Presence of supports and characteristics of the space to ensure the usability</td>
<td>Environmental</td>
<td>Reception; Acceptance area; Waiting area; Corridors</td>
</tr>
<tr>
<td>well-being</td>
<td>Be acceptable for various types of users</td>
<td>Ergonomic solutions suited to different types of users</td>
<td>Environmental</td>
<td>Waiting area</td>
</tr>
</tbody>
</table>

Table 1 - Link between needs of general users, spatial requirements, indicators, type of indicator and spaces analysed.
5.2 IMMIGRANT USERS

The most important requirements in the study of immigrant users from the architectural point of view, that came to light in the study of literature, were those relating to wayfinding, communication and privacy. These macro-needs, although important for all users, are crucial for immigrants, and for this reason, it is necessary to pay more attention to them when this category of users are analysed. As we have seen before, space relations are experienced differently depending on the culture of the person and this can affect the spatial requirements to which spaces have to respond.

Specific spatial requirements and relative indicators have been associated to these three macro-needs and applied to a specific space of the user path analysed. The requirements and the indicators identified, although they derived from the need to improve the immigrant user experience who meets more difficulties in these three areas, are also an opportunity to improve the services for all users.

<table>
<thead>
<tr>
<th>Needs</th>
<th>Spatial Requirements</th>
<th>Indicators</th>
<th>Type Of Indicator</th>
<th>Spaces Analysed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wayfinding</td>
<td>Space accessibility</td>
<td>Value of Integration</td>
<td>Configurational</td>
<td>Corridors; Reception</td>
</tr>
<tr>
<td></td>
<td>Route clarity</td>
<td>Proximity with integrated spaces</td>
<td>Configurational</td>
<td>Waiting area; Reception</td>
</tr>
<tr>
<td></td>
<td>Identifiability</td>
<td>Visibility from the previous step of the path</td>
<td>Configurational</td>
<td>Corridors</td>
</tr>
<tr>
<td></td>
<td>Ease of wayfinding</td>
<td>Number of spaces crossed</td>
<td>Configurational</td>
<td>Acceptance area; Waiting area; Corridors</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Presence of elements which ensure the recognition of the place</td>
<td>Environmental</td>
<td>Reception; Acceptance area; Waiting area</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Presence of elements which facilitate the wayfinding</td>
<td>Environmental</td>
<td>Corridors, stairs, lifts</td>
</tr>
<tr>
<td>Communication</td>
<td>Ease of relationship between operator and user</td>
<td>Operator position in relation to the access flow</td>
<td>Environmental</td>
<td>Reception</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Presence of elements that affect the relationship between operator and user</td>
<td>Environmental</td>
<td>Acceptance area</td>
</tr>
<tr>
<td>Privacy</td>
<td>Privacy of the space</td>
<td>Presence of through flow</td>
<td>Environmental</td>
<td>Waiting area</td>
</tr>
<tr>
<td></td>
<td>Visual and acoustic privacy</td>
<td>Solutions that promote privacy</td>
<td>Environmental</td>
<td>Reception; Acceptance area</td>
</tr>
</tbody>
</table>

Table 2 - Link between needs of immigrant users, spatial requirements, indicators, type of indicator and spaces analysed.

5.3 MOROCCAN USERS

After the focus on immigrant users it was decided to make a further study of a specific culture. As was seen from the study of literature, in fact, every culture has different ways of behaving and of conceiving health and space. For this reason, in addition to the needs that characterize this vulnerable category, there are others that change depending on the culture taken into account. In this research, the Moroccan culture was studied in depth in order to bring out its main features by which the specific needs were later identified. To these needs, spatial requirements and indicators were associated and applied to the spaces of the out-patient path identified.

In this case, socio-cultural features were translated into needs and then spatial requirements which are linked to specific configurational and environmental indicators. During this phase, several professional figures were interviewed with the aim of better understanding Moroccan culture. Interviews were not set with the aim of obtaining significant quantitative data, but in order to match what has been learned from the study of literature with direct testimonies of professionals which are familiar with this community with the objective of developing a framework that is as pertinent as possible to reality. The professional figures met were:
a professor in demoetnoanthropological disciplines (cultural anthropology and medical
anthropology); an MI.SA (Migration and Health) clinic of the Amedeo di Savoia Hospital in Turin;
a physician responsible for Turin’s ISI (Health Information Immigration Center); the President
of the Cultural Mediator Association of Piedmont and cultural mediator at the Regina Margherita
and Sant’Anna Hospitals; a cultural mediator and member of the A.M.E.C.E association
(Association Maison d’Enfant for Culture and Education); various members of staff from the
Moroccan Consulate in Turin.

What emerged was not a detailed anthropological analysis of Moroccan culture, but rather the
result of various contributions that have allowed to better identify the needs of this category
of users.

<table>
<thead>
<tr>
<th>Cultural Features</th>
<th>Needs</th>
<th>Spatial Requirements</th>
<th>Indicators</th>
<th>Type Of Indicator</th>
<th>Spaces Analysed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tendency to create informal relations, importance of physical contact</td>
<td>Relationship spaces that facilitate meeting and interaction</td>
<td>Multi-functionality and spatial flexibility</td>
<td>Presence of elements that encourage interaction between users</td>
<td>Environmental</td>
<td>Waiting area</td>
</tr>
<tr>
<td>Great sense of community and sharing; horizontal social organization</td>
<td>Spatial conformations that allow communication between staff and users</td>
<td>Ease of relationship between operator and user</td>
<td>Elements of the acceptance desk that affect the relationship between operator and user</td>
<td>Environmental</td>
<td>Reception; Acceptance area</td>
</tr>
<tr>
<td>High level of privacy</td>
<td>Presence of morphological elements that allow visual and acoustic privacy</td>
<td>Visual and acoustic privacy</td>
<td>Solutions that promote privacy</td>
<td>Environmental</td>
<td>Reception; Acceptance area</td>
</tr>
<tr>
<td>Traditional architecture consisting of a central plan with a nucleus from which it is possible to supervise all spaces</td>
<td>Easily controllable spaces</td>
<td>Path control</td>
<td>Step Depth from entrance</td>
<td>Configurational</td>
<td>Reception; Acceptance area</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control area</td>
<td>Visibility of points of interest from the area analysed</td>
<td>Configurational</td>
<td>Waiting area</td>
</tr>
</tbody>
</table>

Table 3 - Link between cultural features of Moroccan users, needs, spatial requirements, indicators, type of indicator and spaces analysed.

6. APPLICATION OF THE SPACE SYNTAX CONCEPTS IN THE RESEARCH

The identified indicators were examined in depth through an accurate description and then
applied in the out-patient path of a hospital case study in Turin. The following are some of the
configurational indicators which use the tools of the Space Syntax methodology.

The choice felt on the Axial line Analysis which, making use of the potential lines of movement
to perform their own analysis, is the most appropriate to represent the experiential path that
the user takes within the structure.

Specifically the measure of Integration was used, that expresses how accessible and well
connected each spatial element of the system is compared to the others. This measure has
been applied in two different ways: on the one hand to bring out the degree of accessibility of
the main corridors, on the other to see how much spaces like the reception and the acceptance
areas are accessible according to their degree of proximity to the more integrated areas of
the system. Both of these aspects are inherent to the wayfinding requirements, extremely
important for immigrant users.
Figure 1 - Application of the “Value of Integration” indicator, used to assess space accessibility (Table 2).
From the map it is possible to see how the main corridor on the upper floor appears to be the most connected part of the whole system presenting a red axial line (high integration value).

To respond to the requirement of route clarity, which is very important for immigrants, the graph system was used, in which each node corresponds to a convex space (space in which all people can see all others), and each line corresponds to a connection between them. In this case, the measure used is the depth, which indicates the number of spaces that have to be crossed to go from one place to another.

Figure 2 - Application of the “Number of spaces crossed” indicator, used to verify the route clarity to reach the waiting area of the main acceptance from the entrance (Table 2). In the graph, the waiting area connected with the main acceptance is located 3 steps from the entrance, which is a very good position for its role.
Furthermore, on several occasions, the isovist technique was used, which correspond to the area directly visible from a point. In particular the isovist was used to evaluate the degree of the control area (for Moroccan users), the route clarity through the degree of visibility from one space to another (requirement which is liable in particular to the orientation need of the immigrant users) and the outside view (for all users).

Figure 3 - Application of the “Visibility of points of interest from the area analysed” indicator, which respond to the spatial requirement of the control area (Table 3). The image above illustrates the application of an isovist from some of the stations of the outpatient waiting area, from which there is only a partial control of the areas of interest such as visiting rooms and services.

Figure 4 - Application of the “Visibility from the previous step of the path” indicator, used to verify the route clarity (Table 2). The use of the isovist shows how the acceptance waiting area is only partially visible from the previous step of the path (reception).

Figure 5 - Application of the “Outside view” indicator, used to assess the visibility and quality of outdoor spaces (Table 1). Even if there is no opening in the main corridor on the ground floor, a partial view to the outside is ensured by a window that is located in a space directly connected to the corridor. The view opens onto the main street where the hospital is situated.
The following provides a table summary with the list of the Space Syntax techniques and measures which were used for the elaboration of the proposed analysis methodology, the indicators that have been used, the requirements prescribed for the indicators and the category of users for which particular indicators and requirements are more significant.

<table>
<thead>
<tr>
<th>SSx Measure Or Technique</th>
<th>Indicators In Which It Is Used</th>
<th>Requirement Associated To The Indicator</th>
<th>User Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integration</td>
<td>Value of integration</td>
<td>Space accessibility</td>
<td>Immigrants</td>
</tr>
<tr>
<td></td>
<td>Proximity with integrated</td>
<td>Space accessibility</td>
<td>Immigrants</td>
</tr>
<tr>
<td></td>
<td>spaces</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Graph</td>
<td>Number of space crossed</td>
<td>Route clarity</td>
<td>Immigrants</td>
</tr>
<tr>
<td>Step Depth</td>
<td>Step Depth from the access</td>
<td>Control of the path</td>
<td>Moroccans</td>
</tr>
<tr>
<td></td>
<td>Visibility and quality of</td>
<td>Outside view</td>
<td>General users</td>
</tr>
<tr>
<td></td>
<td>the outdoor spaces</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Visibility from the</td>
<td>Route clarity</td>
<td>Immigrants</td>
</tr>
<tr>
<td></td>
<td>previous step of the path</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Visibility from the space</td>
<td>Control of the area</td>
<td>Immigrants</td>
</tr>
<tr>
<td></td>
<td>to point of interest</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4 - Summary of the Space Syntax measures or techniques used.

7. CONCLUSIONS

After having assigned specific judgments and weights to each indicator, what is come to light is that, in the case study analysed, none of the areas taken into account has an excellent evaluation and the most critical space is the reception. In particular, the most problematic aspects of the reception are:

- the lack of direct visibility from the entrance;
- the no frontal position of the operator compared to the flow of people;
- the necessity of having to cross another environment before reaching the reception space;
- the presence of desk elements that impact negatively on the relationship between operator and user;
- the absence of solutions that ensure privacy during the recording of sensitive data;
- the absence of elements with restorative potential.

The developed methodology therefore, can help to identify the areas most in need of improvement interventions according with the users’ needs. Moreover, it presents several innovative elements extending the concept of humanization in health care to a wider field of investigation and considering it from different points of view:

- firstly it focuses on a category of users which is often not considered, that of immigrants, and the spatial requirements arising from specific cultural characteristics. In particular, it proposes a model in which socio-cultural characteristics are translated into spatial requirements and indicators that are associated with specific analysis techniques;
- secondly it puts the focus on the experential user’s path analysing the spaces that correspond to the procedural steps that he meets in the building in relation to the health service he requires. Therefore, not only the characteristics of the individual spaces are considered, but the relationships between them acquire a fundamental importance, and consequently their configurational features.
These two issues are intimately linked because both the configurational characteristics of the spaces and the cultural characteristics of the users determine and influence the way we live a specific environment. Both of these issues are deal with the Space Syntax methodology, which proposes a configurational approach of space considering on one hand the architecture as the essence of relations between space and society, and on the other highlighting how buildings are bearers of the cultural characteristics in the context in which they occur and how these characteristics play a key role in giving shape to space.

The elaborated methodology of analysis therefore, uses Space Syntax tools as a response to spatial requirements arising from cultural needs and as a link between the cultural characteristics of the users and the configurational aspects of the spaces.
REFERENCES


#7

ADAPTABILITY RETRIEVAL IN ARTISTIC LEARNING ENVIRONMENTS

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ABSTRACT

The current educational paradigm suggests a wide scope of activities with pedagogical potential held in different active learning environments, which impact student achievement. Adaptability as the physical ability of a building to cope with changing activities and requirements, is paramount when regarding artistic schools, lecturing the regular and the music and dance courses.

This paper aims to present an original methodological approach on assessing the adaptability of contemporary artistic schools, as a specific and complex case study on both the activities and spaces to consider. Its purpose is to assess the schools’ ability to cope with the pedagogical and social evolving needs and to conclude on the design attributes that potentially enhance adaptability, for a more lasting and effective building performance.

It introduces procedures from different epistemological provinces, for a more supported retrieval of its adaptability, sequentially as follows:

1. Description of the spatial sample, functional and morphological, informs on how it supports activity allocation. A space syntax analysis regarding convex spaces and axial lines, as places and pathways for learning, will provide a thorough understanding of the sample’s morphology and conclude on the relevance of global and local syntactic measures towards activity allocation, spatial cognition and the overall “social logic of space” (Hillier and Hanson, 1984).

2. Description of all possible activity allocations informs on the pedagogical potential of each educational environment, matching all possible activities to the spaces in a feasibility matrix. It considers maximising entropy, informing on the uncertainty of an activity allocation to both convex spaces and axial lines (Coelho and Krüger, 2015).

3. Description of effective events informs on behaviour and appropriation, holding higher relevance in this artistic ambiance. This stage corresponds to an idiographic approach on singularities, while the latter to a nomothetic approach on regularities (Windelband, 1894).

4. Description of the potential correlations amongst each stage, enables the retrieval of the school’s adaptability, understanding a potential correspondence between integration, entropy and behaviour.
This methodological framework is expected to be a contribute to knowledge advancement, identifying adaptability in this particular contemporary context and combining distinctive study fields, namely space syntax’s inputs, for its assessment. Also, for the practice, the acknowledgment of the spatial configurations with higher representativeness towards adaptability could be informative to future designs.

KEYWORDS
Adaptability, Methodology, Artistic Learning Environments, Morphology, Activity Allocation

1. INTRODUCTION: ARTISTIC LEARNING ENVIRONMENTS AND THEIR NEED FOR ADAPTABILITY

‘By giving shape and form to our material world, architecture structures the system of space in which we live and move.’ (Hillier and Hanson, 1982, p.ix)

This paper derives from the interchangeability between “architecture structures” and the “social relations” that they allocate but, primarily, that they enable throughout the whole building’s lifecycle. This is here specifically translated onto the dichotomy between school and learning, each with their evolving social and pedagogical requirements. Therefore, this paper aims to recognise change as an intrinsic condition of both the learning environments and the pedagogical processes for knowledge acquisition, and to acknowledge spatial adaptability to cope with that imminent, yet, unpredictable, process.

Following the connection between school and learning, Heitor (2005) recognises the school as an “educational tool”, while Monahan (2002) introduces the concept of “built pedagogies” and Moore and Lackney (1994) have proven the relevance of the school’s physical attributes towards student performance, even if it can also be a reflection of non-spatial considerations (ibid., p.14).

In fact, the current pedagogical paradigm is embedded by a wide array of dynamics, widening the active learning environments from the traditional classrooms to informal spaces for non-programmed events, group work and individual creation, regarding socialisation and critical thinking as a means to knowledge acquisition. To school design this implies the consideration of informal and social environments, and even moving pathways, as active learning environments, where peer communication is possible amongst creative and reflective students. Furthermore, the “net generation” (Oblinger and Oblinger, 2005) laid by the widespread potential of technological devices, recognises an increasing need for connectivity, not necessarily in the classroom, nor even face-to-face.

Understanding this current pedagogical context is relevant to consider the potential changes in pedagogical procedures and curricula, implying specific spatial requirements in the future, which the school has to comply with, avoiding early obsolescence and enduring pedagogically, socially and physically in time. The recent Portuguese experience of the Secondary School Modernisation Programme has been developed in order to provide the schools with spatial solutions consistent with this current framework.

The choice of the school space as a case study for assessing adaptability is also supported by the general patterns of programmed activities on the weekly schedule, combined with the variability of the possible daily and changeable small-scale pedagogical events, namely lined by informality.

The specific choice of the artistic schools that combine both the regular teaching - with basic and secondary levels - and also the artistic teaching of music and dancing, is justified by the fact that these schools are a higher aggregator of both users and activities, leading to a more pressing adaptability condition.

Overall, schools with artistic and regular teaching in a shared building, have more demanding needs for adaptable spaces, because of the variety of events with different spatial needs, with
varying number of performers and of diverse nature [Figure 1]. Due to the extensive array of formal and informal happenings; programmed and non-programmed activities; for individual, group or external fruition - even more enriched by the spontaneous and expressive profile of the artistic school community - these schools represent overall a higher complexity case study on adaptable learning environments.

Figure 1 - Different ways of experiencing the artistic school spaces (from left to right: the auditorium’s cafeteria, the dance studio, the main hall, open space onto the corridor)

2. DATASETS AND METHODS: DESCRIPTION OF THE METHODOLOGY TOWARDS ASSESSING ADAPTABILITY

‘[…] these spaces must be adaptable not only to a present variety of uses, but also to the changes which the future is bound to bring, sometimes suddenly, sometimes imperceptibly.’ (Ministry of Education, 1957, p.15)

This paper proposes a methodology to identify and assess adaptability, particularly applied to artistic learning environments as the case study, for which it is particularly relevant. Krüger defined adaptability as: “the ability of the built form to maintain compatibility between activities and spaces, as those vary” (Krüger, 1981, p.1169), which is considered to better report this condition on contemporary artistic schools, by the increasingly diversity of activities and spaces, technical requirements, variety and sizing, conforming with the need for spatial adaptability in regard to the activity allocation.

Even if in 1957 the British Ministry of Education had already suggested that changeability in educational pedagogies had to be accounted for in post-war school building, the state-of-the-art on assessing adaptability leads back to the 1970s, from which came the definition of adaptability by the OECD (1976, p.10), as: “essentially large magnitude/low frequency change”. Then, models (Echenique, 1972) took a relevant role for adaptability, providing straightforward results for abstractly portraying a reality by the relationship of its variables (Simon, 1969). The “general theory of adaptability” that Fawcett (1978) intended to accomplish with his Doctoral Thesis, supervised by Lionel March, is a significant approach for modelling adaptability, on the probability of allocating activities to spaces and ultimately relating adaptability to a “quantified measurement” (ibid., p. 54).

The approach to models and analytical frameworks represents a very relevant line of thought for architectural research, nonetheless, it is substantial to critically review it on its potential contemporaneity. Actually, this research gains a higher complexity, due to schools’ contextual variables regarding curricula, spatial and technical features, that will constrain the adaptability requirements. Moreover, the dichotomy between formal and informal learning activities and environments also introduces a determining factor. This will identify adaptability not just as a measure assessed from a simplified model, but rather a closer one to the context, that potentiates encounters, movements and a broader spatial fruition.
Hence, besides the contributions from a mathematical elaboration, also the combination of inputs from other fields, more prone to the social sciences, will consequently provide a more comprehensive outlook on “the social logic of space” (Hillier and Hanson, 1984).

Windelband (1894) introduces the concepts of nomothetic and idiographic, in which the first relates to general laws and regularities, and the latter to the events and singularities. This can be brought to this methodology, assuming the “nomological regularities” (ibid., p.178) of a weekly schedule of formal activity allocations to spaces; and the idiographic related to the individual(s) or collectivities’ informal dynamics.

The original methodological approach presented here [Figure 2] on assessing the adaptability of contemporary artistic schools, aims to assess the schools’ ability to cope with the pedagogical and social evolving needs and to conclude on the design attributes that potentially enhance adaptability, for a more lasting and effective building performance. It systematically introduces procedures from different epistemological provinces, providing a more extensive analysis on the building’s description for a more supported retrieval of its adaptability potential, sequentially as follows:

1. **Description of the spatial sample, functional and morphological, informs on how it supports activity allocation.** This acknowledges an extensive analysis of the school spaces, physical attributes and the activities that there take place. Then, a space syntax analysis regarding convex spaces and axial lines, as places and pathways for learning, will also provide a thorough understanding of the sample’s morphology and conclude on the relevance of global and local syntactic measures towards activity allocation and spatial cognition.

2. **Description of all possible activity allocations informs on the pedagogical potential of each educational environment.** This stage also implies maximising entropy, which will inform on the degree of uncertainty of an activity allocation to both convex spaces and axial lines (Coelho and Krüger, 2015).

3. **Description of effective events informs on actual behaviour and spatial appropriation on the school.** This holds higher relevance in this case study, due to its artistic ambiance throughout the all spatial system. This stage corresponds to an idiographic approach on singularities, while the latter to a nomothetic approach on regularities (Windelband, 1894).

4. **Description of the potential correlations amongst each stage and transversally on all these variables.** This stage examines the potential overlapping of individual outcomes and enables the retrieval of the school’s adaptability, understanding a potential correspondence between integration, entropy and behaviour.
This recalls Hillier and Hanson’s mechanism of “description retrieval”, described in The Social Logic of Space (1984, p.50-51) as a potential link between reality and abstraction. Psarra (2003) also presents a clear definition of this process: ‘Description retrieval is a process by which abstract laws are derived from real space-time events and are subsequently embedded into further actions.’ (ibid., p.2). All in all, “description retrieval” embodies the ability to translate situated events to generalizable patterns in order to reach for conclusions. For this methodology it was assumed to deconstruct this expression into two components, as the “description” of the results of the three approaches, and the retrieval of the space’s adaptability.
This methodological framework is expected to be a contribute to knowledge advancement, identifying adaptability in this particular contemporary context and combining distinctive study fields, namely space syntax’s inputs, for its assessment. Also, for the practice, the acknowledgment of the spatial configurations with higher representativeness towards adaptability could be informative to future designs.

3. RESULTS: APPLICATION OF THE METHODOLOGY TO THE CASE STUDY AND FINDINGS

‘The school must be an ever-changing, stimulating environment where there is a lot going on and there are choices to be made’ (Hertzberger, 2008, p.8-9)

Quinta das Flores School went through an adaptive-reuse process by the Portuguese School Building Modernisation Programme. The architect José Paulo dos Santos has designed a central building in 2008-2009, representing both a street façade and also the core of the school’s administration and communal spaces. This spatial rehabilitation went along with a curricular transformation, in which the Music Conservatory has been added to the Basic and Secondary School [Figure 3].

Pedagogically, it now has an “articulated teaching regime” in which students attend both the artistic and regular classes, besides the regular students and the external students that only attend the music and dance classes at the Conservatory. Therefore, the students’ and teachers’ profiles are diverse, holding a wide array of activities. Spatially, this signifies spaces with assorted spatial features and the sharing of common areas and services, which favours group dynamics, social cohesion and a transmission of competences from each teaching regime. Specifically, the methodology will be applied to the central building that represents the school’s entrance and where the social and pedagogical blend is significantly higher.

Figure 3 - Quinta das Flores School _ Spatial sample identified in grey
3.1 DESCRIPTION OF THE SCHOOL SPACE AND HOW IT SUPPORTS ACTIVITY ALLOCATION

This initial stage comprises a description of the spatial sample, functional and morphological, informing on how it supports activity allocation. Primarily, it will analyse the spatial sample according to its spaces, activities and attributes, functionally describing how and by what means does the space allocate learning activities. Subsequently, a morpho-syntactic analysis will provide an in-depth understanding by the analysis on convex spaces, axial lines and visibility [Figure 4].
3.1.1 DEFINITION OF THE SPATIAL SAMPLE _ FUNCTIONAL ANALYSIS

The initial step consists on identifying the existing spaces and assigning them with coloured hatches for a graphic interpretation on the positioning and density of active/supportive learning environments, informal/formal spaces, moving/standing areas, spaces assigned to each teaching regime,....

The colour schemes presented [Figure 5] display a general colour mix that indicates a respective combination of teaching profiles, formality and informality, circulation and standing, already providing an insight on the adaptability potential of these “multi-option spaces” (Ader, 1975).

A first outlook on the layout of the school may be undertaken, providing the following conclusions:

All circulation areas are considered active learning environments and, although the main corridors on all floor plans have different layouts, all are provided with small open spaces, as possible standing clusters in moving pathways.

Figure 5 - Quinta das Flores School _ Spaces and Activities
Common spaces are used by all and are also the most preponderant spaces amongst the sample. Contrarily, learning spaces rarely allocate both teaching profiles, due to their specificities in acoustics and size.

The second floor has mainly formal activities related to the artistic teaching, while on the first floor the regular teaching has a formal area for sciences, and the ground floor is prone on spaces for social and artistic purposes for all.

Furthermore, this first stage implies a study on spatial attributes for future conclusions on their compliance with activity allocation. Therefore, attributes were listed, according to six properties: dimension, configuration, coating, networks, environmental conditions and accessibility, which may constrain or enable activity allocation to a space, even if previous classifications of spatial features have been undertaken by Duffy (1990) and also by Brand’s (1994) "shearing layers of change".

The most remarkable difference regarding the attributes on this spatial sample is between the spaces for the artistic teaching from the remaining ones, especially for their acoustics. Besides, power access and connectivity are paramount for today’s learning models. Proportion and overall dimension, in regard to height, length and width, are proven to be relevant attributes: narrowness hampers standing activities, which is exemplified by the cafeteria’s layout. Contrarily, width may induce several clusters of activities on the same space, like on the main hall. This has clear relation to the adaptability potential of each space for holding a wider range of activities.

3.1.2. SPACE SYNTAX _ MORPHOLOGICAL ANALYSIS

"Space syntax is a method we have developed at the Bartlett Unit for Architectural Studies to describe and analyse patterns of architectural space—both at the building and urban level. The idea is that, with an objective and precise method of description, we can investigate how well environments work, rigorously relating social variables to architectural forms." (Hillier et al., 1983, p.49)

The space syntax approach aims to analyse the school from a configurational point of view. Findings allow the understanding of movement and standing spaces and their potential as active learning environments, deepening the knowledge on "spatial form" for a more inclusive understanding of the social relations of people from space, recalling Hillier’s (1989, p.13) “Type 3: Laws from space to society”, as well as Popper’s (1972) thoughts on the third world.

Syntactic analysis has been approached by means of convex spaces, axial lines and visibility techniques. Recognising all the attributes’ relevance, this analysis will focus on global integration and local connectivity, for the understanding of spaces’ overall syntactic structure and their configurative relations, towards patterns of co-presence and movement.

Integration as a global measure provides an overall description of the space: “Clearly the more a space is integrated, the more it may be able to exploit the existing pattern of movement of people caused by the arrangement of space.” (Hillier et al., 1983, p.59). The most integrated spaces and axial lines have been identified by DepthmapX’s graphics and by its attributes’ extended listing. The most integrated convex spaces are the main hall and the main corridors and the axial lines placed on those same corridors are also the most integrated ones. Besides the main corridors, the most integrated convex spaces are generally the most connected ones, like the library, the auditorium and the cafeteria: all spaces with a communal use [Figure 6].
Similarly, axial connectivity has also been paralleled to axial integration, and the overall conclusion is the potential correspondence between the corridors as convex spaces and their axial lines, bearing in both situations the highest values of global integration and local connectivity.

Nevertheless, the axial line analysis is more comprehensive because the axial lines cross not only the mentioned corridors but also other convex spaces. This is particularly relevant when identifying the most integrated axial line on the ground floor, gathering the library, the main hall and the auditorium’s cafeteria, the first with a more formal and programmed activities’ profile and the latter with a more spontaneous and social one. This adds pedagogical diversity to this pedagogical line or “learning street” (Hertzberger, 2008), for both moving and standing activities, spontaneous and/or programmed.

Analogously, another highly integrated and connected axial line is the one linking both extremities of the first floor: the small auditorium to the dance studio, where formal and informal artistic events occur, and whose convex integration is low. Again, these findings contribute to a mixture of environments for knowledge transmission that hold diverse situations and even a broad community of students and teachers.

Therefore, when analysing this school by means of axial lines rather than convex spaces, the outcomes are more representative of the spaces’ actual layout and foremost of its pedagogical enriched curricula. Corridors with movement, associated with socialisation and communication, can be considered active learning environments, having in this school a very integrated position, metaphorically denoting its pedagogical significance.

A visibility analysis also bears particular relevance for this case study, because highly visual integration may enhance patterns of encounters and therefore informal learning. By the analysis of the graphs the spaces with the highest visual integration are also the most integrated, namely the main corridors on each floor. Additionally, highly visual integration of the open spaces to the corridors, deemphasises the sole moving nature of the corridor, introducing pedagogical, artistic and social activities in the common spaces, proven to be highly integrated.
and connected in the building. This conclusion carries additional relevance on patterns of co-presence, not particularly significant by axiality or convexity, regarding the fact that students there visually perceive others.

Secondly, a visibility analysis justifies the more operative locations for the subsequent observations, provided by the visibility graphs and isovists of the identified spots with higher visibility because isovists "provide a description of the space 'from inside', from the point of view of individuals, as they perceive it, interact with it, and move through it." (Turner et al., 2001, p.103) [Figure 7].

This overall process depicted above provides a wide-ranging understanding of the school's activities and layout, its attributes and the topological relations between them all. It also provides a detailed portrayal of each space's main activities, significant for the subsequent entropy analysis.

3.2 DESCRIPTION OF ALL POSSIBLE ACTIVITY ALLOCATIONS TO EDUCATIONAL ENVIRONMENTS

3.2.1 ENTROPY _ NOMOTHETIC ANALYSIS

"If an element had many alternatives and all were equally probable, then the activity would be at its loosest; if an activity could only use one space it would have a probability of 1, and then there would be no looseness. [...] The measure of this looseness across the probability distribution is Shannon’s entropy." (Fawcett, 1978, p.182)

The following procedure relates to an analytical approach to adaptability, whose foundations have been laid in the 1970s for its assessment as a figure provided by an adaptability model from a combinatorial procedure (Fawcett, 1978). As previously recalled, Fawcett parallels adaptability with a probability.
The procedure for calculating the entropy of a space has been determined by a set of stages. The crossing of the existing spaces of the school identified in the previous stage of this methodology with the possible learning activities that occur there, provides a feasibility matrix that describes the activities that each space can cater for, according to its attributes. Then, other mathematical elaborations are undertaken using stochastic matrices, in order to lastly apply Shannon and Weaver’s (1949) entropy formulation for each space: \( S = -\sum p_i \ln p_i \). This provides an accurate outlook on the adaptability of each space of the school.

This procedure has also been developed by Krüger (1981, p.1169) determining “a model building approach towards the maximization of adaptability between activities and spaces, at the architectural scale”, which leads to the highest binary matches between activities and spaces. Similarly, this study also proposes maximising entropy for maximising adaptability of activities to spaces.

The correlation between space syntax parameters and entropy has already been presented in the 10th International Space Syntax Symposium (Coelho and Krüger, 2015), in which the full explanation of this complex and extensive procedure is explained in detail. Besides proving the correlation between convex integration and entropy for adaptability, that paper has also established the concepts of “axial line entropy” and “average axial line”, within ‘An entropy approach to space syntax’.

Having already applied this procedure to this case study, results have concluded that the highest entropy spaces were the: “library, orchestra room, music studio, auditorium, spare space, generic classroom and science lab” (ibid., p.11), which are the spaces where there is greater uncertainty on the activity allocation, due to their wider pedagogical potential.

Besides, the most remarking correlation was between the axial line integration and the axial line entropy for the ground floor (Coelho, 2015), but overall for axial lines:

‘[…] there is a higher correlation between integration and entropy for axial lines rather than for convex spaces, proven by the regression lines and respective determination coefficients (R2) of both graphs. Pedagogically this is crucial, because it supports the fact that this school considers not only formal learning spaces, but also spatial sequences as potential moments and environments for active learning.’ (Coelho and Krüger, 2015, p.18)

3.3 DESCRIPTION OF EFFECTIVE EVENTS AND EXPERIENCE IN THE SCHOOL OBSERVATION MATRICES AND WALKTHROUGHS _ IDIOGRAPHIC ANALYSIS

“Educational space needs are designed primarily around patterns of human interaction rather than the needs of particular subjects or technologies.” (Worthington, 2007, p.17)

After describing the spatial sample, space is now perceived in regard to the living experience it shelters, embodying Hill’s words: “[…] architecture is not just a building. It is, primarily, a particular relation between a subject and an object [...]” (1998, p.7).

Observations derive from the need to assess effective spatial fruition, aiming at registering movement: pathways and directions, and standing activities in coloured dots according to the type of activity considered. Density has been indicated by the thickness of both the lines and the dots.

The spaces observed have been selected from the initial spatial analysis, as the ones with blended activities, namely: the main corridors of the second and first floor, the main hall, the library, the cafeteria and the refectory. Isovists have also lead to the positioning of the observers for higher visibility. Each observation took 30 minutes, 8 observers and included the classes’ most significant breaks for attending the common spaces: the morning arrival, the morning break, the lunch break and the afternoon school exit.

The niches on the main corridors are effectively used for standing while waiting for a class, socialising or taking up other learning activities, but also for practicing on musical instruments. This has been recently published in Domus magazine (2016, p.66): “It is rewarding to see students and tutors rehearsing all over [...]".
Paths diverge according to the users: teachers often go straight to the teachers’ offices on the first floor, while regular teaching students usually cross the main hall towards regular teaching pavilions, whereas artistic students and teachers are the ones that use all the building’s floors.

A vertical stratification of the users has also been verified, from the ground floor that congregates all the school community, to the second floor that is only frequented by the artistic community.

Observations differ according to each chosen interval. The morning arrival at school holds a high frequency of moving activities. The mid-morning interval has the highest density of movement through all the floors, in order to reach spaces such as the cafeteria or the library. It is also the densest interval for standing activities while awaiting the following class. The lunch break is when the refectory is open, aggregating a large group of students. As the afternoon progresses, the frequency of use of the artistic classrooms increases, along with moving and standing on the corridors.

Programmed activities of social nature occur at the refectory as opposed to the cafeteria that has mostly social non-programmed activities. The library allocates programmed and non-programmed learning activities and even social and more spontaneous events at the afternoon, but rarely artistic. The main hall gathers all activities, programmed and non-programmed, social, artistic and learning, supported by its significant width and length, besides its accessibility between the street and the other pavilions, acting as a “communal living-room” of the school (Hertzberger, 1991, p.62) [Figure 8].
Finally, rather than observing natural movement (Hillier et al., 1993) in a non-participated manner, walkthroughs sustain an effective understanding of spatial adaptability from the users’ perspective, complementing the entropy approach and the observations [Figure 9].
Pathways for the walkthroughs

- teachers
- students from the regular teaching
- students with artistic and regular teaching

Indication of the most adaptable spaces
(bigger size shape according to bigger adaptability)

Second floor plan

First floor plan

Ground floor plan

Figure 9 - Walkthroughs — Photos and plans with the most adaptable spaces identified
For this methodology, the selected groups were: students from the regular teaching, students that attend both, and teachers, all very diverse. Each group has been asked to conduct a separate interpretative visit to the central building of the school, commenting on the spaces’ adaptability and justifying it according to the types of activities that usually each of them undertook. Interestingly, from the diversity of individual profiles, there is a similarity in pointing out the main hall, as the most adaptable space, even if the activities that each group performs may differ.

Students pointed out the corridors on the upper floors as being central to their life in the school, for moving but also for waiting for classes, socialising and for pedagogical activities. Unsurprisingly, the second floor, which is used particularly for the artistic teaching, is considered the students’ own space, justifying its higher frequency on spontaneous artistic activities. Both students’ focus groups identified the niches on the corridors as being very frequented spaces by all. This is due to the high connectivity that these spaces have with the classrooms and to their global integration as a meeting point for all. But also, this is similarly justified by the proportion of these spaces that bestows a sense of intimacy that does not occur on the main hall, gathering smaller groups for socialisation and for spontaneous pedagogical or artistic happenings. Natural lighting conditions, temperature and furniture also determine the choice of spaces by students, regardless of their similarity in coating materials or dimensions.

4. CONCLUSIONS: RETRIEVAL OF AN ARTISTIC SCHOOL’S ADAPTABILITY

‘This process would depend on the mechanism of description retrieval discussed earlier, that is the ability of human being to retrieve an abstract description of spatiotemporal events and use it as a template for further action.’ (Hillier and Netto, 2001, p.13)

After proceeding with the overall methodology it is concluded that all procedures bear relevant significance for assessing adaptability and their sequential application provides data on different aspects that weight on the adaptability potential, comprising Schön's (1993) “reflection in action”.

Spatial features enable activity allocation, which has been analytically supported by the entropy approach, associating activities to spaces according to their physical potential. Nevertheless, the effective use of space is also determined by individual or collective preferences or routines that can overlap the potential of spaces with similar physical features. This is why each of the focus groups has particular movements and activities in specific spaces, as demonstrated by the observations and walkthroughs.

All in all, the findings on every approach coincide with the choice of the main hall as the space with the highest diversity of activities and the main aggregator of users, considering it to be the most adaptable space, due to its physical attributes and to entropy results. In fact, its uncertainty in which activities may be occurring there, determines its higher entropy in regard to other spaces, where there is more certainty on the activities occupation and that, inherently, are more specific. Likewise, conclusions from the effective use’s approach have also established overall the main hall to be the most adaptable to a wide assortment of activities for all the school community [Figure 10].

[Figure 10 - Analysis of the correlations between Integration, Entropy and Experience from the methodology]
Space syntax is paramount to support the understanding of these results, because it identifies the space’s morphology that can be associated with the users’ choices for activity allocation and the patterns of co-presence and natural movement in space. Actually, similarly to the surveys, the morpho-syntactic analysis has also identified the main hall, along with the main corridors as highly integrated, besides the library, the auditorium and the cafeteria.

General integration is therefore a determining factor for the gathering of a broader community, proven by the main hall as both a convex space but also by all the axial lines it comprises. Besides, its intensive effective use also validates it to be a space that caters for different activities with pedagogical potential and also a highly dense pathway for vertically accessing other floor plans, and longitudinally other spaces of the school, as well as transversally towards exterior spaces outside the central building.

Furthermore, the axial line results have proven to be more comprehensive for this particular brief, for comprising a set of convex spaces as a whole active learning environment. Hence, this process concludes that spaces with the ability to have both moving and standing activities, considered highly integrated convex spaces but also with high axial integration, are the most significant as active learning environments, as spaces of informal knowledge transmission amongst peers. This is particularly frequent in the corridors’ openings that hold small staying spaces, highly connected with formal classrooms.

This leads to the conclusion that informal spaces bear higher pedagogical potential when connected with more formal ones, whose mean depth is smaller, because students lay in a more inclusive space, embedded with formal and informal, programmed and non-programmed activities, pedagogically facilitating their learning in several different situations and spaces, under the current learning approach. Naturally that spaces with higher mean depth only aggregate a smaller fringe of students that moves there for more specific purposes, and are hence less aggregators of a more general student community.

Finally, this paper considers that high adaptability enables a wider variety of social relations and inhabitants, potentiated by the attributes introduced in spatial design and the spaces’ morphology, but it also considers the users and their spatial fruition to define the effective potential variety of social relations in space and, in this case, of activities with learning potential, in their wide array of contemporary possibilities. Ultimately, this reports to an early assumption by W. R. G. Hillier, in a conference in 1969 on “The people/artifact interaction”:

‘There are some interesting differences between the ‘physical system’ and the ‘experience system’. In the first place, the physical system is subject to normal process of entropy (the tendency towards disorder or formlessness), in that it decays if it is not subjected to a programme of action aimed to prevent this. The experience system does nothing of the kind. Often its tendency seems to be in the opposite direction. Once basic stresses are removed, a given physical system, partly through action on it, and partly through adaptation in experience itself, becomes an increasing source of life enhancement by becoming a tangible framework for associations, social relationships, memories and perhaps also a very fundamental kind of stability.’ (Hillier, 1970,p.28)

Notes:
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ABSTRACT
This paper focuses on the adaptive reuse of the MUDE Museum building, located in the centre of Lisbon. Previously a bank, construction works started in 2016 to fully accommodate the museum, rehabilitate the building’s structure and infrastructure, ensuring the accessibility and security features on its 8 floors and 15,000 m². The aim of this research is to inform future designs, in order to contribute to an intuitive and user-friendly space for different publics, better integrated in the pre-existence. As we are considering a physical environment built to perform as a bank, its spatial configuration is primarily determined by that function’s specific needs. Furthermore, the museum preserves all the bank’s main accesses and vertical circulations, originally destined to employees, greatly expanding public accessibility and free circulation in the building. Space syntax is used as a tool to understand that heritage and assess the inherent potentialities of the existing building and disclose design opportunities. The results are interpreted within a wider framework of knowledge, built upon an operative history of the building.

KEYWORDS
Visibility Graph Analysis, Graph Theory, Adaptive Reuse, Museum, User-Friendly Space

1. INTRODUCTION
This paper results from a body of work that has the building of MUDE Museum as its object of study. The authors have been conducting research over the years through various channels such as academic works, articles, books and exhibitions, resorting to different resources such as archive research, architectural documents analysis and by experiencing the building as a museum.

The timing adds value and practical usefulness to this paper, for the building is now closed, undergoing major structural and infrastructural rehabilitation, to fully accommodate the museum program in its 8 floors. Also, the museography, museum signage and shop projects are being developed.
The opportunity and relevance of this case-study is also born from the specificity of MUDE, installed in the former headquarters of the National and Overseas Bank (from now on BNU) as a museum in progress (Coutinho, 2014) between 2009 and 2016, during which time the exhibition and cultural programmes were developed on five of its floors. Once a majestic building, which embodied the character of the nationalist and colonial period of Portuguese recent history, it became a ruin as a result of the partial demolition of its interiors in 2001. The first and foremost approach of MUDE regarding the built pre-existence was to consider the physical and spatial constraints not as limitations, but rather as a potential for creativity, making it a setting for research and an experimentation laboratory; a place where different strategies to exhibit design are tested, always dealing with the identity of the space and the ruin aesthetic. The building that is now under rehabilitation is a complex and intricate space with several layers corresponding to different moments in its lifetime. The museological and architectural projects reflect a strategy of adaptive reuse, deeply rooted in the spatiality left by the process of demolition and in the premises of the museum itself. At the same time the configuration of the exhibition galleries should allow different curators, architects and designers to look for renewed geometries, modulations and atmospheres in each new display. The goal is to design a living, inclusive, active and dynamic place pulsing in the city so as to contribute towards much desired and necessary urban redevelopment and a culture of creativity and innovation that increasingly characterizes our times (Coutinho, 2014).

Using space syntax as a tool, the paper evaluates this adaptive reuse, through the following research questions: How can a space originally designed to be a bank headquarters adapt to host a museum? What is the heritage of that original function, and how is it felt in the fruition of the museum? How can MUDE accomplish its propositional premise and take advantage of this many layered, partially destroyed space?

The methodology of this study is well summarized in a phrase by Hillier and Tzortzi (2006): “... spatial layout is both a dependent variable, in that it can reflect pre-given social, cultural, or pedagogical ideas, and an independent variable, in that spatial design can, and usually will, have the consequence of shaping a pattern of movement and co-presence amongst those using the layout.” Considering that we are dealing with a pre-existent building designed to perform a function so distinctive from the one being implemented, the first step is to understand the original morphology and configuration – layout as a dependent variable; secondly it is necessary to understand how and to what degree it will adapt and shape the new function – layout as an independent variable.

The structure of the paper reflects the methodological approach. The first part concerns the analysis of the bank, investigating its architectural and social fingerprint through plans and justified graphs. Afterwards, the museum configuration is explored, as well as the adaptation options, confronting the similarities and differences in the use of the space. To facilitate the comparison between the bank and the museum, the numbers in all plans and graphs were attributed according to the museum spaces, and refer to a specific location in the layout, common in both. A table is presented, in section 3, to account for the changes in function per compartment. Lastly the paper focuses on the museum public spaces, namely the ground floor and the exhibition galleries for their public significance and value, using visual graph analysis to understand the spatial potentialities for public engagement.

2. THE NATIONAL AND OVERSEAS BANK HEADQUARTERS – A HIERARCHICAL AND SEGREGATED SPACE

BNU was a pillar of the Portuguese financial system for more than a century, one of the first national banks to be part of the international market, and the single money issuer in the country’s ex-colonies, except for Angola. It’s headquarters mirrored in the built environment the institution’s relevance and power. The bank moved to Lisbon’s downtown district, Baixa, in 1866 – only two years after its foundation, to occupy a lot inside one of the blocks nearer the river and Praça do Comércio square. From then on the bank consecutively bought adjacent lots until the 1950's, when it became the owner of the whole block. Amongst the many construction works that took place, there are two that stand out:
The 1920’s project by the architect Tertuliano de Lacerda Marques, that united most of the plot, maintained the pombaline facades and built an entirely new interior structure with beams and slabs, proposing a renewed spatiality. The building had then five floors with the public main entrance on Rua do Comércio. The various banking services were organized around a central octagonal atrium, topped by a skylight to draw in natural light overhead. On the ground floor, the public was attended at a wooden counter that was a central piece of the space;

The 1950’s/1960’s project by the architect Luís Cristino da Silva, that unified the whole block in one single building and renovated the interiors. The project went through profound alterations. In the end, the building gained three floors. Cristino maintained the structure and the spatial rhythm defined by Tertuliano Marques, but enhanced and enriched it. From the exterior, the monumental gateway on the main facade lent the building an austere and authoritarian aura, and the richness and detail of the interiors gave it a noble identity. White, green and black marbles, stainless steel, tropical hardwoods and dedicated lighting fixtures were the main materials used. The integration of fine and decorative arts was made with remarkable mastery.

The idea that buildings are sociograms of specific social systems and that their configuration are the embodiment of certain sets of principles (Hillier and Hanson, 1984) is of particular relevance to the analysis of the bank. Considering the attention this institution placed in its approach to the public, the location of its headquarters, the grandiosity of the building, it is expected that the morphology of the built interior also carries meaning and consequence. To better grasp the spatial configuration and its effects on the building users a comprehensive justified graph was elaborated. Each space is represented with a dot, blank if public access is permitted, black if it is for staff only.
The most striking aspect of the graph is the overwhelming amount of private spaces over public ones. The bank clients only had access to three spaces, 4 and 5 are part of the same continuous space around the counter, and this is the only one of them that is not a dead end, as it leads to the counter on the 1st floor (15). The one on the basement (13), and the deepest of them, is the vaults room, reserved only for a few authorized employers and for clients who have rented individual safes, admitting only a maximum of 4 people at a time. There were three public entrances, the main on the west facade, and the others in the east end on opposite corners of the building. Clients interacted with the bank workers with a counter in-between them, and even on the vestibule of the vaults room, where at first was a desk, a high wooden counter came to substitute it in due time. The public is maintained in the shallow part of the building and controlled by confinement, its circuits clearly determined by physical boundaries. This is a clear example of the spatial configuration's role of organizing the relations between inhabitants and visitors (Hillier and Hanson, 1984).

Although the visitors share the same space, the same does not apply to the employees that are tending to them. They are much more segregated and frequently separated by individual booths. This condition is imposed to a group of workers that are performing a similar task, and, therefore, are of the same rank. When we consider employees of distinct hierarchical levels and the way they access the building or the areas where they work and must stay, the differentiation goes much further. With a total of 1,000 people approximately working inside the building, everyone knew its own place and allowed areas. Take now the example of the Administration and Governor of the bank: their working areas are on the 1st and 2nd floors respectively (18 and 28), both on the south wing of the building, which they access through the west staircase and elevator, the latter with its own entrance from the exterior of the building. The circuit is private and individualized, and this distinction is made further evident in the choice of materials, namely in the staircase which is all made of white and green marbles, and the handrail is of steel and brass.

By contrast, all the employees that work on the upper floors must cross the counter perimeter to access the central elevators and staircase, whose walls are cladded with monotonous micro tiles and has a plastic handrail. On each floor, on both sides of the staircase, one enters a corridor that leads to another corridor or an antechamber that finally gives access to a set of workspaces. The level of deepness of the dead-end spaces, which is to say the number of spaces the inhabitant has to cross to reach his or her destination, is associated with a controlling environment, while the sheer number of such spaces thus positioned in the graph speak of the segregation imposed by the architectural configuration. It is interesting to notice that the Administration and Governor's spaces are much more integrated and shallow in the graph, revealing a much-facilitated entrance and exit of the building. Great liberty and freedom of movement implicate that, in contrast with other workers, they exert some control over their environment.
The inherent spatial qualities brought out by this analysis reinforce the thesis that a certain spatial configuration is the embodiment of established social relationships and cultural canons. The tight control over most workers and the inequality between employers and employees’ space is a translation of a marked class society that echoes the ideology of dictatorship of the current political regime. The analysis showed that BNU fits the genotype of bureaucratic building as it is defined by Hillier and Hanson (1984). In this respect, it is worth referring the first project presented by the architect, which had a completely reversed approach to the way the public circulated on the ground-floor (fig. 3a): the visitor occupied the centre of the space, which was accentuated by a double-height skylight, in an atmosphere of openness, contrasting with the corridors along the counter in the built version. The visitor would enter directly to the main public space where the inhabitants in booths would attend them behind a counter.

However, if we decompose the first version in terms of its syntactic relations, we find that the structure is really the same as the one built (fig. 3b). This is an example of how architecture can dramatically change the way a space is perceived, without changing the substratum of an unconscious set of principles that will irrevocably condition spatial appropriation. Still, the reverse is also true: in the same original configuration it is possible to change the spatial relations within, just as it will be discussed in the next chapter.

3. MUDE DESIGN MUSEUM – A CASE OF ADAPTIVE REUSE

BNU’s importance reduced significantly after the Portuguese revolution in 1974 and the consequent independence of the African colonies. By the end of the 20th century, BNU was merged with the bank Caixa Geral de Depósitos. In 2001 the building underwent major interior renovations that were stopped during the demolition phase owing to its patrimonial and architectural significance. The counter became a protected piece of interior architecture, along with other relevant parts of the building. The works stopped in 2004, and the building remained closed, almost unusable and with an uncertain future.

"Restoring or radically transforming this heritage would represent another act of aggression towards the building and a substantial loss of its authenticity, poetry and significance as a living expression of our architectural culture and of the site itself. Its adaptive reuse allows us to comprehend the various architectural styles, historical periods and building technologies. (...) As a result, respect is shown to all that preceded the present time, enabling the present cohabitation of the varied experiences of the past, even if these were acts of demolition.” (Coutinho, 2014)

As we can understand by Coutinho’s statement, the option to preserve the physical form and not redraw a new interior was a key decision for the museum idea. It requires that the functional program of the museum, nowadays increasingly more complex and specific, becomes pliable enough to be cast into an existing mould.
<table>
<thead>
<tr>
<th>Compartment</th>
<th>Functions per compartment in each period of occupation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Outdoor</td>
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<tr>
<td>2</td>
<td>Employees entrance</td>
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<tr>
<td>3</td>
<td>Governor and Administration entrance</td>
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<td>4</td>
<td>Main entrance</td>
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<td>5</td>
<td>Ambulatory</td>
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<tr>
<td>6</td>
<td>Changing room</td>
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<td>7</td>
<td>Restroom</td>
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<td>8</td>
<td>Waiting room</td>
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<td>9</td>
<td>Currency exchange</td>
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<td>10</td>
<td>General Transactions, Securities, Treasury and</td>
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<td></td>
<td>Reception of Cheques</td>
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<tr>
<td>11</td>
<td>Technical area</td>
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<td>12</td>
<td>Technical area / Vaults</td>
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<td>13</td>
<td>Renièd Vaults</td>
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<td>14</td>
<td>Bank’s Safe</td>
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<td>15</td>
<td>Bills of Credit Due and Bills of Credit Paid</td>
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<td>16</td>
<td>1st floor hall</td>
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<td>17</td>
<td>Reception room</td>
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<td>18</td>
<td>Administration Offices and Council room</td>
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<td>19</td>
<td>Supervisory board</td>
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<td>20</td>
<td>2nd floor hall</td>
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<tr>
<td>21</td>
<td>Informations and Credits and Accounts Department</td>
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<td>22</td>
<td>Office of the Government Commissioner and Secretary</td>
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<td>23</td>
<td>General Meeting</td>
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<td>24</td>
<td>Credits and Accounts Department and General Secretary</td>
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<td>25</td>
<td>Credits and Accounts Department</td>
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<td>26</td>
<td>Secretary of the Governor</td>
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<td>27</td>
<td>Vice-Governor’s Office</td>
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<td>28</td>
<td>Governor’s Office</td>
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<tr>
<td>29</td>
<td>3rd floor hall</td>
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<tr>
<td>30</td>
<td>Registrations, the Mechanographic Centre, General</td>
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<tr>
<td></td>
<td>Correspondence, Telegrams and Legal Department</td>
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<tr>
<td>31</td>
<td>Telephone Switchboard, Social Services, Archive and</td>
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<td></td>
<td>Office Supplies</td>
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<tr>
<td>32</td>
<td>Inspectorate of the Head Office, Continent and Islands,</td>
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<td></td>
<td>the Inspectorate General for Overseas</td>
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<td>33</td>
<td>Workshops</td>
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<td>34</td>
<td>Collectors and Check Stamps - Cobradores e</td>
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<td></td>
<td>embregmento de cheques</td>
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<tr>
<td>35</td>
<td>Archive, Head of minor staff and Security</td>
</tr>
<tr>
<td>36</td>
<td>Changing room</td>
</tr>
<tr>
<td>37</td>
<td>Storage and Changing room</td>
</tr>
<tr>
<td>38</td>
<td>Restaurant entrance and restroom</td>
</tr>
<tr>
<td>39</td>
<td>Bar</td>
</tr>
<tr>
<td>40</td>
<td>Restaurant for the Administration</td>
</tr>
<tr>
<td>41</td>
<td>Kitchen and Plating area</td>
</tr>
<tr>
<td>42</td>
<td>Outdoor terrace</td>
</tr>
</tbody>
</table>

Figure 4 - Table with functions per compartment, relating bank and museum
Figure 5 - Photographs of the building, with specific examples of functional adaptation within the given spatial configuration.
Following the museological premise, the current architecture project relies on minimal intervention, as the plans make clear. All the main differences in interior configuration were caused by the demolition: the destruction of walls and consequent opening of large continuous areas in the totality of the 3rd and 4th floors and half of the 1st and 2nd floors. Pavements, walls and ceilings were stripped, leaving the structural frame exposed, along with remains of older coverings. That makes possible the identification, by naked eye, of three periods layered in the raw walls and ceilings: the first one from the foundation of the district in the late 18th century, the second from the main construction in 1920’s and the third from the expansion and ennoblement works finished in 1967.
The graph shows a pronounced difference of the public accessible areas between the bank and the museum. In the former only 2% were public spaces, while in the latter that percentage grows to 44%. It is also evident that the museum has less levels of deepness than the bank. This results not only from the destruction of interior compartments but also from the liberalization of circuits. For example, to reach room 28 one may come from the staircase/elevator near the main entrance, or through the central staircase/elevators; indeed, the 2nd floor went from having 7 levels of deepness to 3 levels. That liberalization also means that the workers' circuits merge with the public's, and is an unavoidable consequence of the adaptation with minimum intervention. Attending to the stairs and elevators that articulate the various floors, they are now the main vertical arteries of public circulation, besides continuing to serve the museum workers. The bank only had the need for two public staircases, one connecting the ground-floor to the 1st floor, and another to the basement vaults. The new use requires that the public reaches the top floor, the terrace and restaurant, making the deepest vertical space, a panoramic room previously reserved for the bank's administration, available for everyone's enjoyment.

The justified graph transmits a generalised openness, due to the expansion of public spaces, but also due to a great reduction in compartmentalisation. Considering that the bank's basic distributive element was the corridor, the elimination of interior partitions affected not only the level of segregation but also of deepness of the spaces – 3 levels is the maximum deepness on each floor – making them more accessible, or integrated. Taking for example the relative shallow position in the graph occupied by the exhibition spaces (17, 21, 30 and 31) that absorbed a series of bank rooms, indicating that these spaces are not subject to much control – the spaces are open to everyone. This is also emphasised by the fact that the galleries are integrated on rings, affording the visitor some control over the space, materialised by the possibility to choose his way in, through and out of the space. The ring circulation scheme is ever more present in the museum, which is a translation of the museum's intention to democratize it's space: a shift between a position system, that exercises control over people as categories, to a personal system, one that considers them as persons and as spatial entities, capable of acting and controlling themselves the space (Hillier and Hanson, 1984). That strategy answers positively to the museum's intention to offer an open narrative and encourage an active role by visitor. “Visitors may choose their own route and plot their own way of visiting the exhibition. Instead of being obliged to follow a linear narrative, visitors can wander through the space in a random fashion, according to their own curiosity, attention span and available time.” (Coutinho, 2014).

Another notable characteristic of the exhibition spaces is that they are an indelible part of the distributed system. Contrary to many museums that have a circulation system parallel to the galleries, MUDE has a perpendicular one - the vertical axis. The only space where the visitor can cross from one side to the other of the building without passing through an exhibition, besides the terrace, is the ground floor.

The appropriation of the ground floor works as an analogy for the entirety of this adaptive reuse. At the same time that the counter returns to its original function – as the museum reception desk and ticket office – it utterly inverts the use of its previous highly restrictive, segmented and controlled interior by transforming it into a museum shop where everyone enters, roams and leaves. The nature of the shop’s products (Portuguese and Ibero-American design), is itself an overturn of the original ideology of the space. Likewise, the encouragement of freely exploring this street level space, without even entering the proper museological spaces, entirely reverses the restraint expected in the interior of the bank, whose only expected visitors were registered or future clients. Here, the architecture is maintained while the perception of the space changes: the counter is still there, but ceases to be a barrier.

4. SPACE AND VISITOR ENGAGEMENT

Public engagement with the museum space is studied through visual graph analyses in the two main areas, the ground-floor and the exhibition galleries.
Ground Floor:

By opening its ground-floor to the public in the four facades at the ends of the interior main axis, the museum creates an extension of the surrounding streets, allowing anyone to arrive from point A to point B cutting through the interior of the building, and thus making it an indelible continuum of the public city space.

This permeability generates a series of alternative routes, augmenting the choice value, allowing the street walkers to take a shortcut, to pause on their way or to explore the interior space. The main entrance is on the busiest street of the area, a pedestrian street, main axis of Baixa (Lisbon’s downtown), culminating in a triumphal arch before a great plaza by the river. This strong axially with a physically marked destination makes people’s exploration of Baixa more uneventful and shallow. By introducing the possibility of entering the building from this street and getting out on another one of three, the museum is already transforming the relations in the immediate urban fabric, rendering those secondary streets more integrated in the whole complex than before. This intention recovers the function and spatial organization of the bank. This is even more significant when we take into account that no other block in the area offers this kind of permeability, nor the possibility to walk through it along its interior.

Another way in which MUDE will use its ground floor to connect to the activities of its surrounding is by transforming the area circumscribed by the counter (the element in grey in fig. 9) in the museum shop. The attribution of this function to this space, which is enclosed but visible from all sides (the counter is about 1m high), as the consequence of definitely transforming the referred interior paths in interior streets or galleries. Moreover, all the gratings that caged the bank’s windows from the outside will be removed and the glass will be an interface of communication between the museum and the city, as well as shop windows.

Figure 9 (a) shows the juxtaposition of the isovist fields from all entrances. Coming through the main entrance, the visitor is lead straight to the museum reception and ticket office, while being given a glimpse and the choice of exploring the rest of the floor from both sides. The other four entries give the visitor a more intelligible first glance of the space, covering a field of wide angle and length, since there are fewer obstacles and the configuration of the walls in the interior follows the exterior.
SPACE SYNTAX AS A TOOL FOR AN OPEN MUSEUM PRACTICE:
The case of MUDE Museum

Figure 9 - (a) Isovists from the 5 public entrances; (b) Stepdepth from the 5 public entrances

Figure 9 (b) shows the value of Step Depth from every entrance, accentuating the main access with the lowest value (orange). Crossing the two maps above it becomes evident that the shop is a fairly accessible space, given the reduced number of steps one has to go through to reach it from an entrance, and is the dominant feature of the ground floor, visible from 4 of the 5 entrances. Furthermore, it uses its own boundary, the counter, to articulate movement outside its perimeter, promoting a first exploratory walk outside, and, only after, a second more decisive movement to enter. This transition from the periphery - the longitudinal galleries - to the area inside the counter is also a shift from a position of observer to the position of observed, an interesting preamble to the interactions in the exhibition spaces on the upper floors, between individuals of the public.

Exhibition Galleries:

Museums are more often studied with the focus on their traditionally main function, the exposure of objects to the public. However, in this case the focus is on the relationship between visitor and space itself. Making this paper all the more relevant since it is the purpose of the museological program to face the building as content and not merely as container (Coutinho, 2014).

To understand the spatial characteristics of this museum, it is essential to know the building’s history and study the process of demolition it was subject to, for it was crucial in the transformation of the interior space. Indeed, the destruction was the generator of the large open areas deprived of partitions and coverings, opening the possibility of installing a museum with the philosophy of MUDE. To follow its trace we need only to track the bank workers’ spaces, the ones not meant for the public or the bank administration. These were the deepest and most compartmentalised, and completely torn down in the process, originating the mentioned large areas.

Almost intuitively, the open spaces on floors 1 to 4 are allocated as exhibition spaces. They will host the museum collection (3rd floor) as well as temporary exhibits (1st, 2nd and 4th floors).

Morphologically the opposite of the traditional structure of enfilade, the open plan also invites for non-deterministic layouts that take advantage of cross visibility and thus promote cross-referencing between works, allowing the construction of new meanings through visitor autonomous exploration (Peponis, 1993). Maintaining the exhibitions galleries as open spaces, the project allows each new exhibition to transform the perception of the space, with various entrances, circuits and display solutions altering the way the space is experienced and lived. Besides being ideal for these purposes in terms of their area and spatial flexibility, permitting an infinitude of layouts and routes, they are ideal public spaces inside the whole building as a system. Just as figure 10 clearly shows, the better integrated areas are the exhibition areas.
Figure 10 - Visual Graph Analysis: Measures of Integration in the public areas on floors 0 to 4.
It has been argued in previous works, (Hillier, Hanson, Peponis, 1984; Hillier and Penn, 1991), that integration, a measure of how many spaces must be crossed (or are seen) to reach all the other spaces of a layout, relates directly with patterns of human movement and is therefore an indication of the probability of encounter. By implication, they emerge from the structure of the configuration as the natural congregating spots, be that for the convergence of seeing paths or their divergence, by congregating more visitors who in their turn diverge their gazes to other points in space.

In employing a gradation of colour to indicate the gradation of integration, space syntax makes tangible important properties of these large areas, outwardly homogeneous. Knowing which parts within the layout render themselves as gathering areas, and the ones which tend to be avoided, is of invaluable interest to a museum that has as mission to be an intuitive and user-friendly space.

These facts not only influence the design of future exhibition layouts and museography, but also help shaping the way people use the whole museum. The museum shop and signage may be designed intelligently by acknowledging some of this information, for example the spots with more cross visibility or potential for encounter. Wayfinding in particular has the objective of rendering the space more intelligible and consequentially more natural to the visitor, and could use its own potentialities to build a system that is more guiding than leading.

Understanding these specific spatial relationships also propels the formulation of design intentions, as the relations inherent to the existent built environment become explicit. The accesses to each exhibition space are less integrated than the gallery itself, although there is always a direct line of sight between the top of the stairs and the exhibition entrance. This indicates that the visitor will know where to go, and once inside will be able to read the space as a whole with minimum changes in direction, with the exception of the 1st floor, where the gallery expands unpredictably from a long corridor to an adjacent large squared area, much less integrated. It is possible to identify a pattern in the circuit to reach each exhibition, that is marked by the vertical movement. Each exhibition space is explored in one horizontal plan, and to change to another space the subject must move vertically in an axis, to arrive in one similar topological circumstance. The axes are always the same and the morphology becomes familiar, making for a more comfortable fruition of a complex system. This shift in vertical position is also a natural pause in the sequence of successive engagement with the exhibitions, a role that could interfere with the design of the mediation spaces.

5. CONCLUSIONS

Through space syntax we have concluded that MUDE will be able to be an inclusive and dynamic space, despite being installed in a pre-existing building that was designed as a closed, hierarchical and segregated space, to perform as a bank with a nationalist symbolism. It was possible to understand the set of social meaning-use behind the bank’s configuration, how they translate an autocratic culture regulating the way visitors and inhabitants lived the space. It also allowed to foresee how these principles are subverted within the given configuration by some changes of spatial relations, sometimes drastic, others very subtle. This attitude communicates a democratic culture and shapes a different social relation. The former changes were the result of the demolition, an uncalculated event occurred before the museum occupation, that opened large areas capable of being engaging and flexible exhibition venues. The latter are based in the liberation of circuits and offering the previously restricted and private spaces to the public.

Nevertheless, there are remnants of the bank era that strongly condition the use of the space and the fruition of the museum. The ground floor counter that is only twice and very narrowly interrupted, thin filtering the entrance to the museum shop, constitutes a marked imprinting on the overall experience of that public space. Likewise, the implementation of the main vertical circulation in the midpoint of the counter, far from the main entryway, is another inheritance. MUDE understands the building as a significant place, taking advantage from the pre-existing space’s identity. This strategy adds a political, economic and social meaning to the museal discourse, and can be related to the critical museology. It also sets MUDE apart from the doctrine of designing iconic museums, not place related, to be consumed by the global economy.
The paper also deduced that MUDE may transform the building, with its many layered, different periods of construction left exposed and half destroyed space, in a live lesson of architecture. Through the experience of the space and materiality visitors engage in learning Portuguese history and architectural culture. From the main entrance forward, the public may identify the genius loci and experience the aura of the place. The container becomes itself content of a museum devoted to design and the patrimony to preserve is transformed into operative heritage, making MUDE an authentic and one-off museum.
REFERENCES


ABSTRACT
Supermarket floor layout has influence on customers shopping behaviour and movement path. However, past findings are mainly concentrated on layout patterns identification, lacking computational evaluation of real world layouts. In former research, algorithms in Depthmap such as VGA (Visibility Graph Analysis) and MAS (Multi-Agent Simulation), based on the core concept of isovist, are proved effective in quantitative evaluation of spatial traversability and attractiveness. These algorithms could be new approaches for evaluating supermarket floor layouts.

This paper is intended to verify the application of VGA and MAS in supermarket layout analysis by comparing their calculation results with both sales experiences and real world data. Firstly, typical layout patterns are analysed with the two algorithms to verify their consistencies with sales experiences. Secondly, calculations of an experiment supermarket are conducted with parameters adjusted according to the actual environment; tracking points of customers are also collected with a high-precision indoor tracking system. Correlations between the calculation results and real world collected data are demonstrated.

The main conclusion is that VGA has its value in position evaluation however cannot predict people flow, while MAS result can be an important reference to both layout evaluation and customer flow prediction. Additionally, applications and some possible refinements of the existing algorithms are also suggested for future studies.

KEYWORDS
Isovist, Visibility Graph Analysis, Multi-Agent Simulation, Supermarket, Indoor Tracking, Layout Analysis
1. INTRODUCTION

In the research realm of interior retail environment, floor layout design is vital as it exerts spatial influence on in-store traffic patterns, shopping atmosphere, shopping behaviour and operational efficiency (Lewison, 1994), which further significantly impact commercial performances such as price acceptability, shopping quantity, store loyalty and etc. (Merrilees & Miller, 2003; Levy & Weitz, 2001; Underhill, 2000). In the first stage of layout studies, most findings focus on the form of guidelines on technological constraints, such as minimizing the distance between refrigeration system and electrical power sockets (Boros et al, 2016). With the advance of equipment and prosperity of marketing theories, the focus shifted to layout patterns and category allocation. The summarized typology of layout patterns - grid, race track, free form and circulation spine, are applied and analysed (Levy & Weitz, 2001; Lewison, 1994) in complementary with marketing and customer studies. Meanwhile, types of product assortment are investigated (Borges, 2003; Cil, 2012) and experiments on shelf orientations adjustment are conducted (Hwang & Lee, 2005). On the other hand, quantitative techniques, analytical methods and simulation models has emerged to evaluate a given floor layout, including customer flow simulation applying the concept of Traveling Salesman Problem (Boros et al, 2016; Misiecius, 2005; Aleisa & Lin, 2005). In a word, during recent decades, the study of supermarkets layout has developed to be more quantitative and involved with customer research owing to advanced algorithms.

Since Bill Hillier suggested that spatial form predetermines the function of space and human activities (Hillier, 1996), people began to conduct objective analyses of space to tackle practical problems. Based on isovist concept and Space Syntax theory, a collection of algorithms and tools including Axial Map Analysis, Convex Map Analysis, Visibility Graph Analysis, Segment Map Analysis and Multi-Agent Simulation have been developed and applied to a wide range of scales of spaces and compatible occasions (Al-Sayed et al, 2014). These analysis tools exclude social, functional and other factors to reveal the impacts that space imposes on man to pursue objective and quantitative outcomes. Among these tools, VGA (Visibility Graph Analysis), Convex Map Analysis and MAS (Multi-Agent Simulation) are more widely used in building scale. Unlike Convex Map Analysis that only fits the type of building with explicitly defined rooms, VGA and MAS have a much wider application.

VGA and MAS have been carried out in urban context or art galleries analysis and have proved high consistent with distribution of people in real situations (Duan & Hillier, 2015). The compatibilities of these tools for supermarket scene still remains to be examined. Unlike other approaches, such as TSP (Travelling Salesman Problem) algorithm which tackles the analysis situation as a mathematic model, VGA and MAS aim to solve the problem from a cognitive perspective.

To verify the applicability of VGA and MAS in supermarket layout analysis, this paper is organized as follows. In the first part, this paper introduces the concept of isovist and explains the principles of VGA and MAS, especially their relationships with isovist. In the second part, some typical layouts are analysed with VGA and MAS to demonstrate the relevance between analysis results and classic sales experiences. In the third part, the effectiveness of the methods is verified quantitatively with position evaluation experiences and real world data collected with a precise indoor positioning system in an experiment supermarket. The position value indicator (Magnetic related/All) and R2 (coefficient of determination) are calculated to quantify the consistency. At last, this paper discusses the limitation of tracking technology, and proposes further algorithm refinements.

2. DATASETS AND METHODS

2.1 ISOVIST, VGA AND MAS PRINCIPLES

After the idea of isovist/visual field was proposed by Benedikt, it offers a new insight into how people navigate through space. An isovist is the set of all points visible from a given vantage point in space and with respect to an environment (Figure 1), and it forms an alternative...
description of environments to further understand view control, privacy and defensibility in dynamic complexity and spaciousness judgments (Benedikt, 1979). Benedikt supposed that people would be guided by isovist properties rather than objects, while Gibson further suggests that people may be guided by direct (or active) perception without higher cognitive functions (Gilson, 1979). As it is agreed that vision is the most critical sense upon which most humans are dependent in environment sensing and reacting, some algorithms are developed based on the isovist concept to predict people movements. VGA and MAS are just two typical algorithms representing modelling and simulation approaches respectively to address the issue of pedestrian movement analysis (Penn & Turner, 2001).

Figure 1 - An isovist polygon representing the visible area from a generating location (Benedikt, 1979)

VGA is a spatial analysis method combining isovist concept with space syntax theory, which can be shown on a grided graph with the grids coloured according to their spatial properties. Hillier and Hanson developed the theory of space syntax and created various representations for the components of space; they then drew maps of these components, and crucially the relationships of the components with each other (Turner, 2004). The properties are statistics of isovist characteristics and visibility configurational relationships. Isovist characteristics include Isovist Area, Isovist Compactness, Isovist Occlusivity, Isovist max Radial and others. Visibility configurational relationships of grids laid, can be either global or local, i.e., for each vertex and for the entire system, include Visual Control, Visual Controllability, Visual Integration, Visual Clustering Coefficient and others. These properties display differences in cognition of space, in other words, people in different behaviour objectives may take some properties prior to others in their actions. In former researches, different properties are selected to fit in proper scenes (Orellana & Alsayed, 2013; Kalff et al, 2010). VGA outcomes are proved efficient as the past findings show that between 50% and 80% of the variance in pedestrian flows from location to location in an environment can be explained in terms of variations in configurational properties of those locations in the network (Penn & Turner, 2001).

The isovist based method MAS, utilizing vision as the driving force in path planning that developed by Penn and Turner, has been proved to match the movements of real pedestrians by a simple rule (Penn & Turner, 2001). It is proved efficient to predict the collective behaviour emerged from individual random walks constrained by geometry but aided with what agents can see in different scales of scenes (Batty, 1993). The simulation rule of agents can either use VGA properties or just as simple as a random next step rule. In fact, the simplest random next step rule performed better than the complicated rule which uses Visual Clustering Coefficient data in the retailing store experiment (Penn & Turner, 2002). So the simplest random next step rule is recognized as the default rule. This isovist based simulation is different from others in that it doesn’t assure a certain destination or assume a rational choice in order to optimize some measure of cost such as travel time.
These two algorithms are both implemented in Depthmap, which is a program developed by Alasdair Turner (Turner, 2003). The working process is shown in Figure 2. Before applying to different scenes, some parameters need to be decided for MAS; on the other hand, the most relevant properties among VGA should be picked up. In this study, the properties and parameters are decided according to the key points mentioned in layout experiences.

2.2 PROPERTIES AND PARAMETERS DECIDING

The first step is to decide the grid size for subdividing the supermarket plan. It is set at 0.6 x 0.6 meters as it’s the average step length and also the passing through width of an adult, which facilitates both MAS with the proper step length and VGA with the proper human scale. Although the program only takes the grid location but not the grid square, this setting makes it easier to relate real human steps to the steps taken in simulation, and achieving a balance between accuracy and computing time.

Conventional retailing store layout theory has summarized three typical types of store layouts, namely Grid, Freeform and Racetrack/boutique, with each one having its advantages and disadvantages (Lewison, 1994; Levy & Weitz, 2001). The grid layout is a rectangular arrangement of displays and long aisles that facilitates routine and planned shopping behavior, providing flexibility and speed in identifying products; Freeform gives customers enough freedom to move in any direction and increases time spent in the shop; racetrack/boutique leads the customer with well-organized structure and creates shopping entertaining experiences. The most commonly used layout in a supermarket is the grid pattern, based on the assumption that at least half of the customers already have clear motives when they enter the shop.

In the descriptions of how the patterns facilitate customers, some key characteristics can be identified. Routine and shopping time are main concerns of the whole shopping process, while freedom of choice, routine length and structure are also mentioned as important spatial issues. According to these aspects, the four properties of Isovist Area, Isovist Occlusivity, Visual Control and Visual Integration are selected from VGA properties as most related to customer distribution. These four properties are defined as follows:

Isovist Area: Isovist Area counts the number of nodes that are visible from a certain location. As the visible defined in the program is undirected, the spot with higher Isovist Area in a plan has a large vision and also has high visibility from other parts of the space.

Isovist Occlusivity: Occlusivity accounts for parts of the isovist area that are occluded but permeable. It implies the degree of closure of a certain area.
Visual Control: Control picks out visually dominant areas - in order to be controlling, a point must see a large number of spaces, but these spaces should each see relatively little (Turner, 2004). Areas with high control value always play an important role in the spatial structure.

Visual Integration: Integration is an essentially normalized version of the mean depth. Former researches have proved its correlation with pedestrian flow amounts - the higher integration, the more possible to occur large amounts of pedestrian flow (Hillier et al., 1993).

There are four parameters in MAS that would affect agent movements: the number of steps before turn decision, field of view, timesteps in system, and system analysis length. The default value is 15 bins of field of view equivalent to 170° and 3 steps before turn decision. The default value is proved correlating well to real situations in former research (Turner and Penn, 2002). However, in the experiment conducted in an airport, the author adjusted the step number to 6 to make the simulation path better fit individual navigation path, resulted in a better correlation rate (Orellana & Alsayed, 2013). As the common width of supermarket aisle is about 1.2 meter, plus the 0.9 meter width of shelf, 2.1 meter will be the distance between two adjacent aisles. In this sense, the 2.1 meter length has a span of 3.5 grids with 0.6 meters sides, assuming that the 3 steps turn parameter is reasonable in the supermarket scene. Timesteps in system in the experiments are decided assuming the customers go through all the aisles in the supermarket, so it can be calculated according to the grid numbers of the plan. System analysis length is four times of agents timesteps to ensure a relatively stable status.

3. THEORETICAL ANALYSIS BASED ON SALES EXPERIENCES

3.1 FIGURING OUT MAGNETIC POINTS

One type of sales experience analysis of a supermarket layout is to identify the most valuable positions in a given plan. Those positions are called Magnetic Points (Katsutoshi Niiyama & Hu, 2011), which usually appears at the end of shelves along the main aisle, or in the open area in front of the cashier. Items around these points have to be carefully arranged in order to attract and guide customers to make them stay longer in the shop.

To testify validities of VGA and MAS, the two methods are applied on the given example showing magnetic points (Katsutoshi Niiyama & Hu, 2011), and the results are shown in Figure 3. The parameters of MAS are set 15 bins of field of view and 3 steps before turn decision. The timedsteps is set to 200 (total grid number 768) and the system analysis length is set to 800. The agents are released at the entrance’s location.

Seen from the VGA graphs, the Magnetic Points are located near the high isovist, high visual control and high visual integration locations. In other words, these three graphs reveal the locations that have the highest privilege to be seen and surpassing by customers. Seen from the MAS graph, the main aisle drawn in the experience layout is passed by most agents, which directly represent people flow.
3.2 REPRESENTING LAYOUT RULES

Another type of supermarket layout experiences is the layout rules—dos and don’ts about how to organize the shelves. Figure 4 shows two inefficient layouts that couldn’t lead the customers into vast areas of a supermarket. From the analysis results, we can see only the MAS shows some similarities with the experience, while none of the VGA results reflects the experience. This reveals the differences between the two approaches that the VGA algorithm may not successfully represent real customer movement. When switch to a maze plan as in Figure 5, the differences can be seen more clearly. The agents formed a path through the maze which may occur in real situations, while the VGA can’t directly represent movement. From here, the assumption is raised that even VGA approaches have been proven to correlate with pedestrian flow in urban spaces and indoor space, such as galleries, museums, and large commercial buildings, they may not be fit for supermarket environment with narrow passages and explicit entrances. On the other hand, the MAS is able to represent the possibilities of customer flow to a certain extent.

Figure 4 - Two inefficient layouts, VGA and MAS outcomes (from left: isovist area, isovist occlusivity, visual control, visual integration, MAS)

Figure 5 - The VGA and MAS result of a maze (from left: isovist area, isovist occlusivity, visual control, visual integration, MAS)

Concluded from these two theoretical analyses, a preliminary conclusion can be drawn that VGA has its value in position evaluation but cannot predict people flow, while MAS result can contribute to layout evaluation and prediction of customer flow; and among the VGA results, visual control property is the most effective one. However, to what extent is the VGA result correlated with real people flow caused by spatial effects and what kind of errors may occur are to be discovered quantitatively by real world experiments.

4. QUANTITATIVE VERIFICATION WITH REAL WORLD DATA

An experiment is conducted in a supermarket with a medium size of 40*25 meters, arranged in a typical grid layout. Entrances and cashiers are marked on the floor plan in Figure 6. Because the behaviour of vegetable and fruit purchasing includes cues and weigh, it is excluded from...
the studied area. Also, the cashier and exit region at the bottom right and the top left corner of equipment charging area are excluded due to the inevitable data deviation. The merchandise is roughly divided into five groups, including dairy product and drinks, daily necessities and snacks, wine and beverage and frozen food. The arrangement is relatively balanced for household shopping, eliminating the effects of people’s preferences for different merchandise to a great extent. Depthmap calculated outcome of isovist area, isovist occlusivity, visual control, visual integration, visual integration R3 and MAS are shown in Figure 7 with a unified colour legend of red to blue representing high to low value of statistics. The parameter of MAS is set 15 bins of field of view equivalent to 170°, 3 steps before turn decision, 325 timesteps and 1400 system analysis length.

Figure 6 - The floor plan and merchandise arrangement of the supermarket

Figure 7 - Depthmap calculation results (from left: isovist area, isovist occlusivity, visual control, visual integration, visual integration R3, MAS)
The technical problem is how to record and describe people flow. In former studies, the most commonly used method is person following (Batty, 1993). However, this method is not feasible in a supermarket because of the small scale of space and psychological interference on customers. Gate count method is also not feasible in such small scale. In this experiment, we use the distribution of tracking points to represent the people flow. It serves as a more precise method which can overcome the drawbacks of other methods. Positions of customers inside the supermarket are recorded by a high-precision indoor tracking system based on Ultra-wide Band. Tracking devices called “tags” are attached on the shopping baskets. As the participants are asked to take a basket with them at the entrance, the position of the customer is represented by the position of the basket. The sampling interval is 10 seconds. After the experiment, tracking points are overlapped in the plan to form a location point graph. Although the distribution of tracking points dose not exactly equal to people density, by reducing the sampling interval or enlarge the recording period, it can approach the actual people flow infinitely. The tracking system recorded 639 tracking points in the process, and they are shown in Figure8. To compare the recorded data and calculation results, the plan is divided into 17 parts according to the main aisles. There are altogether 1257 grids within the analysed area.

Figure 8 - Tracking points and region index of the supermarket plan

4.1 VERIFICATION OF POSITION EVALUATION

According to the alliance of shelves, the magnetic points and main isles in the supermarket are marked as in Figure9. Regions highlighted represent areas that magnetic points have the strongest influence on. As the sales experience suggests, these regions have higher commercial values, which in other words should enjoy more possibilities to be seen by customers and have more people passing by.
The statistics of calculation results are listed in Chart 1. The average statistics of highlighted regions, called ‘magnetic points related regions’, are compared with the whole supermarket’s average level, making the ‘position value indicator’ (magnetic related/all). The highest ratio is 1.27 in the gate count statistic volume, while the isovist area and visual control property are the second and third highest ratio of 1.18 and 1.10. It can be seen from the chart that the grids in the highlighted regions have a higher level in both VGA and MAS results, proving that these methods both works to identify the most commercially valuable positions in the supermarket plan. In this sense, the applications of these two methods are verified.

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<th>Grid Counts</th>
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| Magnetic Related | 623 | 64,286.39 | 23766.83 | 684.25 | 5358.90 | 5388.39 | 25917.99 |
| Average           | -   | 103.19    | 38.15    | 1.10   | 8.60    | 8.65    | 41.60    |
| All Regions       | 1257| 110123.37 | 44102.15 | 1253.69 | 10216.96 | 10281.92 | 4328.00 |
| Average           | -   | 87.61     | 35.09    | 1.00   | 8.13    | 8.18    | 32.88    |

| Magnetic Related/All | 1.18 | 1.09    | 1.10    | 1.06    | 1.06    | 1.27    |

Table 1 - The calculation statistics and position value indicator (magnetic related regions/all)
4.2 VERIFICATION OF PREDICTING PEOPLE FLOW

Density of tracking points in each region is calculated for comparison with VGA and MAS outcomes. The correlation is represented by $R^2$ (coefficient of determination) between tracking points density and Depthmap results, as listed in Chart 2. From the chart, we can see that the $R^2$ of tracking points density and MAS is 0.6544, indicating a strong correlation. In the correlation chart, it shows that these two points that most deviated from the trend line are index 15 and 16, with fewer tracking points than expected. Generally, the MAS method can effectively predict customer distribution in a supermarket. On the other hand, the $R^2$ of tracking points density and VGA is much lower, with the highest value of 0.1192 of visual control, indicating a weak correlation. So it can be concluded that all of the VGA analyses failed to predict customers’ behaviours in a supermarket.

This result is almost consistent with the preliminary conclusion drawn from the theoretical verification that VGA has its value in position evaluation but cannot predict people flow, while MAS result can contribute to layout evaluation and customer flow prediction.

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$R^2$ Results with People Density (per grid) | 0.0758 | 0.0919 | 0.1192 | 0.0724 | 0.0759 | 0.6544

Table 2 - Recorded people density, Depthmap results and their correlations
5. LIMITATIONS AND CONCLUSIONS

Due to the limitation of the tracking system, the sampling frequency is not high enough to record the actual moving track of a certain customer. So the distribution of tracking points is used in the comparison instead of the real track, which could lead to some deviation in the result. Future research work may explore some improvements of algorithms. The MAS now used in Depthmap can work out a relatively satisfying result to correlate with real situation; however, the parameters can be adjusted to fit the supermarket scene better. First of all, the timesteps value that removes the agent after a certain running period should be replaced by a group of various values, since customers don’t spend the same amount of time in the supermarket.

Floor layout design plays an important role in supermarket design, since it directly affects people traffic pattern and behaviour, thus influences sales volume. This study tries to verify the effectiveness of VGA (Visibility Graph Analysis) and MAS (Multi-Agent Simulation) on the supermarket layout analysis. The two analytical tools each represents modelling and simulating approach, and embodies its own technical algorithm. Meanwhile, they both are based on the same idea that vision is the upmost important human sense to receive environmental information and leads movement, and are developed based on the concept of isovist which defines the area visible from a given point.

By comparing algorithm results, marketing experiences and real world data, the effectiveness of these two methods are evaluated. The conclusion is that VGA has its value in position evaluation but cannot predict people flow, while MAS result can be an important reference to layout evaluation and customer flow prediction. Additionally, some possible refinements of the existing algorithms are also proposed for future studies.

The results are of commercial values. As it is verified to predict customer density caused by spatial effect, the comparison of calculation result and real customer allocation can be used to analyse marketing issues such as packaging attractiveness, advertising, price and other commodity properties. The sales amount is more feasible to analyse separately with positioning factor and other factors. Besides, the study is meaningful in the revealing of algorithm adjustment possibilities. New movement rules concerning diverse timesteps and disappearing areas may be developed in future work to better fit supermarket scene, which also may be applied in other similar scenes.

ACKNOWLEDGMENTS

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ABSTRACT

The set-up of spatial configurations is an essential topic in architectural design. The logics behind this configuration of spatial networks are significant for architects as it denotes social as well as physical implications. If we accept that design is an experiential process, then experimenting and probing gain much prominence in the process. Experiments lead architects to discover, and then to redefine their design concepts.

This study focuses on the potentials of analytical methods via graph theory based tools and how to apply network thinking in architectural design. The study questions the following: If spatial systems are regarded as networks, how do various network visualization and assessment tools are useful to extrapolate the inherent pattern and the logic? How do space syntax, graph theory based tools and diagrams aid the exteriorization of this logic? How does the architect think through these tools and learn from them?

The topic will be expressed by presenting an experiment from architectural practice. This experiment deals with an iterative process of “a hotel specialized on the elderly and the disabled with rehab centre” (a mix-used building which includes a hotel, a rehabilitation centre and assisted-care apartments). In the design scheme relationships based on circulation scenarios of daily activities and services are modelled and animated by network related tools like Syntactic, the Space Syntax tool in Grasshopper, a plugin for the digital design platform Rhinoceros; a software for network visualization and evaluation Cytoscape, and a mind mapping software TheBrain. This experiment aims to explore how scientific; graph theory based tools feed design thinking and making.

Exploring alternative ways to integrate theoretical and practical implications of network thinking in architectural design is valuable for those in the architectural education and in practice. Findings of the research show that, graph theory based tools provide a useful basis for architects both for making and thinking about architectural space by generating scientific and numerical data. The study concludes with an array of advantages in working with network models in architectural design, and suggests future methods for design analysis and design research with network mapping tools.

KEYWORDS
Spatial Network, Architectural Design, Space Syntax
1. INTRODUCTION

Design is understood as a form of thinking (Wigley, 2007). This complex cognitive thinking can be described as a process of discovery that involves both experimenting and probing (Dursun, 2007). The strategy of providing solution proposals, analysis, evaluation and improvement of these proposals until arriving at a satisfying solution is recognizable right across the design professions (Dorst, 2010). In architecture, solution focused activity (Lawson, 2003) involves a creative process that concentrates on a kind of making (Schön, 1987) which is largely learned and practiced through “action and reflection” rather than trying to find out optimum solutions (Simon, 1996). The architect thinks with different design tools and brings different forms of knowledge together to evaluate designed outcomes during this process. In other words, he/she reconfigures design ideas by learning from his/her designs, testing and exploring the possible effects of his/her decisions.

As reported by Cross (2001, 2007), design practice has its own intellectual culture. This culture concentrates on “designerly ways of knowing, thinking, and acting”. Design research literature is full of remarkable quotations that try to make a distinction between science and design. According to Gregory (1966) “the scientific method is a pattern of problem-solving behaviour employed in finding out the nature of what exists, whereas the design method is a pattern of behaviour employed in inventing things...which do not yet exist. Science is analytical; design is constructive.” Simon (1996) states that “the natural sciences are concerned with how things are...design on the other hand is concerned with how things ought to be.” Similar with Cross’s idea, this study does not intend to highlight this sharp distinction between design and science once again. By accepting that architects have their own way of perception, cognition and production, the paper aims to explore how these opposite ways of understanding, intuition and reason, can be brought together in a creative process to build up architects’ own intellectual design culture. On other words, it concentrates on alternative ways which science based knowledge or analytical tools can be used to make “non-discursive intuition more rational and therefore more discursive” (Hillier, 1996; Hillier and Hanson, 1997) in the architectural design process. It is suggested that architect is an intellectual actor who is aware of different tools and knowledge resources and has a capability of using them to lead his/her design thinking (Dursun, 2007).

Architectural design involves configuring complex spatial relationships. These include sophisticated links that involve new social connections and their spatial expressions. The architects need to find alternative ways to grasp these transitional spatial formations-complex relationships and their possible social meanings to produce novel encounters. This study focuses on network thinking in architecture and explores the potentials of analytical methods / graph theory based tools in architectural design. In this paper, a sample experimental case from practice is presented, in which various network visualization and analysis tools help to decipher the spatial logic of a mix-used building. By creating an interactive dialog with numerical and graphical data, it is indented to come up for discussion on how architects think through these tools and learn from them.

2. DESIGN AS A SPATIAL CONFIGURATION

One main consideration in architectural design is about setting spatial configurations. As reported by Nourian et al. (2013a) the outcome of an architectural design process is essentially a configuration. Space is substantially defined by the configuration of spatial cells (Dade-Robertson, 2011). Configuration in architecture describes a set of spaces that are connected to one another as a network and points out a relational pattern among these spatial elements. Hillier (1996) explains that configuration exists when relations between two spaces are changed according to how we relate one or other or both to at least one other space. Configurational descriptions therefore deal with the way in which a system of spaces is related together to form a pattern rather than with the more localized properties of any particular spaces (Hanson, 1998). We can describe this pattern as a kind of network, which reveals complex relationships/interconnections, orders and rules among the spatial elements. The logics behind configuration
of a spatial network are significant for architects as it implies social implications. Topological description of space can account for aspects of architectural experience by constraining or generating the possibility of human social interaction (Dade-Robertson, 2011). Relationships between spaces once regarded as mutable, also constitute the potentials of encounters for the users through connections and borders. Thereto, they constitute the basis for the social interactions between users, defining both functional and latent routes, and indicating spatial proximities and neighbours (Kozikoglu and Dursun, 2015). A space does not encode information individually. However, the way in which a space comes together with other spaces to form a structure or pattern reveals information and constitutes the core of spatial experience. This structure or spatial configuration influences social, economic, environmental functioning of cities and complex buildings by mainly conducting human movement pattern (Hillier et al., 1993; Nourian, 2016). In other words, the meaning is structured in architecture through the topological / configurational relationships between spaces that are experienced when we move through space.

Researches on network systems mainly make use graph theory based tools. Graphs serve as mathematical models of network structures (Easley and Kleinberg, 2010) and present a language for talking about structural features and potentials of network systems. According to Barabasi “graphs or networks have properties hidden in their construction that limit or enhance our ability to do things with them. The construction and structure of graph or networks is the key to understanding the complex world around us. Small changes in the topology affecting only few nodes or links can open up hidden doors allowing new possibilities to emerge” (Barabasi, 2002).

“Network in architecture focuses on systematically mapping relations among spatial elements through their shared and relative characteristics, in other words, neighbouring and attracting qualities in rule-based dynamic network models. The “relations of the relations” and “the protocol between the rules,” that refer to the order and the scale that the rules will be enacted during the design process, are of prime importance in these models. By observing the effects, the creative process can be interpreted as a kind of choreography, one in which “pace” is also interrogated for the elements of the parametric model.” (Kozikoglu and Dursun, 2015).

The use of graph theory based tools in architectural design is mostly executed as description of spatial form (Alexander, 1964; March and Steadman, 1971) and the application of these tools in generative design in a creative way remains limited. Attempts for searching possible spatial forms in an automated, systematic procedures (Mitchell et al., 1976; Steadman, 1983) are followed by the evaluative works (Hillier and Hanson, 1984, Hillier, 1996) that intent to discover “social performance” (Nourian et al., 2013b) of designed spaces. In recent years, there have been attempts to bring these ideas together to transform configurative ideas into desired geometric compositions (Nourian, 2016). The main idea of Nourian and his colleagues (2013) is about “going from abstract graph description of spatial connections to topological planar embedding of that graph, analysing that graph in real time and finding feasible geometric cell configuration that admits the proposed graph connection”. Significance of this kind of work is coming from its emphasizes on spatial exploration process in which designers have full intellectual control and get objective real time feedback on the spatial qualities of their design. These approaches provide communicative tools between designer and his/her design by presenting evidences for searching geometric rules and formal possibilities.

Application of graph based tools in a creative manner in design process is valuable for architects who develop their ideas by “making” and learn by “doing” (Schön, 1987). This study mainly concentrates on graph theory based tools in generative design and explores their contributions to design process in formal compositions both topologic as well as geometric. Main interest is on the dynamic “space making process” in which space is evolved by evidences on interactive interpretations of what architects design.

If we accept architecture “as a system composed of interlocking elements, operating as a kind of biological mechanism and evolving on many fronts” (Lima, 2011), can this graph theory based tools be used as creative thinking machines for architects to play with in architectural design process? The authors concentrate on the architectural design practice to put this main
research argument into more comprehensive debate. The last part of the study explores how these scientific, graph theory based concepts and tools could feed design thinking through an experiment from architectural practice.

3. AN EXPERIMENT FROM PRACTICE: ELDERLY CARE HOTEL AND REHAB DESIGN SCHEME

3.1 ARCHITECTURAL PROGRAM DESCRIPTION

MASYT is a project of a centre for health tourism in Antalya, Turkey (Figure 1). The client is the owner of three facilities totalling 450 beds for mentally disabled, elderly care and rehabilitation patients that are distributed in the same region and she was determined to transfer her expertise into a touristic stay basis. The brief of the project prompted the following three topics in one facility: health and tourism centre for the disabled for an optimum stay of one week, therapeutic stay of minimum 3 weeks as well as long term rehab program for orthopaedic and cancer patients an average stay of 2 months complemented with assisted living apartments as final homing mostly for patients tied to bed up to 1-2 years.

Although the program required the similar, if not the same professional care and management expertise, the spatial needs, and neighbouring requirements are very differentiated between, the more touristic weekly stays of the incoming guests and the therapeutic stay of the cancer or orthopaedic patients, to the longer stay of elderly care residents. There are several locations in the project that will enjoy common use, however the tranquillity and emergency requirements are different from the rehab unit which is basically a health facility with an emergency hall that is quite the opposite in atmosphere than the entrance hall of the intended 4 star hotel. Such considerations urged for a deliberate probing into the programmatic requirements and spatial relationships together with the client.

3.2 MIX USE DILEMMAS / COMPLEX RELATIONSHIPS

The project as an economic model as well as an architectural program challenged multi-program, multi-temporality, multi-user and mix use. There are several studies that discuss age and program integration for elderly care and disabilities and search the relation between physical features of the building design and quality of life of the residences (Hanson and Zako, 2005). Additionally, studies on behavioural patterns of elderly care residents have shown a preference for places for higher traffic like corridors gate entries passages. Akan and Unlu (2015) states that elderly users preferred areas such as corridors and block entry areas looking towards the outer space which involved activity rather than places which were originally planned to be the social interaction areas. The diversity programmatic requirements as well as compactness in services purported as possible by the client who had 15 years of experience in disabled and elderly care urged an analytical approach to the design of the layout. To better understand how the system will operate, the potential relationships in the list of rooms are mapped in network
diagrams during the initial stages of the design process. This helped to better understand and simplify the requirements.

The method experimented in the iterative “make & assess” sessions for the layout configurations, in short is listed as steps below:

- **step 1**: list relationships between rooms out of the room requirements list,
- **step 2**: map layouts in graph tools and read thresholds and conglomerations,
- **step 3**: analyse syntactic figures,
- **step 4**: model and extract architectural plans and repeat 1,2,3 as necessary.

In step 1 designated relationships are listed as simple as room A connected to room B, the direct access is considered as a relationship (Figure 2). There are more relational data like those places that are visually connected or those rooms that need to be kept a certain distance apart, etc. Such parameters serve the systems intelligence. However, for practicality only “access from one distinct place to another” is the listed parameter. User scenarios as well as regulatory needs are useful information in the preparation of this initial list.

![Figure 2 - Relational list of room requirements](image)

Step 2 is plotting this relational data (Figure 3). There are various applications for mapping network data, Cytoscape3.4 is used in this process. Cytoscape is an open source software platform for visualizing molecular interaction networks and biological pathways and integrating these networks with annotations, gene expression profiles and other state data (url 2). Although Cytoscape was originally designed for biological research, now it is a general platform for complex network analysis and visualization. This core distribution provides a basic set of features for data integration, analysis, and visualization.

Layout algorithms provided by the software are used for mapping the relational network data. For example, the Prefuse algorithm, or force directed spring embedded layouts enable to visualize the network clusters. Such layouts as opposed to the circular or grid layouts for networks allow reading of compartments, or fragments that may turn into separate floors, separate wings or even distinct buildings. This is especially important in mix use buildings where corridors risk becoming labyrinths and fluent circulation become too dependent on signage and building identity on make-up interventions. In this second step, descriptive criteria for networks such as “average shortest path length” or “edge betweenness” allow deeper reading into the network of rooms.
Step 3 is reading of the space syntax values of the layout for better understanding the extremities and distribution for isolation, entropy etc. (Figure 4). In this case Syntactic, a tool that brings Space Syntax theory into parametric design workflows, is used as a calculation platform. This tool was developed as a plugin that is installed on for Grasshopper (Nourian et al., 2013b; url 2).
Step 4 is modelling, plan extraction and repetition of the previous steps. The excel file needs to be revised according to the plan revisions as it feeds into both the network mapping and space syntactic programs. Zooming in and out of the relational network, adding/deleting places, rooms or relationships, thus the design exercise is played out parallel to the 3d modelling, as rooms or new relationships are introduced or deleted and/or floors added/subtracted places like elevator hall, staircase halls etc. reshape the network model.

3.3 THE METHODS IMPACT ON THE DESIGN OF THE SAMPLE PROJECT

In the specific project the method was experimented, the initial spatial requirements as presented by the client were unprecedented, ambiguous, overlapping and complicated. The method enabled to specify security and social thresholds for compartmentalization, vital for the project’s success. In a way, by iteratively mapping, plotting and modelling it is possible to visualize the whole organism and to distinguish the organs; the clusters that were separable from one another by courtyards, or where folding vertically for floor repetitions is possible or where separate building arrangements are needed.

One pitfall may be that the initial network diagram is produced out of the relationships that are listed according to a mental pre-existing model, either defined by the client or else designed by the architect. However, as the process is iterated, new relationships are introduced and some of them disintegrated, or buffer spaces intervened, so the process serves as learning, negotiating, discovering and, thus, designing tool. Although the effort in listing relationships is a meticulously one the expressive quality is evidently the strong point of the method. The designer can read the potential conformations and work on them or those that are not preferable and rework the model. The model serves as a design dialogue between the requirements and the possibilities.
In this example of the health tourism project different program clusters meant not only circulatory arrangements, but also differences in needs for changes in the moods, physical qualities, atmospheres and performances, such as the hotel residents are more mobile during the day, however the rehab rooms are active the whole time and in a frequent traffic, and in parallel and contrast the daily care housing units are occupied whole day but are more tranquil.

Figure 5 is an example of the force directed layout in one of the iterations, in Cytoscape. Here the node size denotes Average Shortest Path Length (low values to large sizes) and their colour denote Betweenness Centrality (low values to bright colours). Major clustering is evident as the three branches of the hotel floors with the bedrooms on the lower left and the assisted living residences at the top, with the skinny rehab emergency branches on the lower right. The three bright (red) units are main gate, arcade to the assisted living and the Loading Bay to the technical area especially the kitchen.

The modelling enables to visualize the major role players in the network of relations, as well as those groupings that may be translated to specific comfort qualities (internal protocols for heating, cooling etc.) as well as separate building / or building part formations. It must be noted that these graphs change in the iterations, even sometime dramatically, because each connection counts (Figure 6).
In graph theory, betweenness centrality is a measure of centrality in a graph based on shortest paths (url 3). Betweenness centrality measures the extent to which a vertex lies on the paths between other vertices. Vertices with high betweenness may have considerable influence within a network by virtue of their control over the information passing between others. They are also the ones whose removal from the network will most disrupt communications between other vertices because they lie on the largest number of paths taken by messages.

In the design process those nodes (spaces) with higher betweenness centrality are mediated in a spinal configuration, with changes to the external spaces that connect the three main compartments in the facility including the underground service distribution. It became very much evident how the services circulation in these facilities as well as the circulation of the users defines the spatial configuration to the extent that the facility is compact or disintegrated (Figure 7).

The experimented method revealed that a network literacy is worthwhile for the designer in understanding, improvising and explicating on architectural program and functions into spatial configurations. This is possible with the space syntax criteria and computation.

The Syntactic plugin for Grasshopper enables to design with space Syntax criteria. The program reveals depth maps for any node, and provides the Integration, Control, Choice and Entropy values for each node totalling 289 differentiated spaces.

Figure 8 reveals selected six automated justified graphs that visualize distances on depth levels starting from different points in the configuration. The justified graph from main gate shows shallowest graph among the six with the max depth of 9. This graph reveals that the furthestmost units are the rehab rooms, which are deepest as they are confined and concentrated therapy stay areas, the users are mostly orthopaedic guest and do not move further than the first circle areas. Whereas the hotel guests arrive and depart fast and frequently and the assisted living units need to be able arrive at the gate without disturbance in case of an emergency. The justified graph from arcade that connects the assisted living apartments to the system as an integral part also presents a shallow graph with the max depth of 10. On the other hand, the justified graph from the laundry hall on the hand reveals a deeper structure with the max depth of 15.
Through feeding real-time data as tables of relations into the syntax modelling and analysis enables iterative shaping of the relations. Instead of a finished situations analysis, the model is dynamically reorganized.

The analytical data derived from the process are interpreted for this feedback. The plugin returns 4 major qualifiers for space syntax: integration, control, choice and entropy (Figure 4). Integration (closeness) is a normalised measure of distance from any a space of origin to all others in a system and it expresses how close this origin space is to all other spaces (url 4). Integrated spaces tend to draw the entire configuration towards the root (shallow justified graphs), segregated spaces tend to push most of the rest of the spatial complex deep (deep justified graphs).

Syntactic analyses show that in this design the most integrated spaces are personnel parking (1.278), main gate (1.231), arcade garden passage (1.198), entrance personnel hotel (1.196), reception hotel (1.159), personnel rooms hotel (1.154), entrance personnel rehabilitation (1.111), elevator hall hotel (1.089), entrance personnel kitchen (1.089), entrance wellness spa (1.062), lobby main (1.052), health personnel room - elevator hall rehabilitation (1.044), garden (1.034). On the other hand, the most segregated spaces are emergency observation wc (0.548), consultation room rehabilitation - physio therapist room - group therapy room - psychologist room - medical equipment - sleep lab (0.550), bedrooms (0.576), fire exit (0.601), emergency station - emergency treatment - emergency medical storage - emergency wc and (0.606), emergency observation (0.607).

Control measures what degree of choice each space represent for its immediate neighbourhoods as a space to move to (url 5). It should be reminded that control is a local measure, since it only considers relations between a space and its immediate neighbourhood, whereas integration is a global measure since it considers the relations of a space to every other space in the system (Hillier and Hanson, 1984). Syntactic analyses show that hotel corridors (20.25), rehabilitation corridor (11.5), entrance health centre (6.142), entryways residences (6.083), storage linen hotel (5.833), waiting room rehabilitation (5.7), garden (5.416), technical courtyard (5.25) are strong control spaces. On the other hand, hotel bedrooms (0.047), dining terrace - terrace - shared terrace - dining service area - rehabilitation bed rooms (0.833) and assisted care compartments (0.111) appear as weak control spaces.

Choice (betweenness) measures how likely on axial line or street segment it is to be passed through on all shortest routes from all spaces to all other spaces in the entire system (url 6). Syntactic analyses show that arcade garden passage (57325), personnel parking (48679), main...
gate (45553), reception hotel (39165), elevator hall hotel (37803), entrance personnel hotel (27025) have higher values. This means that these spaces have the highest total values of accumulated flow.

Entropy is a measure of the distribution of locations of spaces in terms of their depth from a space rather than the depth itself (url 7). Syntactic analyses show that entrance personnel hotel (2,481), personnel parking (2,533), elevator hall rehabilitation (2,547), entrance personnel rehabilitation (2,555), health personnel room (2,575), goods lift (2,629), entrance personnel kitchen (2,667) have lowest values. This means that many locations are close to these spaces.

Such findings are the looping feed-in and feedback in the design process. Constant and iterative assessment of the potentials of a node in the network and the networks own qualities ascertain a design dialogue between a designer team or a singular designer’ own design methodology. It is possible to assess all nodes in perspective and especially a set of selected nodes and some random selection during the process.

3.4 THE SERIAL EVOLUTION OF THE SAMPLE PROJECT

To display a serial disposition of the project differentiable stages are described below: In an initial sketch from building regulations a volumetric composition that corresponds to the total area requirements is shown in the initial figure (Figure 9). Later in the process the hierarchical mind mapping via the Brain software enabled the visualisation of the branching qualities, then the Cytoscape models are introduced due to layout and the network and visualisation potential of the software, and in parallel Syntactic modelling in Grasshopper enable assessment with space syntax criteria. The project evolved to a more fragmented configuration in the second iteration, and later, the client focused on integrating the services, and the assisted living units re-coupled with the hotel as a new wing, whereas the physical therapy hospital and spa got fragmented only to re-join again in the final stage.

Sample findings from the case study are:

1. The network visualization patterns enable to apprehend the nuances between clusters of rooms. Such as rooms around a corridor is different in the rehab situation than the hotel and much to different in the workshop rooms and assisted living. This is a sound contrast to partitioning spaces in the modern conventions.

2. Network modelling and assessment criteria, and tools like space syntax are valuable to assess multiple data structures like architectural spatial relationships (Dursun, 2007). In further analysis one can denote characteristics of these spaces in the network analysis. The mapping is a tedious one and patience and rereading is necessary during the process. In the exemplified dynamic systems game played in class, the designer is well aware of the dynamic quality, and these tools even accentuate that quality further.

3. The experiment expresses the importance of exterior spatial elements that separate as well as bind the neighbouring organs, which are usually not listed in the built space allocation lists. These units like the canopy, the courtyards, even the alleys and passages play an integral role in the physical, social and service related qualities. In the case of more active and less noise zones, the addition of a compact, controlled outer space that buffers the enables the continuity of services, and separation of the physical qualities. Evidently, this finding supports the research data of Akan and Unlu (2015) regarding on key role of garden space for an elderly care institution.

4. Spatial analyses show that mix use program changes the way of experiencing space for some particular prescriptive design programs such as hotels and hospitals. In this case, some service spaces and their attached units in the spatial configuration such as personnel parking, entrance personnel hotel become important actors that produce and distribute movement in space.
4. CONCLUSION

In architecture, design activity begins by understanding important features of the program and project site and continues to generate an abstract idea. Architect then transform this idea to concrete spatial formations, a kind of spatial configuration that is inhabited and experienced. By generating different proposals and testing them, the architect consolidates his/her ideas or re-defines them to gain satisfied spatial formations (Dursun, 2007). This study suggests that graph theory based tools can be used in two interrelating modes during this process.

1. To explore the intrinsic nature of built environments and to search explanations about "how the things are". This mode can be regarded as more analytic and scientific but it is very useful to comprehend the spatial dynamics.

2. To evaluate performance of the built environment and to search "alternatives in inventing / making things". In other words, in this mode, main effort would be given to investigate how the designed spatial system might be. This mode can be regarded as more creative and intuitive, but it is very useful to access designed space and explore its possible forms.

The authors suggested that relevant graph theory concepts and produced data sets representing the spatial systems lead to powerful instigation, management, and assessment of configured spaces. As Hillier and Hanson (1997) indicate, these tools have potentials to be the tools with which we can think during the design process. These tools supplement creativity and constitute a generative component within the research/evidence-based design. They also advance design thinking, enable interactive exploration of the effects of programmatic relations on form and suggest a method to structure correspondence of form and function (Kozikoglu and Dursun, 2015).

Based on the research findings, the authors believe that mixed use programs are a major trend in today’s architectural programs, and projects intentionally differ invariably to hybridize fragments of urban programmatic units. Syntactic measures and design methodology inform such projects with thresholds and basins of concentration so that the designer can
feed in and get feed-back from the project about issues of comfort, security, and scenarios. The network analysis is intelligible as a pathway for the design of the future adaptations of the projects. Architectural program shifts as technologies, policies and needs change, and building adaptability requirements sometimes lead to build-space without identity. However, an iterative design process that is syntactic, enable road map for adaptation possibilities. Filtering the network of rooms into sub networks for potential user footpaths would be useful. Not all users step into all rooms therefore a control space for the generic layout might not be as efficient in the scenario of a user. Open source software tools like Cytograph and Syntactic enable the educators as well as professionals to engage readily with the relatively sophisticated concepts of Space Syntax.
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THE IMPACT OF SPATIAL DESIGN ON THE LEARNING PROCESS AND STUDENTS’ SOCIALISATION: 
A Study of Secondary Schools Within the UK

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ABSTRACT

The last century has witnessed an evolution in our understanding of learning from being a spoon-feeding process towards a process based on the ability of the human mind to receive information, construct knowledge and gain understand according to the learner’s perceptions (Brown, 2004). However, the spatial relation between the learning process and the physical environment is less well understood. This research attempts to focus on learning in schools, while aiming to understand the spatial impact of the building design on the students’ learning process. The academic life of students inside the school premises is deeply entangled with social patterns. Consequently, the research considers the spatial dimension of both learning and socialisation of the students. Nine secondary schools in the UK are presented as a comparative case study based on quantitative analysis of the school buildings. Space syntax analysis is the key criterion of evaluation, supported by studying the organisation of various spatial components (circulation, courtyards, social and learning spaces). The research highlights the important role of the spatial design and configuration. The paper explains the spatial potential within the school building design that is argued to stimulate the students’ socialisation patterns. Moreover, it unveils the potential within the spaces that contributes to students’ learning, while focusing on how the design of the learning spaces and their layouts could accommodate the learning process inside the school. The results of studying the nine school buildings show that there is a moderately strong correlation between the syntactic measure utilised in the analysis (Visual Mean Depth) and the performance of the students within each school. The study proposes that the configurational analysis should become part of the original school design process to help understand the possibilities of the students’ social activities and mixing patterns. Additionally, it is concluded that learning spaces should be designed to afford various learning formats, not to be limited to the typical classroom layout.

KEYWORDS

School Buildings - Spatial Configuration - Students - Learning - Socialisation

1. INTRODUCTION

According to Bill Hillier, the generic function of every building is to initiate, facilitate and accommodate movement patterns by the users (Hillier, 1996). Movement then leads to patterns of co-existence which evolve into users’ social interactions (mixing, socialising, etc.). While spatial design and configuration play an important role in triggering the users’ movement, they also affect their interaction patterns and social behaviours. This proposition has led to a rich
and varied research programme using Space Syntax theories and its analytical tool Depthmap, which generates different syntactic measures (Choice, Integration, Visual Mean Depth, etc.). Following the generic function of movement, which Hillier has conceptualised as the first filter separating real buildings from the unlimited possibilities of form, Hillier suggested a secondary filter which is the programmatic requirement of the building (Hillier, 1996). In simple words, it is the function or service the building is meant to provide for the users which is (for most of the users) the primary purpose of the building; learning in a school or exhibiting in a gallery. The question here is: what is the impact of the spatial design and configuration on this function and to what extent does the design impact the fulfilment of (what most people perceive as) the main function of the building?

In order to investigate this, research cannot be generic for all types, but rather focuses on one type of buildings. This research studies the design of secondary schools, and the relation between space and the learning process as well as the students’ social life. The main hypothesis of this research is that the spatial design and configuration of a school building impacts the students’ academic performance. To test this hypothesis, nine different secondary schools all situated inside the UK were used as case studies. In addition, the performed analysis aims to evaluate the school buildings and help understand the potential of space to ‘afford’ the learning process and facilitate the students’ socialisation patterns. The term affordance is actually introduced by Gibson (1979) as the possible actions that might occur in relation to an object or environment, so in return, this object (or environment) affords this action. For example, a chair affords sitting. Within the school building context, affordance of the learning process is the level by which space is flexible to accommodate the format of learning taking place and not to obstruct but actually to facilitate the students’ ingestion of knowledge. Space is also meant to afford, facilitate and trigger the students’ social interaction inside the school building.

To understand the relation between the three main factors (space, socialising and learning), this paper is structured as follows: the literature review will discuss how learning is conceptualised based on research in the field. The methodology section will illustrate the analysis of the nine school buildings and explain the metrics used. After that, the paper will utilise the syntactic analysis to evaluate the spatial performance of the buildings and focus on understanding the affordance of the school building for social encounters and learning. Results are discussed and a final concluding section will highlight limitations as well as future research plans.

2. LITERATURE REVIEW: PERCEPTION OF THE LEARNING PROCESS

Society’s views and understanding of the learning process has evolved over time. Markus (1993) proposed that schools and systems of education have always mirrored modes of economic production. Sailer (2015) summarised Brown’s description of learning in the nineteenth century as a spoon-feeding process mainly concerned with injecting the learners with knowledge and information. In the twentieth century, this process was re-conceptualised by Vygotsky (1930) who argued that the learners’ ingestion or comprehension of knowledge provided by the teacher is mainly dependent on their mental development. Furthermore, Vygotsky argued that the environment, physical and social, will impact the learning process. He gave the example of early learners’ education and maintained that it is wrong to assume that a children’s source of knowledge will be provided only inside kindergartens (Vygotsky, 1978). To complement this idea, Jonassen adopted constructivist conceptions of learning which declared that education cannot be transmitted. Instead, “knowledge is individually constructed and socially co-constructed by learners based on their interpretations of experiences in the world” (Jonassen, 1999, P.217). With the rise of the learner as the key player in the process of learning, the sociologist Bernstein (1973) explained that education will evolve from a strongly framed system into one with weaker boundaries. To explain this concept, Bernstein identified the curriculum content of learning as weakly or strongly classified, i.e. the degree of boundaries between the material being taught, and how they inter-relate. As for the method of learning, Bernstein described it either as weakly framed with much freedom for the learner, or in contrast, strongly framed with a high degree of control by the teacher over what is taught. Within these two concepts, school education could be sub-categorised according to whether it is course or subject based (Bernstein, 1973).
Moreover, Day and Midbjer discussed Piaget’s ideas on learning as an interweaving network of relations. They clarified that “perception, action, interaction with others and reflection develop, modify and consolidate it” (Day and Midbjer, 2007, P.4). Brown also added the idea of learning as a “modification of behaviour brought about by experience” (Brown, 2004, P.6). Sailer (2015) further explained consequences for the role of the teacher who becomes an enabler whose role is to set the environment where the learners acquire knowledge themselves. She described this development in the learning process as a “shift towards a learner-centred view rather than a teacher-centred view” (Sailer, 2015, P.2).

In summary, social aspects are no longer a secondary factor in the background of the learning process, but actually a dominant factor that shapes the outcome of learning and should be carefully considered in the spatial design. It could be argued that learning becomes a social and behavioural process dependent on the physical environment as the context of learning; thus it occurs not only inside classrooms, but wherever there is a social interaction or behavioural experience. Thus, space, its configuration and organisation would possibly play an important role in the learning process.

Previous research has explored the role of the school building on attainment and learning outcomes (Tanner, 2009; Barrett et al, 2013), yet configuration did not feature explicitly in these studies. From a space syntax perspective, existing research has studied encounter patterns (Pasalar, 2003; Kishimoto and Taguchi, 2014) yet did not bring this together with attainment. Therefore, this research aims to fill a gap by investigating school buildings syntactically and analysing consequences for learning outcomes, but also linking a detailed configurational exploration with learning processes and socialisation more broadly.

3. METHODOLOGY AND DATASETS RESULTS

In order to investigate how spatial design impacts the students’ learning and socialisation, the research compares nine school buildings, all designed and constructed recently by the same architecture firm; Feilden Clegg Bradley Studios. Plan material was kindly provided by the architects. The rationale for choosing buildings by one particular architect was to minimise the chances of having major variations in the design which might lead to variations in the programmatic functionality of the building. The nine buildings indeed have similar types of spaces. Still, the spatial organisation and configuration of the school buildings are very different. Figure 1 shows the footprint of the buildings as well as a summary of each of the nine school buildings including key statistics such as number of floors, year of completion, total area and total number of students.

<table>
<thead>
<tr>
<th>School</th>
<th>Year of completion</th>
<th>Number of Floors</th>
<th>Total Area</th>
<th>Location</th>
<th>Total Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2005</td>
<td>3</td>
<td>83085</td>
<td>Easton area, Bristol</td>
<td>833</td>
</tr>
<tr>
<td>B</td>
<td>2012</td>
<td>3</td>
<td>15114</td>
<td>Harold Hill, Greater London</td>
<td>796</td>
</tr>
<tr>
<td>C</td>
<td>2013</td>
<td>3</td>
<td>8085</td>
<td>Hastings, East Sussex</td>
<td>812</td>
</tr>
<tr>
<td>D</td>
<td>2013</td>
<td>4</td>
<td>17294</td>
<td>Manton, Blackpool, Lancashire</td>
<td>1097</td>
</tr>
<tr>
<td>E</td>
<td>2012</td>
<td>3</td>
<td>15339</td>
<td>Ilford, London</td>
<td>630</td>
</tr>
<tr>
<td>F</td>
<td>2007</td>
<td>3</td>
<td>10013</td>
<td>City of Westminster, Greater London</td>
<td>1192</td>
</tr>
<tr>
<td>G</td>
<td>2008</td>
<td>4</td>
<td>5712</td>
<td>Mansfield, Nottinghamshire</td>
<td>936</td>
</tr>
<tr>
<td>H</td>
<td>2013</td>
<td>4</td>
<td>11077</td>
<td>Liverpool Road, London</td>
<td>375</td>
</tr>
<tr>
<td>I</td>
<td>2013</td>
<td>4</td>
<td>15310</td>
<td>Greenford, Ealing</td>
<td>375</td>
</tr>
</tbody>
</table>

Figure 1 - The Nine Secondary Schools
Each building was analysed in its configuration using DepthmapX (Varoudis, 2012). The first section of this paper will analyse Visual Mean Depth (abbreviated as VMD in the following), which is a syntactic measure that calculates the shortest visual path of a space to all other spaces within the same building. It indicates how integrated/segregated a space is, or how shallow/deep from the rest of the spaces. The lower the value is, the fewer visual turns, and thus the more visual integration. It is convenient to utilise as it measures the mean global number of visual turns to reach one specific point from every other point, and thus its values are comparable between different schools. The syntactic measures are exported into a Geographical Information System software (QGIS) to extract descriptive statistics for specific areas (Average, Minimum, Maximum, Standard deviation, Frequencies of certain values, upper and lower percentiles). An additional complementary measure used is Visual Step Depth (VSD), which shows how deep or shallow certain areas of the plan are from the entrance.

The second section of this paper will use the syntactic results plus data of the students’ attainment to provide an evaluation of the school buildings and the learning process. However, since learning is argued (in the literature review) to be a social and behavioural process, students’ attainment is only one facet of student’s performance and the proficiency of the learning process inside the schools. That is why the third and fourth sections will attempt to highlight the spatial potential of a school by asking how it may facilitate or prohibit students’ socialisation patterns (by analysing socialising spaces, i.e. all the gathering spaces, meeting areas and common rooms inside the building) and how it could afford the learning process (by focussing on classrooms, lecture halls, seminar spaces and workspaces).

### 4. THE SPATIAL CONFIGURATION OF THE NINE SCHOOLS: A SYNTACTIC ANALYSIS

This chapter will discuss the distribution of VMD across the schools (figure 2) alongside descriptive statistics (table 1) including mean VMD, standard deviation and minimum/maximum values. Standard deviation highlights variation of VMD within the same building and is important to consider in addition to mean values, especially for high deviation. Furthermore, the maximum value acts as a critical threshold to indicate the visual segregation of some areas within the plan which might not be obvious when checking the average value.

The syntactic results reveal that school D has the lowest average VMD, lowest standard deviation and lowest minimum value. School F is the exact opposite (ranked 9th) with highest VMD figures, however school H shows the highest standard deviation. School C has average values compared to every other school. Figure 3 shows a complementary measure which is Visual Step Depth (VSD). This analysis marks the spaces which are more than three visual turns from the school entrance which are relatively deeper (segregated) than the rest of the school spaces considering the school entrance as a starting point of the journey.

<table>
<thead>
<tr>
<th>School</th>
<th>Average VMD</th>
<th>Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4.05</td>
<td>0.71</td>
<td>2.45</td>
<td>6.50</td>
</tr>
<tr>
<td>B</td>
<td>3.59</td>
<td>0.87</td>
<td>2.36</td>
<td>6.68</td>
</tr>
<tr>
<td>C</td>
<td>4.04</td>
<td>0.50</td>
<td>2.66</td>
<td>7.10</td>
</tr>
<tr>
<td>D</td>
<td>3.11</td>
<td>0.56</td>
<td>2.19</td>
<td>6.69</td>
</tr>
<tr>
<td>E</td>
<td>4.45</td>
<td>0.84</td>
<td>2.86</td>
<td>9.20</td>
</tr>
<tr>
<td>F</td>
<td>4.79</td>
<td>0.75</td>
<td>3.09</td>
<td>7.81</td>
</tr>
<tr>
<td>G</td>
<td>3.64</td>
<td>0.76</td>
<td>2.27</td>
<td>6.41</td>
</tr>
<tr>
<td>H</td>
<td>3.99</td>
<td>0.90</td>
<td>2.47</td>
<td>8.69</td>
</tr>
<tr>
<td>I</td>
<td>4.47</td>
<td>0.77</td>
<td>3.05</td>
<td>7.50</td>
</tr>
</tbody>
</table>

Table 1 - Descriptive statistics for VMD of the Nine Schools
Figure 2 - Visual Mean Depth (VMD) of the Nine School Buildings (Entrance Marked with an Arrow)
Figure 3 - Visual Step Depth from the Entrance. Dark Grey: More Than Three Turns. Light Grey: Less Than Three Turns
The following discussion includes comparative quantitative data of the spatial components of the school buildings. The most important spaces are the entrance location, circulation, courtyards and atria beside the main socialising spaces and classrooms. The attempt to focus on circulation spaces and courtyards is derived from the idea that learning is perceived as a social process not only occurring inside the classrooms but everywhere in the school building (Sailer, 2015). Studying these elements explains the differences between one design and another in terms of spatial organisation, which indicates possible strengths or weaknesses in the design of each school. The organisation of these components is linked to the overall spatial configuration of each building (one component would affect the whole building and the building would affect each component).

School A:
The primary horizontal circulation axis is the most visible route in the school, followed by the vertical secondary branches. The importance of the courtyard is portrayed in maximising the visual connection across the floors, still most of the classrooms (98%) lie in areas with a VMD of more than four.

School B:
The existence of the highly integrated, open courtyard enhanced visibility within the ground floor but not across different floors. Almost all classrooms (99%) are very isolated on the upper floors (VMD>4) especially the main cluster of classes on the first floor which are five turns from the entrance. The main vertical axis of circulation on the upper floor is very shallow. However, due to the upper floors arrangement on one side of the building, the right hand side learning spaces became more segregated. This effect was further amplified because the secondary horizontal axis was obstructed by an enclosed staircase which broke the continuity of the circulation.

School C:
Although the school has no major atrium that might enhance visibility across floors, VMD is in the middle ranking among the nine schools with no drastic variation across floors (second lowest standard deviation). This is achieved through a powerful circulation grid spreading across the plans and minimal labyrinthine areas. Unlike the previous two schools, there is only one axis of circulation as the most visible backbone of the school. Although the building appears to be symmetrical in its form, VSD shows that the shift of the entrance towards the left (with walls restricting visibility to the right hand side) resulted into overall shallower spaces on the left hand side from the entrance.

School D:
The building is ranked first in terms of visibility (lowest average VMD) with an even distribution, due to the powerful courtyard creating an extremely porous open ground floor plan. Unlike other schools (especially B and E, where the openness is gradually constrained across the upper floors), school D has four upper atria with a rectangular circulation grid. All classrooms and the socialising spaces (except the sports hall) lie in the areas with VSD less than three.

School E:
The building is considered middle ground between a closed environment (school F) and the other extreme of complete openness (school D). School E provides a design that features three middle courts showing as three atria on the first floor, but are then reduced to a single atrium on the other floors. In other words, the overall visibility is reduced gradually and the privacy starts to increase in terms of enclosures.

School F:
The design of school F is based on closed plans with no atria or visibility across floors (similar to C). In addition, the following reasons lead to the overall high VMD of the plans. Firstly, the circulation is highly controlled in terms of access points and limited connections between various zones. Secondly, the stripped floor plan is formed of elongated clusters resulting in a
labyrinthine layout. Thirdly, the plans have short broken circulation corridors. This is portrayed in the VSD results where the art studios on the third floor are six, seven and eight steps away from the entrance.

School G:
This is the only one-storey school in the study. Its plan is divided into four main zones linked by a central circulation grid. VMD reveals the similarity in the values for three of the zones (average = 3.6, 3.7 and 3.8) except the fourth lower right zone which is deeper than the others (average = 4.5). The floor plan organisation dictates that one circulation artery is visually deeper in the whole system. The result is that the whole area linked through this corridor is visually separated from the rest of the school building.

School H:
VMD shows an even distribution of values within the central zone around the courtyard and atria in all of the floors (standard deviation = 0.56 for this specific area), the variation in the values of the VMD start to increase as spaces get further from the centre and deeper into the two wings (especially the right wing). Thus the standard deviation rises to 0.90 for the whole floor area including the two wings as well as the whole building which is the highest value among all the schools. In contrast to school G, where the location of the central entrance facilitated the visual connection to the rest of the plan, VSD shows that the main entrance of school H is situated in the furthest right end of the school causing an unbalance in the depth of many classrooms and socialising spaces from the entrance.

School I:
Although the school design has a courtyard, its VMD average is quite high (second highest in the sample). The building does not benefit from the visual connections a courtyard can provide. On the upper floors, the classrooms have small windows overlooking the courtyard. The ground floor seems to be divided into two zones: the triangular space with the courtyard and the lower rectangle. The two zones are connected using a horizontal axis of circulation, but there are only limited points of access between the two zones (three gateways). One of the gateways is relatively deeper than the others which results in amplified visual depth for the whole zone accessed through this gateway. Surprisingly, the VSD illustrates that the classrooms on the first and second floor are actually fewer than three steps away from the entrance, which is relatively shallow. While the performance of the courtyard and atria do not pay off, the vertical circulation (five staircases, one of which is open) caters for connections between the floors of the building.

5. PERFORMANCE EVALUATION OF THE SCHOOL BUILDINGS
To evaluate the spatial performance of the nine schools, VMD is used. In addition to the above provided metrics and visualisations, coloured histograms for the frequency (count) of 12 ranges of VMD values are compared (figure 4). This visualisation gives an idea of the distribution of values across the range and the distribution of areas within each range of depth. The more the values are shifted to the left (red) the higher the performance of the building in terms of visibility (low VMD), i.e. more integration and higher chances of students to meet, mix and socialise. School D is ranked first in terms of having the biggest portions of values in the integrated spectrum. Again, school F ranks lowest, as it lacks highly integrated spaces.
THE IMPACT OF SPATIAL DESIGN ON THE LEARNING PROCESS AND STUDENTS' SOCIALISATION: A Study of Secondary Schools Within the UK

Figure 4 - Histograms of the Visual Mean Depth (VMD) Distribution.
A simplified way of assessment for the nine buildings and one way of testing the hypothesis that
the spatial configuration has an effect on learning is plotting overall average VMD against the
students’ attainment results of each school (Figure 5). The students’ attainment is obtained from
governmental census datasets as well as the governmental online Ofsted reports (Ofsted, 2015)
that provides evaluations of the schools in the UK. The value is the average of the attainment
grades in the last four years (2012-2015) and the evaluation grade from the Ofsted report. The
scoring system used means that lower values represent higher attainment. Schools I and E
show the highest students’ performance. Calculating the P-value and the R² for the resulting
chart shows a significant correlation (P-value=0.034) which is moderately strong (R²=-0.50).
This proves that students’ achievements relate to spatial configuration with higher performing
schools being more spatially segregated as a whole. However, it is important to mention that it
is not proven how the variation from one configuration to another (for example: from an open
porous plan to a visually restricting closed zoning) would directly impact the students in terms
of their academic achievement.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students’ Attainment</td>
<td>3.27</td>
<td>1.92</td>
<td>2.17</td>
<td>3.12</td>
<td>0.96</td>
<td>1.49</td>
<td>3.37</td>
<td>1.76</td>
<td>0.92</td>
</tr>
<tr>
<td>Average Visual Mean Depth (VMD)</td>
<td>4.05</td>
<td>3.59</td>
<td>4.04</td>
<td>3.11</td>
<td>4.45</td>
<td>4.79</td>
<td>3.64</td>
<td>3.99</td>
<td>4.47</td>
</tr>
</tbody>
</table>

Figure 5 - Correlation Between the Students’ Attainment and the Visual Mean Depth for the Nine Schools

A more specific way of testing the hypothesis of the effect of configuration on attainment
is achieved by correlating the VMD values for specific areas with the students’ attainment
results. The rationale here is to investigate whether integrated or segregated classrooms, or
integrated or segregated spaces for socialising have a particular effect on attainment. Figures
6a and b show the results of correlating the students’ attainment against VMD of social spaces
and classrooms respectively in each of the nine schools. Similar to the previous correlation,
the results show a moderately strong correlation between attainment data and VMD of social
spaces and classrooms (R²=-0.45 and -0.44 respectively).
THE IMPACT OF SPATIAL DESIGN ON THE LEARNING PROCESS AND STUDENTS’ SOCIALISATION: A Study of Secondary Schools Within the UK

6. THE LEARNING PROCESS: MORE THAN JUST ATTAINMENT

The previous section has highlighted a significant relation between the spatial configuration of the school buildings and the students’ performance portrayed through their attainment results. Whilst it appears crucial to make use of the available quantitative analysis and data to prove the relation between space and learning, it should not be the final outcome of the research; because the learning process cannot be reduced to just attainment results of the students.

What is interesting in this respect is the strength of the correlation with average VMD for the school as a whole, where a higher correlation coefficient was achieved. It seems that the overall configuration of the school is more important than the structuring of social spaces and classrooms. If learning only happened in classrooms, we would expect to see a greater effect of segregated classrooms on attainment scores. The contrary is the case. This again brings in the idea of learning as a social process where every part of the student’s life (including their interactions and behavioural experience) impacts the process of acquiring knowledge. The research continues with an attempt to understand more about the spatial potential that contributes to the affordance of the school building for social encounters and learning.

7. AFFORDANCE OF THE SCHOOL BUILDING FOR SOCIAL ENCOUNTERS

The building as a whole (through its configuration) can be argued to function as the main facilitator for movements and social encounters. To an even greater extent, the designed social spaces should be able to fulfil their role as incubators for students’ interactions. Figure 7 illustrates VMD of the schools’ social spaces only. VMD values are highly dispersed across the spectrum (from 2.9 to 5.3). The spatial configuration of some schools (D, B, C and G) renders the main social spaces as estuaries where the primary or secondary axis of circulation pours into. In order to reach some areas of the plan, the students and staff will have to cross the social common space. Consequently, social spaces function as by-products of natural movement. If socialisation is proportional to the users’ encounters, then this design layout (circulation intersecting the social spaces) would increase the potential of students’ socialisation, as the social spaces become part of the students’ through movement. It also increases the natural surveillance by staff on the students’ gathering spaces. However, School E and F are the complete opposite, where social spaces do not overlap the circulation, which means that the potential for mixing their encounters is only reliant on the ability of theses spaces to act as attractors for the students (destinations). Moreover, the histograms illustrated in figure 7 show a discontinuity in the VMD values (shown as wide gaps) within certain ranges for the social spaces (example: school H).
This might reflect the lack of organisational design hierarchy between the social spaces; their dispersion across separate locations of varying VMD within the same building just to fulfil the space programme requirements of the school. Also, the graphs (figure 7) show that the larger and more open the social spaces are, the higher the concentration of the count in fewer bars at the left end of the spectrum (school B and E).

It could be argued then that in cases where the design of the circulation axis follows the general form/outline of the building, the resulting mean depth values are evenly distributed with less drastic changes across the floor plan (examples: School A and C). When one zone in the floor plan is attached to the other spaces through a single linkage, the visual segregation of the linking circulation results in amplified segregation of the internal spaces (example School G). Furthermore, it is crucial to mention that a courtyard design makes a major difference to the overall openness and visibility across the school building, yet the degree of its contribution is purely dependent on how other spaces are configured in relation to the courtyard which is solely a design decision. Other important spatial components like circulation; its form, its degree of hierarchy (branching) and the distribution of the staircases all subsidise the spatial performance of the school building.

In summary, it could be hypothesized that configuration exerts an influence on the ability of students to mix and encounter others. In schools structured like examples B, C, D and G we would expect to find a higher rate of encounters, whereas schools such as E and F would be more inhibitive of encounter and mixing.

Figure 7 - VMD of social spaces only and including frequency distributions
8. AFFORDANCE OF THE SCHOOL BUILDING FOR LEARNING

Following the previous argument, learning inside the school building is assumed to take place across all spaces of a school. One question arising out of this is whether the available learning spaces in the shape of classrooms can or cannot afford the current learning processes, and what is the potential of space to accommodate other various learning formats. Analysis of the classrooms (figure 8) show their VMD values as highly condensed in the spectrum ranging from 4 or 5 turns (except school D with VMD=3.24) unlike the social spaces where VMD values for the nine schools were dispersed across the spectrum. Also, VMD of classrooms is higher than the average VMD of the whole school building (except for school I where the two values are almost equal). Based on the histograms it is proposed here that schools with a higher variation of VMD as expressed in a high spread of values across the histograms (no discontinuity in the graph) have more variety of learning spaces in terms of depth which increases the potential of the spaces to afford various learning formats (ranging from active busy integrated spaces to quiet segregated spaces for high concentration).

Schools A, F and G have a low number of separate bars in the histograms and their floor plans are characterised by equally deep monotonous learning spaces forming 32%, 39% and 29% of the total classroom area, i.e. low potential to afford various learning formats (table 2). If learning is prevailed through an open interactive environment and through different formats (not just the traditional closed classroom), then students’ understanding and comprehension is expected to be higher within buildings with the potential to accommodate/afford different learning formats and provide various levels of spatial privacy, porosity and visual connectivity.

In summary, it could be hypothesized that schools with more varied VMD values for classrooms would also afford more different learning formats.

<table>
<thead>
<tr>
<th>Number of filled histograms</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest concentration in one histogram</td>
<td>1400</td>
<td>500</td>
<td>800</td>
<td>700</td>
<td>2400</td>
<td>1300</td>
<td>500</td>
<td>580</td>
<td>1080</td>
</tr>
<tr>
<td>Total of all histograms</td>
<td>4439</td>
<td>4314</td>
<td>2836</td>
<td>4445</td>
<td>8538</td>
<td>3330</td>
<td>1746</td>
<td>3906</td>
<td>4890</td>
</tr>
<tr>
<td>% concentration out of the total area (Monotony in the VMD)</td>
<td>32%</td>
<td>12%</td>
<td>28%</td>
<td>10%</td>
<td>28%</td>
<td>39%</td>
<td>29%</td>
<td>15%</td>
<td>22%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ranking according to affordance of various learning formats (variation in the VMD)</th>
<th>1&lt;sup&gt;st&lt;/sup&gt;</th>
<th>2&lt;sup&gt;nd&lt;/sup&gt;</th>
<th>3&lt;sup&gt;rd&lt;/sup&gt;</th>
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<th>6&lt;sup&gt;th&lt;/sup&gt;</th>
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<th>9&lt;sup&gt;th&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>H</td>
<td>D</td>
<td>I</td>
<td>C</td>
<td>E</td>
<td>G</td>
<td>A</td>
<td>F</td>
</tr>
</tbody>
</table>

Table 2 - Affordance of the Nine School Buildings to Accommodate Different Learning Formats
9. DISCUSSION AND DESIGN IMPLICATIONS

The findings of this research can be divided into two main sets of results which both have utilised spatial syntactic analysis to explain the relation between space and learning inside schools. The first combined quantitative data (students’ attainment for the nine schools) with syntactic metrics to prove the hypothesis that spatial configuration impacts learning outcomes. More segregated schools were found to show better outcomes. This is in line with findings from previous research, where highly integrated schools were reported by teachers as less suitable in supporting varying teaching styles (Kishimoto and Taguchi, 2014).

Since attainment figures do not fully describe learning and socialising inside the school building, the second set of results established foundations for the relation between space, socialising and learning through exploring the spatial potential of the building to afford, facilitate and trigger students’ social activities and learning.

Regarding socialising, it was proposed that building form and configuration, i.e. the way functional elements are connected could affect socialisation patterns. This builds upon previous research which highlighted that compact buildings showed different encounter patterns from finger layouts (Pasalar, 2003). Here it is argued that the exact interplay and connections of functional elements needs to be taken into account in a more detailed way.

Regarding learning processes, it was argued that a higher variation of syntactic values for classrooms could better support a variety of learning formats. Extreme ends of the spectrum (very integrated and shallow vs very segregated and deep) are neither supportive nor inhibitive for the learning process, because it depends on what format of learning is being implemented.
The analysis showed that some of the learning spaces (assigned with specific functions of lectures, seminars, discussion, etc.) were concentrated on the upper floors, yet often without any direct links to social areas. Rather than assigning classrooms segregated spaces by default only accessed through narrow corridors, their location could instead be derived from the spatial need of the learning process. If learning is considered “a social process where new insights are actively constructed in the mind of a learner through a mix of activities and processes” (Sailer, 2015, P.15), and if the school is interested in implementing a weakly framed learning methodology with more freedom granted to the learner (Bernstein, 1973), then openness, connectivity and flexibility are appropriate spatial criteria to implement. Yet, if privacy and isolation are favoured for another learning format, then the upper more segregated floors might be more suitable. The main point is that the allocation during the design process might not be based on the normal top-down zoning process (which is based on area fulfilment and checklists). The design of the school building could instead respond to the needs of the learning process and the school vision in order to facilitate the learning process set by the management.

This research has been able to explore these issues and propose hypothesis to be tested, however the actual relation between spatial characteristics of classrooms and suitability for different learning processes and formats are yet to be more fully established in a rigorous empirical study.

10. CONCLUSION

In this paper, learning was re-conceptualised as a social process mainly dependent on the perceptions, interactions and the comprehension of knowledge by the learner where the learning context (the built environment) is not just the background but actually impacts the process. Space was argued to have an impact on learning outcomes since it was shown that spatial configuration impacts students’ attainment with more segregated schools showing better student performance. The research also explored the spatial potential and affordance of school buildings for social encounters and more varied learning processes beyond attainment scores. Hypotheses were formulated that could be tested against empirical data in further research.

Limitations of this study include the rather small sample size for statistical analysis and a lack of observational and behavioural data which could be addressed in further research. The Built environment is one factor of many impacting on student learning outcomes. Thus, extrapolation of any conclusion from the results of this research should be carefully considered and should be supported by further research that covers other physical resources, learners, learning leadership, and school policies. The future studies could include specific non-spatial parameters such as social deprivation of schools, school management and quality of teaching alongside variables of spatial configuration in a more complex multivariate model. The ultimate contribution would be to provide guidelines that might assist architects during the design process, in order to create buildings that are optimised to accommodate functional programmes and new modes of teaching and learning.
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ABSTRACT

Starting in 2009, the Brazilian government implemented an enormous housing program known as “My Home, My Life” (Programa Minha Casa, Minha Vida – PMCMV). Part of its objective has been to promote access to adequate housing among low-income populations. Currently, the program is in its third phase and if its goals are met, in 2018, after nearly a decade of construction, it will have created 6.5 million homes throughout Brazil. It is the largest housing program since 1964 and its scope has changed Brazilian cities and the lives of millions. While researchers are making an effort to analyse its impact, in terms of housing policy, it is also important to join efforts to better understand its meaning as an architectural proposal for social housing. It is critical to understand the differences among spatial proposals, including the adaptations and appropriations undertaken by beneficiaries. Since PMCMV was first implemented, it has been the focus of several important studies. This research fits among these, adding an approach-to-space proposal as well as a take on socio-spatial practices within these homes. If having a home is the dream of Brazilian people, as the saying goes, it is important to know which dream, in terms of spatial configuration, is being effectively built. This research, still in progress, targets different administrative regions in the Federal District’s metropolitan area destined for families with the lowest levels of income. The scope of this paper is restricted to housing units in Bracket One of the PMCMV, comprised of those families that earn less than three times the minimum wage. The selected site, located in Block 8 of the West Sector of Cidade Estrutural, includes 289 units. Using Space Syntax methods, this study analyses not only built projects, but also adjustments and adaptations (in use or shape) made by beneficiaries. The goal is to evaluate the extent to which this program is contributing to a reframing of our housing culture and needs. Is there novelty at hand, or is it simply repeating historical modals?

KEYWORDS

Design Synthesis, Space Syntax, Morphology, Social Housing, PMCMV
1. INTRODUCTION

The Brazilian housing deficit has long been one of the largest social problems facing the country. Estimated at 8 million homes, 6 million of which are urban, this deficit has become one of the greatest challenges in the struggle for adequate housing (FJP, 2015). Although there were many attempts to improve the situation in the 20th Century, starting in 1930 with the Vargas administration and continuing with the National Housing Bank (BNH) between 1960 and 1980, none managed to resolve the problem. In the Federal District alone, the housing deficit stands at more than 260,000 homes (CODHAB, 2013). In recent years, one of the country’s largest housing construction programs emerged, carrying in its name a dream held by many Brazilians: the My House My Life Program, Programa Minha Casa Minha Vida (PMCMV) in Portuguese, is aimed at promoting access to adequate housing for low-income families.

Despite its critics, the housing program is the largest of its type since 1964. In 2018, there will have been nearly 7 million homes constructed through this program in Brazil. Many researchers are making efforts to analyse what this means in terms of housing policy. The present study is included in this growing body of scholarship, contributing an approach-to-space proposal and analysing socio-spatial practices within these built homes. This study includes an analysis not only of the built projects but also of the adjustments and adaptations (shape) made by their beneficiaries. One of the objectives is to understand if habitants adopted the original proposal or if their modifications reveal another genotype, instead. For this, two levels of analysis were considered: the geometric and topological aspects. In the geometric analysis, residents were found to predominantly desire the following: to expand or create new spaces. To analyse configuration, Space Syntax methods were employed. The goal of this study is to identify whether or not this program is prompting a reflection on national housing culture and, in doing so, such a process has found novelty or, rather, simply a repetition of historical models (modern or pre-modern).

As a study in progress, for this paper we chose an area with single-family units in Vila Estrutural, an area located close to an old dumping grounds and approximately 15 kilometres from Brasília’s Pilot Plan. In total, 28 homes were included in the analysis, 25 of which underwent physical alterations (modifications to expand or create new spaces).

This text is divided into four parts: i) a brief history of the PMCMV together with background on Vila Estrutural; ii) the second part describes the methodology used to define the sample and data collection, as well as the methods used for analysis; iii) the third part includes the analysis; and iv) the final part offers preliminary findings.

2. DATASETS AND METHODS

2.1. HISTORICAL CONTEXT

2.1.1. THE MINHA CASA MINHA VIDA PROGRAMME (PMCMV)

Launched by the federal government in 2009 under the Lula administration (2003-2010), the PMCMV was created with the goal of reducing the housing deficit among low- and middle-income Brazilians, contributing to an improved quality of live among this population. The program targets families in three income brackets: i) Bracket One, which comprises 90% of those lacking housing in Brazil, includes families that earn less than three times the minimum wage (around Us 300 per month); ii) Bracket Two includes families that earn between three and six times the minimum wage, and iii) Bracket Three covers families with an income of up to ten times the minimum wage. The PMCMV is currently in its third phase.

The program’s original goal was to build 1 million homes, a quantity that generated shock and disbelief when announced. By December 2010, the first phase of the program had met the stated goal and surpassed it by 5,000 units (PRESIDÊNCIA, 2011). In the same year, the second phase of the program was launched, proposing the construction of 2 million additional residences. By 2015, the first two phases accounted for 3.8 million individual contracts. The
third phase, launched in 2016, proposed an additional 3 million contracts through the end of 2018. According to the Ministry of Cities (PRESIDÊNCIA, 2011), 4.2 million units have already been contracted and 2.6 million have already been delivered. This third phase, once finished, should meet the goal of 6.75 million completed units, a larger number than was achieved by the National Housing Bank (BNH) program which, between 1964 and 1986, built 4 million homes (MARICATO, 2009).

Since its implementation, the PMCMV has been the target of criticism by specialists, among them those who have confused housing policy with a job creation policy for the construction industry (ROLNIK and NAKANO, 2009). In general, scholars studying the issue warn that the proposed program fails to consider conceptual advances on the subject of urbanism or those related to social housing concerns in the country (MARICATO, 2009; ROLNIK and NAKANO, 2009; CARDOSO and ARAGÃO, 2013). For Nascimento and Tostes (2011), the same BNH working logic, based on the increased consumption of housing and guaranteed work for contractors, remains intact nearly half a century later.

In the meanwhile, it is difficult to deny the importance of PMCMV, as more than 10 million people have already benefited from the program. The program has become a preponderant factor in the struggle to lower the Brazilian housing deficit, specifically among the lowest social classes (BONDUKI, 2009).

In 2012, in the Federal District (DF), the Live Well Program was created (Law nº 4.996/2012) with the stated objective of tending to low-income families. The primary financier of this program was the larger My House My Life Program, which served as a basis for the development of the local housing program. With the original goal of contracting the construction of 100,000 units by 2014 (CODHAB, 2013) and with a promise to prioritize the poorest families – those with an income less than three times the minimum wage – and over 14,000 completed homes to low-income families in the Federal District (PRESIDÊNCIA, 2011).

The Live Well Program underwent regional adaptations in its implementation, among them the instated requirement that any beneficiary be a resident in the Federal District for five uninterrupted years at the time of inscription. This limitation intended to prevent available housing from driving a migratory influx into the Federal District (GDF, 2012). In addition, given that the average Federal District income is higher than the national average, the cap for Bracket Three was lifted from 10 times, the limit in PMCMV, to 12 times the minimum wage for the Live Well Program (CODHAB, 2013). The program encompasses 17 areas of the Federal District, including the site of this study: Vila Estrutural.

2.2.2. THE HISTORY OF VILA ESTRUTURAL

Located 15 kilometres from Brasilia’s central Pilot Plan, Vila Estrutural was founded by an irregular occupation on the area surrounding dumping grounds in the 1960s. Known as the Lixão do Joquei or Jockey dumping grounds, and located next to the Brasilia National Park, the dumping grounds attracted informal garbage collectors searching for a means of economic survival. Eventually, some of these collectors stayed on the grounds, founding one of the oldest occupations in the Federal District. In the 1970s, the DF-095 highway was opened. Known as the Estrada Parque Ceilândia (EPCL), it was connected to BR-070, the highway running from Brasilia to Cuiaba, Mato Grosso. It was a structural route (via estrutural) and, as such, gave origin to the name of the settlement (COBRAPE, 2017).

In 1989, the relocation of the settlement to another site was considered, but never carried out. At the beginning of the 1990s, with the growth of the dumping grounds, there were a growing number of informal garbage collectors and huts, transforming the area into the so-called Invasão Estrutural (Structural Occupation). In 2004, the 15th Administrative Region of the Federal District was created, including Vila Estrutural as its urban centre (SCIA, 2017). At this point, the settlement became known as Cidade Estrutural, or Structural City.

By 2008, according to a deadline set by the federal government, all activity at the dumping grounds should have ceased; nearly 10 years later, however, the dumping grounds continues
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in operation (SCIA, 2017). In 2010, nearly 2,000 informal garbage collectors continued to live from the trash they collected and 600 of them, in addition to collecting garbage, also lived in the community established adjacent to the dumping grounds. What began as an occupation that counted just over 100 huts is today a city with nearly 38,000 inhabitants over an area of approximately 29km². Figure 01 shows the location of the referenced area, in the Federal District, and Block 8 (Quadra 8) of the West Sector of the Cidade Estrutural.

Figure 1 – Location map and aerial view of Block 8

2.2 SAMPLE DEFINITION, DATA COLLECTION AND METHODS

2.2.1. SAMPLE DEFINITION AND DATA COLLECTION

The scope of this study is restricted to housing units offered to families in the Federal District that fall into PMCMV Bracket One. The selected site, in Block 8 of the West Sector of Cidade Estrutural, is comprised of 289 units.

The model house was 52.3m² in size, comprised of a living room conjoined to a kitchen in a proposal that diverges from the (modernist) laboratory kitchen and the Brazilian pre-modernist model. The dissolution of the kitchen exposes a less intimate or familiar space. The house includes two bedrooms and a bathroom on a plot measuring approximately 72m². It is a duplex unit in two senses – lateral and back – while front and side clearances create the only option for natural ventilation and illumination. The sole access point is on the side of the house, along a 1.5-meter wide corridor intended to ventilate the bedrooms, kitchen and bathroom, where the uncovered service area is located. This disconnected service area is typical of low-income Brazilian family houses, while the front clearance guarantees a space between house and street.

The front clearance ensures a space between the house and the street. This area was chosen for analysis due to its specific parameters: i) it is comprised of single-family units, in duplex houses laid out on an urban lot; ii) these houses were destined to families in Bracket One; iii) the site is inserted in a pre-existing social scenario and, as such, is not in a new area or distant from the urban centre, as is the case with other PMCMV developments; iv) it has existed long enough to demonstrate adaptations to the space as originally proposed. It is important to note that the informal garbage collectors are among project beneficiaries, residents of the old occupation settled next to the dumping grounds. Figure 02 shows the housing complex when it was completed, in 2010, and the settlement in 2017.
The sample in this study includes 28 units, approximately 10 per cent of the houses of the Block 8, resulting from the random approach taken with area residents. We randomly approached residents with a questionnaire, which included objective and subjective questions. The main goal was to collect data about the house and its occupation, including evaluating aspirations and interventions with relation to the inhabited space. In order to obtain data referencing spatial configuration, we also requested a rendering of the floor plan.

2.2.2. LEVELS OF ANALYSIS

According to Aguiar (2010), the concept of spatiality refers to the insertion of the body in space and includes the concept of physical space, referred to here as geometry, as well as topographical space, which refers to the interactions of the user with the voids. Physical changes to the space, with the goal of adjusting to the needs of its occupants, bring modifications to those voids, modifying its physical conception with the removal or addition of fences while creating or eliminating spaces. This alteration is, by nature, financially taxing, given the need to acquire construction materials and the deployment of a work force.

If we consider that the general cost of construction in Brasília is R$1,073.01/m² (IBGE, 2017), that 73% of those interviewed had a family income of up to R$1,800.00, and that the average area increase was 21m², the approximate cost incurred per family was R$21,400. In addition, 75% of the residents lived in their homes for five years and 42% of reforms were done between 2014 and 2016, starting an average of two years after moving in. Additionally, consider that residents largely co-existed with these works, whether or not they undertake the task themselves (Figure 03). If a genotype that better fit the needs of future inhabitants could be identified, such a burden could be limited.
If the alteration of voids is the focus of the research, the methods used for analysis are two-fold: geometric and morphological analyses of the space. For the geometric analysis, data were synthesized in a quantitative analysis of geometric alterations. This quantification revealed the objective of alterations, both in spaces that were transformed and those that had been added.

To understand the relationship between rooms, and their relationship to the rest of the complex, we turned to a morphological study. It is not possible to do a morphological study using geometric aspects. Geometric order comes as a direct description, such as floor plans, cutaways, and façades, while the topological order, used in morphological analysis, comes “from the perspective of the body in motion, more effective than the geometric order.” In this sense, the methodological tool used was Space Syntax¹, which focuses on the corporal relationship with space. The decomposition into convex spaces, as well as analytic categories for depth², distributivity³, and integration⁴ were used in the analysis.

In the sample, the service area – according to the original project – would not be considered a convex space a priori, given that it is not defined by walls or a roof and, as such, is originally part of the terrain. For its use/activity effect, the terrain will be considered a convex space when it is essential to access the inside of the home. In this study, the exterior is considered to be the street, the point from which our depth analysis departs.

3. RESULTS

3.1. GEOMETRIC CHANGES

Analysis revealed that 77.8% of the studied units underwent some kind of geometric changes. On average, the size increased by 21m², pushing the units from an overall area of 52.3m² to 73m². The high rate of alterations in the residences reveals the true desires of occupations. Among alterations that resulted in an increase to the area, two kinds of alterations stand out: 46.42% increased the size of their kitchen by an average of 7.8m² and, 42.85% of the studied units showed an increase to the total lateral covered area, resulting in a gain of 7m² to the house. One of the most common modifications was the demarcation of this space using walls and a roof, creating a permanent space within the house structure.

Growth to the front covered area was another novelty reported in more than 60 per cent of the sampled houses, used in different ways: i) as a room and porch in 14.2 per cent of the sample, with an average size of 9.7m²; ii) as a garage in 35.7 per cent of houses, with an average area of 13.43m²; and iii) as a work space or commercial establishment in 10.7 per cent of sampled units, with an average area of 8.85m².

Table 1 synthesizes actions taken by residents, altering the space to fit their needs. Most modifications to the space were made in the living room/kitchen, which represents 85.7% of alterations. This shift is directly related to the addition of two rooms – the living room and kitchen as separate spaces. Efforts made by residents reflect a desire for a larger kitchen, a characteristic family space in Brazilian culture, on the one hand. On the other, the action demonstrates the rejection of the single kitchen-living room proposal and a return to a Brazilian colonial or pre-modernist pattern. According to Lemos (1993), the larger kitchen, separate from the dining room, is a predominant feature in Brazilian homes from early constructions.

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¹ The emphasis on Space Syntax is due to the spatial configuration, which includes basic relationships between visibility and permeability between spatial units (for greater detail, see Hillier, 1999; Hillier and Hanson, 1984). Relationships of permeability represent the possibility of a user to move from one spatial unit to another and relationships of visibility represent the possibility for a space or part of a space to be seen from another space.

² The Depth is the topological distance, measured by the number of convex spaces that separate the spaces within the system and these spaces in relation to the outside. All syntactic measurements and the graphics were generated by JASS software (Justified Analysis of Spatial Systems, version 1.0).

³ Distributivity is the tendency of the system to present a “ring” or a “tree” configuration. A system of rings is more distributive, as it presents different options of connections between spaces (different routes). The “tree” system is less distributive, as it does not have rings, and thus offers only one possible route between spaces.

⁴ The Integration measure is an index that defines the degree of inter-relation between the different spaces of the system.
Brazilian colonial (pre-modernist) houses, the kitchen was commonly used as an intimate space for family members – even distant relatives were kept out of space. Even in urban areas, houses were predominantly divided into two areas: a reception area for visitors and another that was strictly intimate.

<table>
<thead>
<tr>
<th>Room</th>
<th>Incidence of modification in existing space</th>
<th>Room</th>
<th>Incidence of addition of new rooms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Living Room/Kitchen</td>
<td>85.71%</td>
<td>Living Room</td>
<td>46.42%</td>
</tr>
<tr>
<td>Circulation</td>
<td>7.10%</td>
<td>Kitchen</td>
<td>46.42%</td>
</tr>
<tr>
<td>Bedroom 01</td>
<td>7.10%</td>
<td>Bedroom 03</td>
<td>10.70%</td>
</tr>
<tr>
<td>Bedroom 02</td>
<td>7.10%</td>
<td>Lateral Covered Area/Service Area</td>
<td>42.85%</td>
</tr>
<tr>
<td>Bathroom</td>
<td>0.00%</td>
<td>Garage/ Front Covered Area</td>
<td>35.7%</td>
</tr>
<tr>
<td>Service Area</td>
<td>42.85%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial Spaces</td>
<td>10.70%</td>
<td>Front Covered Area</td>
<td>14.2%</td>
</tr>
</tbody>
</table>

Table 1 - A synthesis of the modifications

From the geometric analysis, it is important to note that solutions found by residents – the addition of new spaces or the expansion of existing spaces – created a model of occupation that filled the entire terrain and even extended into public space (sidewalks). An important aspect of this pattern is the rescue of the relationship between house and street that is so characteristic of the Brazilian home. For DaMatta, “The house is a category that only defines itself and allows itself to be ideologically captured accurately when in contrast or in opposition to other spaces and domains. (...) It only makes sense when placed in opposition to the outside world: the street universe.” (1991: 13) The house and the street are sociological categories fundamental to the understanding of Brazilian society, as they “speak” of society through social codes, representing public-private relations.

Such construction ended up defining the building as a single massive block. The houses no longer share a wall with the other half of the duplex, but share walls on both sides. The original plan and an example of a modified plan, respectively, can be seen in Figure 04.

Figure 4 - Decomposed floor plan in convex spaces (original and modified)

5 The tripartite model (social, intimate, and service sector) would only appear in the nineteenth century among the coffee-producing elite. (LEMOS, 1999).
4.2. CHANGES TO CONFIGURATION
The architectural proposal of the duplex, with free space in the front and on one of the sides of the house, together with the limited size of the terrain, imposes a limit to growth of the home. The terrain was occupied by the building, impeding various access points from outside or within the terrain. Geometric modifications, as described earlier, show that the systems underwent modifications with the addition of new spaces, thus increasing the number of convex spaces from 9 to 13.

The occupation of the entire terrain by a single building, hindered the creation of new access points and resulted in the configuration of deeper systems with a tree structure in most houses. Following these alterations, 22 houses, which represent more than 80 per cent of the modified homes, displayed a tree structure. Only three houses displayed structures with a single ring. This predominance of the tree structure favoured an increase to system depth, with relation to the exterior (street).

The complex that was analysed presented variations between four and seven levels of depth, while the original structure presents six. The tree structures within systems with seven levels of depth (see Figure 05), given their significant topological distance from the exterior, represented 22 per cent of the sample. This occurred due to the creation of one or more spaces in the front part of the houses, such as a garage, small business, living room, or kitchen.

Systems with six levels of depth (Houses 1, 2, 12, 15, 16 and 17) basically maintained the same number of convex spaces as the model house, with a system including nine or 10 convex spaces. These systems, which largely repeat the tree structure of the original house, represent 35 per cent of the sample. In House 1, there is a novel ring formed by the double access from the terrain and garage, one of the few alterations that breaks with the logic of the single access point characteristic of the sample.

One important aspect to consider is the reduction of system depth. Following modifications, 43 per cent of systems had their depth reduced to four or five levels. Those with five levels of depth were predominant and modifications had largely aimed to enlarge or undo the proposed living room/kitchen, which included three convex spaces that, following the remodel, became a single space.

The majority of modifications were done to remove a wall that defined the cooking area, creating instead a single open space, whether defined as a kitchen. These modifications were
seeking to separate living and cooking spaces, revealing a rejection of the original proposal and confirming a more cultural characteristic of the pre-modern Brazilian household, which had separate living and cooking spaces.

The addition of a garage/front covered area appeared in 35.7 per cent of the houses and, morphologically, responded to the desire of residents to have a space to receive visitors. This confirms the importance of this space as social in nature. Testimony from some of the residents explained this: “…It’s an area with a sofa and a TV.” Or, “…This space is the most external of the house because the visitor is very curious.”

Permeability graphs reveal that, after modifications, the systems displayed a bi-partite structure in the domestic space. In other words, according to geometric analysis and an analysis of the spatial configuration of these rooms, a strong investment in space expansion within social areas reveals a template that reinforces the division of domestic space into two sectors: the social area, with a separation between the living room and kitchen and the creation of a large frontal space used as a room or garage where gatherings could take place, and the intimate space (bedrooms and bathrooms). In its circulation, the tree structure has a space that acts as a connector between these two sectors, actor as a protector of what many residents expressed: “…I don’t like anyone to be in my bedroom” or “…The bedrooms are intimate.”

Another important aspect of the sample is that the systems, post-modification, express certain homogeneity with respect to the measure of integration. The original system had an average integration measured at 0.71. After modifications, average integration ranged between 0.63 and 0.96, fitting into two groups: more than 40 per cent of the systems had integration higher than 0.71. Specifically, consider Houses 1 and 27, with six and five levels of depth, respectively, and with an integration level of 0.96. It is worth noting that House 1, with six levels of depth, is one of few that shows the presence of an internal ring. The systems as a whole, however, were less integrated following the reforms, with 60 per cent reporting average integration levels equal to or less than those in the original house (Figure 08a).
The deepest systems, with seven levels, are the least integrated of those in the analysed complex with an average integration below 0.71, reaching 0.63 in the case of House 5. The predominant modification in these cases was the creation of one or more spaces in the front and side parts of the house, expanding the topological distance from the body of the home with relation to the exterior.

The measure of integration also revealed that the most integrated spaces continue to be the living room and kitchen, as spaces defined by activity and circulation while acting as a connector between social and intimate spaces. In the original floor plan, the most integrated activity space is the living room/kitchen, at a measure of 1.38. After modifications, these spaces had integration levels of 1.90, even when they were maintained as in the original proposal (House 27), characterizing the space as the most integrated social space (see Figure 08b).

The kitchen and living room stood out as the most integrated active spaces in the system in more than 70 per cent of the sample. Still, the kitchen was used to receive guests in only 14.8 of the cases and in 15.4 per cent, visitors did not have access, revealing that its social importance is intrafamilial in nature.

The circulation area was the most integrated space in all the systems, acting as a defining element of one of the most important characteristics of the sample configuration: the fact that the domestic space is bipartite, or defined by two sectors: the intimate and the social (Figure 8c). It is a characteristic that differentiates the sample from the Brazilian middle-class model, which defines domestic space as having a tripartite structure composed of an intimate and social sector, as well as a service sector, including the service area and a room for the service worker.

Another element that characterizes the configuration of this sample well is the high levels of integration in a space that was the target of geometric changes: the multifunctional area created in the front part of the property. Many people described this space as being used to receive visitors, due to its larger size. The configuration reveals that, this space was more integrated in approximately 60 per cent of the houses, compared with the original house. This was the preferred space for receiving guests in 95.6 per cent of the cases. This new space creates a transitory link between the house and the street and, for some residents, "...The porch (front door closed) is the largest" space for receiving visitor. The same happened with the exterior, following modifications, the exterior was more integrated in approximately 70 per cent of the houses, compared with the original house (Figure 7d).
4. CONCLUSIONS

The two levels of analysis (geometric and configurative) were essential to study the experience of PMCMV in Cidade Estrutural. The analysis revealed a diversity of geometric solutions, on one hand, with 25 different modifications to a sample of 28 homes. The solution found by residents – to add new spaces or expand existing ones – created an occupational template in which 100 per cent of the property was occupied (original house, front and lateral areas, in addition to advances into a public space – the sidewalk). Such a solution was seen in nearly the entire sample, indicating that part of the studied complex could form a large, dense block of houses. Instead of a duplex sharing one wall, as in the original project, the houses would share walls on both sides. Even when it inhibited natural illumination or ventilation (since living room, kitchen, and bedroom windows were inside the home), this was the pattern that was adopted, even if it was compromising to the quality of these internal spaces.

Such a solution ended up defining a single entrance to the home, from the street, which reinforced the low permeability of the system and the predominant tree structure. With the creation of the front covered area as a gathering space, the possibility to create different access points from the exterior was eliminated. Internal alternative routes were not possible, either, which made for a sample formed by largely non-distributive systems. Even shallow systems (with four or five levels) present the same configuration.

The sample reveals that the majority of changes or adaptations took place in social gathering rooms, whether it was the reassigning of the kitchen or living room, or the creation of a larger area in front of the house. With different characteristics, however, the first space was the most occupied by the families (affirmed by 70 per cent of residents), while the second was more commonly used to receive visitors. As such, it was confirmed that the great driving force capable of driving modifications is a social force, executed with different goals.

The final result was a complex with particular characteristics: i) the exterior was more integrated in approximately 70 per cent of the houses, compared with the original house; ii) the more integrated rooms continue to be the living room and kitchen, even with new proposals of separate, single-use spaces; and iii) the circulation area is the most integrated in most of the sample, confirming its role as a connecting element that defines the domestic space in two sectors: intimate and social.

These characteristics confirm a rejection of the original proposal and an attempted rescue of pre-modernist patterns. The occupation of the entire terrain (lateral, back, and front) creates a pattern of occupation that references the so-called row occupation (an arrangement appearing as a continuous façade) found in Brazilian cities from the colonial period. Of course, they do not have the generous amounts of land present at colonial houses. The important element in this pattern is the revival of the relationship between the house and the street. In fact, the intense use of the street was proven in an on-site visit, reinforcing the home-street model characteristic of Brazilian traditional urban centres (DA MATTA, 1991).

While it is ongoing, this study indicates two important findings. The first is the diversity of geometric solutions, revealing that a singular architectonic proposal, standardized and repetitive, is not adequate for a community with varying needs. On the other hand, the configuration analysis indicated a level of homogeneity in the systems. The systems, which resulted from physical limitations of the property, are i) relatively non-distributive; ii) non-integrated and hierarchical systems; iii) shallow but hierarchical systems. This confirms a genotype in which the house is divided into two nuclei: intimate (including the kitchen) and social, where the exterior remains integrated, confirming the intense relationship between the house and the street.

There is no doubt, especially in the face of the Brazilian reality, with a financial recession and an ongoing crisis among political institutions, that having a large-scale program that attempts to confront one of the largest social problems in the country is not only important but also necessary. The satisfaction of residents who have a home, including the old garbage collectors, who did not have (71.5 per cent say the house is good or very good) the real possibility of better
living conditions in an urbanized area (water, sewage, paved streets), confirms the importance of the PMCMV. “It is better to be here than at the dumping grounds in some wood hut,” one of the residents confided.

However, with respect to internal spaces of the home and, therefore, architectural solutions, the research indicates it is necessary to improve these in a way that changes the logic of simple repetitive solutions and creates novelty that responds to the needs and desires of the low-income Brazilian family, taking cultural aspects of the Brazilian house into consideration. These, however, represent only preliminary observations of an ongoing research project.
REFERENCES


LAYING THE FUNDAMENTALS
Early methods and intentions from the outsets of space syntax

ABSTRACT

Forty years following the ‘Space Syntax’ paper by Hillier, Leaman, Stansall and Bedford (1976), where its research programme was presented, in this 2017 11th SSS this paper aims to reflect upon the early breakthroughs that have led to all the subsidiary outcomes and technical advancements brought by this innovative approach from the 1970s.

Hence, this paper will address the research context amongst which space syntax has been established, regarding its methodological nature, but foremost as an answer to the Unit for Architectural Studies’ research concerns, in which it was originally implemented. Thus, it will acknowledge the specificities of this contemporary research context, on its theoretical conjuncture, the construction of its fundamental body of knowledge, as well as its organic structure within the context on the mentioned Research Unit, established in July 1967 at the Bartlett School of Architecture.

Accordingly, the outputs of the research contents, but also of its methodological procedures, will be critically analysed, regarding the research initially developed by Hillier and Leaman, then still at the Intelligence Unit of the RIBA and their initial theoretical production. With Leaman, Hillier would present ‘The architecture of architecture’ in 1973, at the Second Conference of the Centre for Land Use and Built Form Studies. And along with Musgrove, from the Unit for Architectural Studies, Hillier and O’ Sullivan would present their outcomes at the third EDRA (1972).

The overall relevance and originality of this proposal lays in its informed reassessment towards architecture, but also to other study fields, whose contribution plays a relevant role in the decision process, as proven by the expanding thematic approaches of the latest Space Syntax Symposia. Moreover, broadening the technological advancements could be lined with an understanding of the theoretical fundamentals that ground space syntax research.

So, the theoretical stabilisation of these concepts in the early 1970s would be seminal to the establishment of space syntax, as the advancement of an artificial understanding of spatial surfaces through aggregation modes, as a pre-topological approach and a still elementary syntax, envisioning a “social logic of space” (Hiller and Hanson, 1984). This acknowledgment would contribute, in the 1980s, to a possible relation between theory and practice, ultimately confirming Hillier’s proposal of linking both realms through research in 1969, when he was considered by the RIBA (1969) to be “the RIBA’s second youngest assistant secretary at 32, [as] the nearest thing we have to a long-haired intellectual”.

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1. INTRODUCTION
Forty years following the ‘Space Syntax’ paper by Hillier, Leaman, Stansall and Bedford (1976), where its research programme was presented, in this 2017 11th SSS this paper aims to reflect upon the early breakthroughs that have led to all the subsidiary outcomes and technical advancements brought by this innovative approach from the 1970s.

Firstly, the research context behind the early beginnings of space syntax will be outlined from an initial social emphasis brought to the Bartlett School of Architecture by Richard Llewelyn-Davies’s pioneer architectonic and experimental behaviourist studies at the Nuffield Foundation Division for Architectural Studies founded in 1954, and subsequently introduced by the Unit for Architectural Studies (UAS) established in 1967, with John Musgrove as its director.

Furthermore, the interrelation between Musgrove’s studies at the UAS and Bill Hillier’s early theoretical work at The Royal Institute of British Architects (RIBA) Education Committee at the end of the 1960s, followed by his relevant role behind the RIBA’s Intelligence Unit, will be reviewed, mainly by their mutual participation in the Editorial Board that founded the Journal of Architectural Research and Teaching in 1970. This would be a mediating platform for the publication of the research work from many epistemological provinces, generally resulting from studies developed in research centres, many of them founded in 1967, as the UAS, the Building Performance Research Unit by Thomas Markus at the University of Strathclyde, or the Centre for Land Use and Built Form Studies by Leslie Martin at the University of Cambridge, with Lionel March and Philip Steadman.

Secondly, the presentation of original studies and theoretical backgrounds and developments, will prove the stabilisation of a conceptual framework for space syntax during the 1970s. This will be undertaken through a critical re-reading of direct sources, mainly Bill Hillier’s and Adrian Leaman’s papers, either from the RIBA’s Intelligence Unit or from the Unit for Architectural Studies at the Bartlett, while also considering the outputs of subsequent studies and the contribution of Julienne Hanson’s research from the second half of 1970s to the seminal 1984’s The social logic of space (Hillier and Hanson, 1984).

Finally, it is expected that the systematization of the theoretical background of The social logic of space may potentially trigger a contemporary critical implementation of instrumental procedures and interpretations, as valuable means for restating architectural and social concerns as ineluctable research ends.

2. THE ‘SUBJECT MATTER OF ARCHITECTURAL RESEARCH’

The conceptual framework of space syntax, its early methodological experimentations and subsequent stages of increasing complexity, have been fostered by a research culture intensified during the 1960s. During that timeframe, architects associated research directly with the urgency of building reconstruction, at the aftermath of the Second World War and with a consequent social empowerment provided by the Welfare State.

Amongst the architects in-between practice and research, Robert Matthew and Leslie Martin, after prominent efforts at the London County Council, have both become architectural school directors, respectively at the University of Glasgow and at the University of Cambridge. Martin’s famous speech at the 1958 RIBA’s Oxford Conference on Architectural Education stated that: “Research is the tool by which theory is advanced. Without it teaching can have no direction and thought no cutting edge.” (Martin, 1958, p.280). This would already constitute a sign of a research culture that was being forged and expanded.
Ultimately, it resulted in the creation of several research structures within architectural schools during the second half of the 1960s. That was the case of the Centre for Land Use and Built Form Studies in Cambridge, founded by Leslie Martin along with Lionel March in 1967. It was also the case of the Unit for Architectural Studies at the University College London implemented in the same year by John Musgrove, which was a direct result of Richard Llewelyn-Davies’ promotion of research in architecture on several fronts, as director of the Bartlett in 1960.

In fact, Llewelyn-Davies assumed a mediating position between the practice and the research since his 1950s experience as principal coordinator of the Nuffield Foundation Division for Architectural Studies, where he reinforced the establishment of a specific body of knowledge in new hospital facilities. His research team, which was also constituted by John Weeks and later by John Musgrove, developed pioneering survey studies with several experimental methodologies that would constitute an important input to inform the design of new hospital wards. Besides a theoretical approach on the recognition of change and indeterminacy (Weeks, 1964), one of the most innovative methods was the recording of the nurses’ typical day-work movements, by means of string diagrams, in which threading string corresponded to pathways on a plan.

This example epitomises the emergence of architectural studies as a theoretical background for the practice, in which research might constitute a “substitute for tradition”, as Llewelyn-Davies assumed by saying ‘Deeper knowledge, better design’ (1957):

‘It is in some ways the only substitute we have for tradition. Tradition was built up after a long period of trial and error. They tried all sorts of rooms, windows, etc., over many years, research of a slow and very expensive kind. Now we can’t afford to do that; we must use more intensive methods, to get the old quality into architectural design.’ (Llewelyn-Davies, 1952, p.105)

Reyner Banham (1960, p.93) as the editor of The Architectural Review, would invite Llewelyn-Davies to present his ideas on this dichotomy between “tradition-technology”. In his paper ‘Human Sciences’ Llewelyn-Davies (1960) introduced social sciences as an increasing expanding field in regard to architecture, interrelated with the conceptualization of the environment, which would strengthen a research panacea under diverse contexts.

Right next to Llewelyn-Davies, Peter Cowan and Newton Watson at the Bartlett, supported a synthesis between architecture and people, where, as Martin put it, “research is the tool” for knowledge advancement towards the lived environment:

‘Buildings begin with people. Architecture should not be a formal or production-derived solution imposed upon the users, but a growing together of human needs and the industrial equation. Somewhere a synthesis occurs; at this point stands someone – call him architect or what you will – reconciling not leading – creating not directing – not an amateur of other disciplines, but a profession in this task. As our knowledge of human physiological requirements deepens, creative design becomes easier. The multi-disciplinary team is the organisation, research is the tool, and science the discipline which will push our vocation forward in the second half of this century. Buildings end with people.’ (Cowan and Watson, 1961, p.744).

It was precisely the study on the interconnection between buildings and people that established the problematics for the first study under John Musgrove’s coordination, entitled The Use of Space and Facilities in Universities, which laid the foundations for setting up the UAS in July 1967. Its first report (Unit for Architectural Studies, 1968), presented the implemented methodology, explaining how the correlations between spaces and activities could be optimised, while recurring to IBM Port-a-punch cards to collect real activities’ data [Figure 1].
These implementations were presented in 1971 at a research fair, as one of the events that sustained the generalisation of architectural research amongst the schools of architecture. This fair was organised by Thomas Markus at the University of Strathclyde, where he founded the Building Performance Research Unit in 1967, which also implemented studies on the interrelation of activities and spaces with particular focus on secondary schools (Markus, 1972).

The research front in architecture, here embodied by Markus and Musgrove, epitomised a profile of the architect that interacted in the midst between art and science, embodying the interconnection between The Two Cultures (Snow, 1959). Actually, if both were entrepreneurial in introducing a culture of research into architecture, they were also involved in a strong expressive artistic realm. Markus was close to the Glasgow School of Arts, while Musgrove extensively read “history, philosophy of technology and science, and novels from Dickens to
This connection was also translated onto the University of Strathclyde, encouraging the relation with other disciplines, as the pioneer conference Architectural Psychology revealed. Here Bill Hillier (1970), still secretary of the RIBA, presented one of his early papers entitled ‘Psychology and the subject matter of architectural research’, which revealed the intrinsic fragilities of empiric research and induction, reporting to Popper’s (1962) *Conjectures and Refutations*.

Thus, Hillier was becoming the RIBA’s role model for a delegate concerned with the intermediation between the theory and the practice, considered by the RIBA (1969) to be “the RIBA’s second youngest assistant secretary at 32, [as] the nearest thing we have to a long-haired intellectual” [Figure 3]. Ultimately, by leading the RIBA’s Intelligence Unit, Hillier would share with Adrian Leaman the committed role of reflecting upon fundamental views, relating simultaneously research and theory, profession and practice, which was unusual until that moment within a professional organism as the RIBA.

Figure 3 - Bill Hillier, at 32 years old, as assistant secretary of the RIBA.
(Royal Institute of British Architects, 1969, p.426) Courtesy RIBA Collections

The main proof of the relocation of architectural research, between the education and the profession, would be the creation of the *Journal of Architectural Research and Teaching* (ART), first published in May 1970 [Figure 3]. The first numbers from ART framed strategies for architectural research, translated onto a compilation of several research papers. But Hillier also reflected upon the relations between architecture and the profession, as well as other professions like engineering (Hillier, 1972).
Consequently, if education and the profession were profoundly discussed since the 1950s, only at this point were the effective links between both realms being surveyed and problematized through research, as exemplified by the research Schools of Architecture and the Profession, carried out by the UAS between 1972 and 1974.

In 1974 Hillier would assume, along with John Musgrove as the main editor of the UK board, the transformation of the ART into the Journal of Architectural Research (1974), translating it into a cross-Atlantic publication, co-published by the RIBA and the American Institute of Architects. This change envisioned a broader repercussion of the ‘subject of architectural research’, even if in 1975, O’Sullivan, Territt, Musgrove, Hillier and Leaman, recognised the struggles behind a continued research programme lacking institutional and financial support that would hinder much of the future of architectural research.

However, the main causes for an undefined future were actually of an epistemological nature. Therefore, in what concerned the assessment of the interactions between subjects and artefacts, theoretical divergences were behind an epistemological fracture within the research culture of “structuralism” as Hillier and Leaman (1973) would argue. Actually, after Llewelyn-Davies founded an environmental school at the Bartlett (School of Environmental Studies), Hillier and Leaman, while teaching at the MSc course in environmental theory, reflected upon the contradictions within the research paradigm between man and the environment, leading to their influential paper ‘The man-environment paradigm and its paradoxes’ (1973). As they sustained, structuralism proposed a paradigmatic alternative through a “simple yet profound change: the paradigmatic substitution of logical space for spatial space” (ibid., p. 510). Thus, by recurring to Piaget’s ‘Biology and Knowledge’ (1971) in their text, instead of a logic of space, the authors would recognise the research path to pursue a “social logic of space”:

’We exist not in ‘spatial space’ pure and simple, but in spatial space as it has been constructed in terms of the contents and structures of logical space. This has happened, Piaget-wise, through our cognitive activity by which we have made sense of the world, retaining as we go the structure of that understanding, and developing it to assimilate new experiences as they occur in real space.’ (Hillier and Leaman, 1973, p. 510)

That was the assumption of the concept that would construct the theory of space syntax and its fundamental roots on The social logic of space (Hillier and Hanson, 1984) as the natural output of a syntactic assessment of space and as “the generator – of social relations”:

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2 We thank the anonymous referee for reminding the relevance of Hillier and Leaman’s text to the theory of space syntax and the epistemological change in the structuralist approach of the man-environment paradigm.
'By giving shape and form to our material world, architecture structures the system of space in which we live and move. In that it does so, it has a direct relation - rather than a merely symbolic one – to social life, since it provides the material preconditions for the patterns of movement, encounter and avoidance which are the material realisation - as well as sometimes the generator – of social relations.' (Hillier and Hanson, 1984, p.ix)

3. THE OUTSETS OF SPACE SYNTAX

The comparisons between theoretical findings and conceivable breakthroughs will be crucial to report the framework of space syntax as a research field, as we have seen, based on a research culture shared between studies enrolled in several research centres in the early 1970s.

This was the context shared between architecture schools and the RIBA, lived in and stimulated by Bill Hillier’s early studies, which progressively tended towards a rationality behind the design at the outsets of space syntax, and that could complement reality, as the culmination of architecture, as he pointed out in 1970: “Get involved in design so that hypotheses can be tested by that marvellous available instrument, the real building.” (Hillier, 1970, p.29).

Accordingly, the outputs of the research contents, but also of its methodological procedures, will be critically analysed, regarding the research initially developed by Hillier and Leaman, then still at the Intelligence Unit of the RIBA and their initial theoretical production. Hillier and Leaman would present ‘The architecture of architecture’ in 1973, at the Second Conference of the Centre for Land Use and Built Form Studies, published in 1975. And along with Musgrove, from the Unit for Architectural Studies, Hillier and O’Sullivan (1972) would present their outcomes at the Third Environmental Design Research Association (EDRA).

Correspondingly with Hillier’s reflection upon architecture and engineering, the paper ‘Knowledge and Design’ (Hillier, Musgrove and O’Sullivan, 1972) regarded (environmental) research and its connection to the (design) practice. It clearly pointed out the need to diminish the “applicability gap” of research towards the design and to tackle its “credibility gap” (ibid., p.2). Under this contextual framework of the beginning of the 1970s, architects developed design concerned with the practice, rather than knowledge for that practice, which was accorded to other realms of study (ibid.). Generally, by refusing a definite knowledge or a set of rules of thumb, this approach drew near the design and the theory, acknowledging that:

‘Such theories are not pseudo-deterministic ways of telling the designer what will be the outcome of his design, but strong and cumulatively developing bases for conjecturing possible futures.’ (Hillier, Musgrove and O’Sullivan, 1972, p.14).

Following this connection between design and environment, and the assumption of the paradigm’s paradoxes in 1973, the subsequent paper by Hillier and Leaman (1974), ‘How is design possible’, stated that “if design method is to be improved then it is more important to study the environment itself than how designers design” (ibid., p.4), while considering “how designers’ internal models transform environmental reality”.

This recalled the previous 1972 (Hillier, Musgrove and O’Sullivan) idea of the building as a “climate”, “behaviour”, “cultural” and a “resource modifier” (ibid., p.12). Even though this was further developed in this paper, in which the authors advanced a more structured framework for these conditions, namely that the “man-man” relation regards the building as a “behaviour modifier”, whereas the “man-nature” relation regards the building as a “climate modifier” (Hillier and Leaman, 1974, p.8) [Figure 5].

Additionally, already in this paper Hillier and Leaman (1974, p.6) addressed “morphology” and “structure” and referred to a:

‘[...] theoretical approach to space where the fixity of artificial space [...] becomes a primary factor. Such a theory begins with the observation that the simplest structures in environmental action are already complex structures.

Such elementary structures, given that they are identifiable, will contain within themselves rules
for combination into the higher-order aggregations which give the spatial structure characteristics of urban and other higher-order spaces, as mappings of social processes.' (Hillier and Leaman, 1974, p.10)

This latest remark on the “mapping of social processes” could induce the future “social logic of space” (Hillier and Hanson, 1984). Furthermore, the identification of rules of combination of structures and the reference to morphology, could be understood as an anticipation of the ‘Space Syntax’ paper (Hillier, Leaman, Stansall, Bedford, 1976).

But just one year afterwards, Hillier and Leaman published ‘The architecture of architecture: Foundations of a mathematical theory of artificial space’ (1975), within the proceedings of the second conference of the LUBFS, that elaborated on “morphologies and codes” (ibid., p.6-8), “spatial surfaces and aggregation modes” (ibid., p.10-12) and presented an “elementary syntax of spatial structures” (ibid., p.12-16).

So, in 1976 the paper ‘Space Syntax’ by Hillier, Leaman, Stansall and Bedford, which started by questioning: “how and why different societies produce different spatial orders through building forms and settlement patterns” (ibid., p.147), is paramount for the establishment of space syntax, as “a general syntactic theory of space organization” (ibid.).

Structurally, this paper first locates this theory as a "morphic language" that is "used to constitute rather than represent the social through their syntax (that is the systematic production of pattern)" (ibid.) and grounds it, between the mathematical and the natural language, from which it resembles, but also differs (ibid., p.152).

In fact, during the first part of the paper, it addresses the search for the recognition and representation of the “inherent formal structures” (ibid., p.148) to understand spatial and social patterns (ibid.). For that purpose, and under a yet emergent search on the methods, the “syntactic” choice is here justified, rather than a mathematical straightforward approach (ibid., p.149).
Additionally, the paper explains the aim of the “theory of morphic languages” in “understanding how the morphology may be generated from a parsimonious set of elementary objects, relations and operations” (ibid., p.149-150). Syntax plays here a prominent role, which in a morphic language is defined as “a set of related rule structures formed out of elementary combinations of the elementary objects, relations, and operations.” (ibid., p.150).

Furthermore, in this paper, influential concepts of space syntax already appeared, such as: “local” vs “global” (ibid., p.153), “betweeness” (ibid., p.157) vs “insideness” (ibid., p.173),… and it described the postulates, the advantages and its lexicon.

Lastly, it is emphasised that the paper presents an untested theory (ibid., p.179), which is not “causal” or a “reflection” (ibid.) of society and space, but that it is the most exact one that engages syntax with social relationships, whose further developments would also lie in the clarification of this relation. This is the case of the paper ‘Creating life: or, does architecture determine anything?’ by Hillier, Burdett, Peponis and Penn (1987), which examined in detail whether “architectural design create[s] a pattern of spatial life” (ibid., p.234), ending with the suggestion that “cities are not so much mechanisms for generating contact as mechanisms for generating a potential field of probabilistic co-presence and encounter” (ibid., p.248) with a “definite and describable structure” (ibid.).

Besides urban analysis, space syntax has also proven relevant on the analysis of designs for building interventions, as regarded in the several National Gallery Hampton site proposals, which have already been analysed by axial and convex maps (Hillier, Peponis and Simpson, 1982).

In 1983 a paper under the same title: ‘Space Syntax’, by Hillier, Hanson, Peponis, Hudson and Burdett, was published in The Architects’ Journal, which developed this theory further on and closer to what would be presented in the 1984 Hillier and Hanson’s The social logic of space.

This paper already clarified the principles of space syntax and its testing at the Bartlett, having applied it to “more than 100 towns, urban areas and design proposals, and the systematic observation of 15 examples” (Hillier, Hanson, Peponis, Hudson and Burdett, 1983). One of the focused examples is London’s Limehouse Basin, for which four design proposals have been analysed, besides the existing urban tissue. And despite the choice in the proposal, the research showed that the analyses of the existing structure tackled its respective problems and assets and also acknowledged the spatial requirements for bettering its movement and social interaction.

In addition to the fact that this paper presented a well-defined description of space syntax, it held an appendix with the concepts that it took up, and it perceived its purposes and advancements very clearly. It also concluded on the relevance of spatial order towards cognition and behaviour (ibid., p.49):

‘Nevertheless our results show unequivocally that the spatial organisation of towns and urban areas affects patterns of movement and use according to well defined principles, which relate to intelligibility of space […]; the continuity of occupation […]; and the predictability of space […].’ (Hillier, Hanson, Peponis, Hudson and Burdett, 1983, p.49)

Lastly, it strongly acknowledged space syntax as an advancement for urban design, by providing an understanding of the existing situation that could ultimately inform future designs:

‘Space syntax is therefore both a method and a message, and it would seem to open up new perspectives to urban design. It gives a rational way of approaching urban design ‘top down’, so that anyone can participate in the decision taking process from the ‘bottom up’. Space syntax allows the structure of the area to suggest new possibilities. Above all, it is a way of looking at the oldest problem of all in urban design: how to add the new to the old.’ (ibid., p.63)

However, the reception of the space syntax method by The Architects’ Journal’s readers expressed “major reservations” like Richard MacCormac (The Architects’ Journal, 1983, p.14) who, even considering the “intelligibility of a locality” as relevant, argued that “space syntax describes formal characteristics of urban space and I do not feel that a measurable relationship
between these and urban experience is established”.

The only exception on this debate was Thomas Markus, who actually believed in its potentialities, rather than a “mission impossible”. Hence, this could be one of the early signs that revealed subsequent divergent approaches to the man-environment paradigm, foreseen by Hillier and Leaman ten years earlier (1973).

4. CONCLUSIONS: A SPACE SYNTAX CRITICAL RETROFITTING

The First Space Syntax Symposium took place in 1997, for an already established research community. Its opening lecture by Hillier and Hanson (1997) reflected upon the progressive development of space syntax, both as a method but foremost as a theory: “the analytical theory of architecture” (ibid., p.1). This recalled the early papers when Bill Hiller was at the RIBA’s Intelligence Unit while searching for the fundamentals of an architectural theory, which now holds specificities and mechanisms that structure and describe spatial configuration in regard to social relations.

Overall, the case studies and situations in which to apply space syntax have been gradually widened, its disciplinary scope has gained a broader extension, and a potential transdisciplinarity can be perceived, which has been stated promptly in Hillier’s (1996) Space is the machine:

‘At present we are encouraged by the current interest in these ideas across a range of disciplines and, just as the last decade has been devoted to the development and testing of techniques of configurational analysis within architecture and urban design, so we hope that the coming decade will see collaborations amongst disciplines where configuration is identified as a significant problem, and where some development of the configurational methodology could conceivably play a useful role.’ (Hiller, 1996, p.2)

Simultaneously, Hillier and Hanson (1997) stated that space syntax goes along with "design intuition" for the understanding of the possibilities:

‘Space syntax works with, not against, design intuition, and generates new generic possibilities for design intuition to explore rather than simply constraining design. It can do this precisely because it is a theory, and could not do this if it were not. [...] Space syntax makes the deployment of nondiscursive intuition more rational and therefore more discursive. It aids design as what it is: the reasoned deployment of intuition. Architecture remains, as ever, the reasoning art.’ (Hillier and Hanson, 1997, p.4-5)

Both of the quotes above revealed the will to broaden space syntax’s scope and potential as a theory, in its interconnections to other means of approaching space and society.

Hillier’s reference to “collaborations amongst disciplines”, may imply a way of surpassing the paradoxes on the man-environment paradigm, foreseen in the early paper with Leaman (Hillier and Leaman, 1973). These paradoxes have certainly contributed to the delimitation of the theoretical fundamentals of space syntax and its subsequent developments. Actually, in its outsets, by concentrating its methods in securing a rigorous and stable assessment of the structural logics that influence social relationships in space, the theory became intentionally biased by not taking into account subjects’ sensorial experience and intentions and, thus, without aiming to resolve the holistic complexity of social encounters.

At the same time, this theoretical assertiveness brought some arguments from several critics, pointing out fragilities that were, from the beginning, outside of the fundamentals proposed by the theory. The recent clarification of the field’s limitations, by Vinicius Netto (2015) when questioning “What space syntax is not”, while systematically identifying the intrinsic goals of space syntax’s theory, also underlines its abstraction when it reduces "social practice" and “the actors” to syntactic measurements.

From opposing epistemologies many of the controversies have grown towards space syntax, as we have seen in the publication ‘Mission Impossible’ (The Architects’ Journal, 1983). Hence, more than a permanent and unresolved fracture, questions can be placed on how far
the confrontation between space syntax and divergent theories, might constitute a way of surpassing the above paradoxes, while respecting their mutual fundamentals.

From the three different possibilities pointed by Netto (2015, p.8) to this “epistemological dilemma” on the future of theory – “maintenance and reproduction”; “rupture”; or “adaptation and evolution” – we argue for the critical dialogue between theories, and a constructive triangulation of their original principles.

Hence, more than adapting and envisaging an expanded theory through its adaptation, its interaction with other theoretical contributions would comply with a critical and more complete sociospatial assessment, such as attempted in recent researches (Coelho and Krüger, 2015). This particular research associated space syntax with other approaches for assessing adaptability in educational spaces, in order to reach a more thorough conclusion on the relation between space and the learning experience, whose “[...] final outcome potentially provides a comprehensive outlook on spatial analysis and a methodological development on architectural research, to be applied to other design briefs.” (ibid., p.2)

Already in ‘Morphology and Design’, Hanson (2001) aimed at expanding the field towards the intellect, intuition and ethics, in the reflective practice of architecture, for the Third Space Syntax Symposium, where it is recalled the engagement of morphology to design, but also, intuition and ethics to space syntax. Furthermore, Hanson also highlighted the relevance in studying morphology at an early stage of the briefing, which provides a significant contribution to architecture, both to the practice but also within the academia:

‘[...] the potential for space syntax to guide the relation between morphology and design at the briefing stage, when the limits of architectural possibility need to be set against the constraints of the unique design context, may represent its most vital contribution yet to architectural knowledge and also to present its strongest claim to be a legitimate academic discipline within the modern university.’ (Hanson, 2001, p.17)

Presently, this approach, linking spatial morphology to The social logic of space (Hillier and Hanson, 1984), conveys information to a widespread number of study fields, from the urban scale to the dwelling, which largely demonstrates the wide framework of approaches on space syntax research and the current extensive community of researchers, that can also contribute to a critical reflection upon its fundamentals.

Ultimately, by acknowledging that the development of space syntax has been instigated by the questioning of the spatial structures in the 1970s, which also engaged other researchers at that time with different approaches to this subject (Hillier and Hanson, 1997), a contemporary, renewed and entangled research culture might capture that ambiance for a more comprehensive study of the man-environment paradigm:

‘Space syntax originated in the early seventies in an effort to understand why, from a spatial point of view, buildings and built environments were as they were, and occupied only a small corner of the theoretically vast field of architectural and urban possibility. From the earliest days we focussed on the study of real cases, and our efforts could be contrasted with the parallel efforts of others such as March and Steadman at Cambridge (and then at the Open University) to identify the formal and geometric limits of architectural possibility. They studied possibility, we studied actuality, and we compared notes in the friendly rivalry of a mobile joint seminar, which soon expanded to include George Stiny, Bill Mitchell and others. The earliest space syntax work took real environments, such as organic settlements, and vernacular buildings, and tried to identify the formal, spatial and functional forces that generated their characteristic spatial forms.’ (Hillier and Hanson, 1997, p.1)
REFERENCES


#14

SPATIAL NAVIGATION IN REAL AND VIRTUAL MULTI-LEVEL MUSEUMS

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ABSTRACT

Atria in public buildings, such as museums and cultural environments, serve the purposes of architectural expression as well as spatial navigation. This is clearly seen in numerous existing buildings and modern extensions, such as in the Ashmolean Museum in Oxford, the most recent masterplan of which uses atria to link the old with the new sectors of the building, attract human activity and facilitate three-dimensional exploration. Until recently, most space syntax studies on navigation focused on route choices and spatial characteristics in two dimensions, consequently by-passing the effect of the third dimension on spatial exploration. Although common sense acknowledges a link between three-dimensional design and human movement, there is no substantial research on how the third dimension relates to patterns of exploration. Using the Ashmolean Museum as the main focus study, this paper explores the relationship of actual human movement (visitors’ paths), virtual movement (VR) and spatial structure (space syntax), in order to understand how the multi-storey complex environment impacts on users’ free exploration. The findings suggest that verticality three-dimensional visibility, have a significant effect on how people move in a museum setting. Virtual experiments including spatial alterations of the volumetric structure of the Ashmolean clearly show the impact of the third dimension on path selection and configuration as well as gaze direction. This paper can inform three-dimensional architectural design with the goal of creating user-friendly buildings. The ultimate aim is to provide principled understanding of the variability of three dimensional design and cognitive dimensions in museum buildings for the public.

KEYWORDS

Museums, spatial navigation, virtual reality, space syntax, atria

1. INTRODUCTION

The paper explores how the three-dimensional design of atria museums affects the ways humans experience these environments. The first part of the study includes a detailed description of how the experiments were set up, organised and performed, describing the three-dimensional model, apparatus, virtual scenarios, processes and participants. The second section compares the virtual navigation patterns to those paths observed in real visits. In addition, the head movements ‘visitors’ make while exploring virtual environments are discussed. The primary aim is to explore and calculate head movement data to shed light on the effect of the third dimension on navigation. In this way, the paper moves between scales of analysis, from the aggregate level to the micro scale spatial decisions that are taken progressively while moving.
To start with, atria seem to be endowed with a cognitive function, as orientation and reference points within complex buildings. A courtyard or an atrium, as Werner and Long (2003) argue, can act as an orientation point within a global frame of reference. In addition, Choi (1997, p. 2) describes how atria ‘offer a variety of possibilities for peoples’ co-awareness due to the amount of vistas that are offered’. In other words, the architectural layout, when experienced from a multitude of points with the aid of the voids, would seem to have a direct impact on navigation.

Space syntax is used to analyse the two-dimensional properties of the layout, revealing and predicting patterns of pedestrian movement. It sheds light on navigation processes and wayfinding (Broesamle et.al 2009; Hoelscher and Broesamle, 2007; Penn, 2003; Peponis, 1993; Peponis et al., 2003; Peponis and Conroy Dalton, 2004; Psarra, 2009). In addition, agent-based models are used to study movement patterns (Turner and Penn, 2002), which are further correlated with observed navigation. These syntactic methods highlight the relationship between the two-dimensional layout and human exploration. Nevertheless, there is an important factor missing from its framework: this is the effect of the third dimension on navigation.

Although the existing literature is rich in theoretical and methodological background, it does not provide any rigorous account of the ways multi-level environments relate to the overall navigation paths structured by their layouts. In addition, most approaches focus on wayfinding. As Montello and Pick (1993) and Hoelscher et al. (2009) argue, most research on wayfinding and large-scale complex spaces has focused on two-dimensional layouts with isolated floor levels. However, the real world is three-dimensional, something that needs to be further explored. Other researchers have tried to bridge this gap, by investigating the role of vertical access points in shopping complexes (Passini, 1984), or estimating distances between spaces located on different floors (Foley and Cohen, 1984). Hoelscher et al. (2007) studied how experienced and inexperienced human subjects, in terms of their familiarity with the building, navigate inside the multi-level layout. The users reported wayfinding problems regarding the lack of visual access to vertical points of circulation and incongruent floor layouts. In addition, Hoelscher et al. (2009) examined wayfinding strategies in complex buildings, showing that users first move horizontally inside the building towards the target area and thereafter change floor level to reach their goal. The present study will focus on the ways free exploration is structured in multi-level museums.

For this reason, virtual reality (VR) is used to capture the three-dimensional factor on exploration. Numerous researchers (Bishop and Rohrmann, 2003; Dalton, 2001; Haq et.al, 2005; Franz and Wiener, 2008) have shown that virtual stimuli are a reliable tool to capture real-world behaviours. Building upon existing research, the paper aims to implement aspects of three-dimensionality in relation to navigation and visitors’ free exploration, unexamined by other studies. These will be addressed with spatial alterations, related to the use of the third dimension in museum layouts, and the impact of atria on navigation.

Thus, the paper will explore the following research questions: Is there an impact of atria as well as the three-dimensional architectural design on visitors’ patterns of movement and exploration? b. how much do spatial changes related to the atria account for different navigation patterns? c. to what extent is virtual navigation similar to real exploration within a multi-level virtual environment? The overall aim is to gain a better understanding of the impact of the third dimension on human experience.

To this extent, the Ashmolean Museum is selected as a case study for the virtual reality experiment. Comprising of four atria that are tightly embedded within the spatial structure of the galleries, the museum provides a solid ground for exploring the impact of the voids and the third dimension on how people navigate inside exhibition environments.

SPATIAL NAVIGATION IN REAL AND VIRTUAL MULTI-LEVEL MUSEUMS
2. DATASETS AND METHODS

SPATIAL CHARACTERISTICS OF THE MUSEUM LAYOUT

The Ashmolean Museum is situated on Beaumont Street in Oxford, United Kingdom. It was designed and built by Charles Robert Cockerell (1845). Since then, it has undergone a succession of additions, the most recent being in 2009, by Rick Mather Architects. The museum has a floor area of approximately 3,900m². The architectural design for the new extension, with its insertion of numerous atria, has introduced a significant number of transparent glazed facades enhancing panoramic views. The mix of double-height and single-height galleries, as well as the staircases and the bridges that traverse the double-height volumes, provide a multiple array of vistas into other galleries (Figure 1). The building consists of four differently sized and shaped atria located in the new extension at the rear of the museum (Figure 1). Specifically, the positioning of the staircases inside atria A and C provides vertical links to the rest of the floors. Further, two major routes, designed by Cockerell, intersect at the entrance and connect the various spaces. The ‘Main’ axis is at right angles to the Cockerell axis, connecting the entrance with atrium A. The ‘Cockerell’ axis, linking the entrance with the Egyptian collections, is immediately upon entering and turning to the left. A third axis, the ‘Western’, links together the galleries located on the west side of the museum, with atrium C at its far end.

3. NAVIGATION PATHS IN THE REAL ASHMOLEAN

Initially, in order to understand how the building’s design relates to the actual movement patterns, a detailed observation study was conducted. 50 people per floor were observed for all floors. The tracking lasted for a maximum of 1 hour for each subject. When a visitor changed floor, the researcher moved on to the observation of the next user.

The analysis of paths reveals two kinds of exploration patterns (Figure 4). Exploration pattern ‘a’ refers to those visitors who on entering follow the main axis of the building (50%) and encounter the three-dimensional voids A and B. Exploration pattern ‘b’ concerns the other 50% who turn left to the Cockerell axis and the sequential galleries. These paths unfold three-dimensionally on the other floors and are interfaced around the atria. Thus, they reveal a spatial exploration that has a twofold character: pattern ‘a’, where three-dimensionality acts as a strong attractor of movement towards the atria, away from gallery spaces; pattern ‘b’ as a sequential system driving visitors through the gallery spaces and encountering the atria at a later stage in the process. The differences between the two patterns of exploration capture a complementary relationship between the architectural and museological function (Lazaridou and Psarra, 2015).

4. VIRTUAL REALITY

4.1 THE VIRTUAL SCENARIOS

As a next step, virtual experiments were conducted, to capture the role of architectural design and the effect of atria on navigation. The experiments included two different virtual worlds defined as Condition A and Condition B and based on the spatial configuration of the Ashmolean. Condition A was the exact representation of the real building. Condition B was based on Condition A, but with the glass walls or railings surrounding the voids being replaced with opaque walls. Thus, the two-dimensional configuration of the museum remained the same. However, the three-dimensional visibility structure was altered by replacing the transparent surfaces around the atria with opaque walls to test the impact of the atria and the third dimension on navigation (Figure 1).

In addition, Visibility Graph Analysis (VGA) was performed for both Conditions, taking into account permeability and visibility measures. Focusing on the VGA graph in Condition A (Figure 2), the visibility structure extends over the atria. In contrast, visual integration in Condition B is limited due to the closed off voids, while the permeability structure continues to be the same with that of the real museum.
Figure 1 - 3D model of the real Ashmolean or Condition A (left) and Condition B (right). The location of the spatial changes are highlighted in red. Source: Athina Lazaridou.
4.2 VIRTUAL ASHMOLEAN

A virtual three-dimensional model of the Ashmolean Museum was designed in great detail. The 3D visualisation included all four floors, materials, glass facades, views to the city, lights and structural details. Additionally, the researcher employed a 3D scanning process to scan the collections of the building (82 artefacts). The only parameter missing from the 3D virtual world was the presence of other people (Figure 3). The end file was imported in Unity 5.1.2f1, to enable the application of collision effects (no walking through the walls), set up the First Person Controller (height: 1.67, eye height: 1.60 and walking speed: 1.79m/s, no flying or jumping) and control the lighting conditions. An audio was compiled by the researcher from real-world sounds of the museum to simulate the real acoustic conditions. The aim of all this detailed implementation was to make the subjects feel more present, grounded and aware of their virtual presence. 64% of the participants felt that it helped them be more aware of their virtual movement.

Figure 2 - VGA analysis showing permeability (left) and visibility (middle, right) relations in Conditions A and B.
The experiment ran on an iMac with an operating system OS X Yosemite, Windows 7, 21.5”, LCD, Core 2 Duo, 4GB RAM, based in the Bartlett School of Architecture, UCL. The Oculus Rift Development Kit 2 Virtual Headset (DK2) was used for the experiments. The paths were recorded ten times per second offering a great amount of precision.

Figure 3 - Views of the real (left) and the virtual environment (right). Last row: Photos of the participants during the experiments.
4.3 THE EXPERIMENT

Users were asked to freely explore the multi-level museum in any way they wanted, acting as if they were visiting the museum in reality. They had to cover as many spaces as possible and when they thought they had explored the whole museum they would need to return to their starting point (entrance). All subjects were initially positioned at the entrance of the building facing towards the external surroundings, to avoid creating any bias and skewing the results regarding their initial route choices. They were not informed about which real world building they would be immersed in. They were given a maximum amount of time (15 minutes) to navigate in the virtual environment. The average period of time subjects spent in the virtual Ashmolean Condition A was 9.9 minutes and in Condition B, 10 minutes.

4.4 THE PARTICIPANTS

Twenty five unpaid participants explored Condition A and twenty five different ones navigated in Condition B. Half of them were female and half male. Half (54%) of the subjects were young adults (18-29), 38% were aged between 30-34 and 8% of them were over 40 years old. The subjects were selected from different disciplines with 36% having an architectural background, 15% being researchers, 22% IT specialists and the rest (27%) coming from the humanities field. The majority were right handed (92%) and 66% of them had no known vision problems. More than half (56%) of the subjects had no previous familiarity with Virtual Reality environments, 42% of them had limited experience and only 2% had regular interaction with this technology. Interestingly enough, 90% of them were familiar with video games on computer screens. Finally, 92% of participants had never visited the Ashmolean Museum before, eliminating any memory effects and biases regarding their movement.

After participating in the experiment, the subjects were asked to answer some additional questions regarding their virtual experience. Half of them (56%) found the use of the VR easy and 30% of them very easy. 98% of them experienced motion sickness, which reduced their navigation endurance.

5. RESULTS

5.1 REAL VERSUS VIRTUAL EXPLORATION PATTERNS

The objective of this section is to compare users’ performance between real and virtual environments and examine the role of three-dimensionality on exploration. The paths are plotted against the convex breakup of each floor (Figure 4). The comparison between real and virtual movement is realised floor per floor.

Figure 4 shows that the degree of correlation between real and virtual paths in Condition A is strong and positive (R^2>0.40, p<0.01). This finding demonstrates a clear analogy between virtual movement and real navigation. In contrast, focusing on the relationship between real and virtual navigation in Condition B, the R^2 values highlight weaker parallels. It seems that the three-dimensional alternations in the visibility structure of the museum alter navigation patterns. Thus, the isolation of atria and the third dimension seem to have a significant effect on exploration.

Interestingly, the highest degrees of correlation occur on the basement and on the second floor, when comparing real and virtual traces (Figure 4). This is because no spatial changes occurred on the basement, thus, the correlations remain very close to each other. On the second floor, movement is highly directed due to the spatial configuration of the galleries. Users need to follow the prescribed routes and effectively the relationship between real and virtual exploration is very similar and is less influenced by three-dimensionality.
Figure 4 - Correlation matrix. Real (left) and virtual traces for Conditions A (middle) and B (right) in the Ashmolean Museum. Table shows the correlations R-squared between observed and virtual movement (normalised values) in Conditions A and B.

<table>
<thead>
<tr>
<th>Correlation R²</th>
<th>Traces VR A</th>
<th>Traces VR B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real traces (Basement)</td>
<td>0.75 (p&lt;0.01)</td>
<td>0.72 (p&lt;0.01)</td>
</tr>
<tr>
<td>Real traces (Ground floor)</td>
<td>0.40 (p&lt;0.01)</td>
<td>0.28 (p&lt;0.01)</td>
</tr>
<tr>
<td>Real traces (First floor)</td>
<td>0.66 (p&lt;0.01)</td>
<td>0.30 (p&lt;0.01)</td>
</tr>
<tr>
<td>Real traces (Second floor)</td>
<td>0.86 (p&lt;0.01)</td>
<td>0.74 (p&lt;0.01)</td>
</tr>
</tbody>
</table>
Looking more closely at the r-squared values, the ground floor (real compared to condition A), presents the lowest correlation (0.40, p<0.01) (Figure 4). This could be associated with the fact that people in VR are familiarizing themselves with the technology. An additional reason could be that users revisit more than once the ground floor to reach the other levels and return to the exit, in order to finish the experiment. All these factors could contribute to skewing the relationship between virtual and real movement. On the other floors, the correlations are very strong with the highest one occurring on the second level. The same factors apply when comparing real with virtual movement in Condition B, where the ground floor shows overall the lowest values (0.28) and the highest correlations are identified on the second floor (0.74, p<0.01) (Figure 4). The experimental procedures and subsequent comparative analysis, show that three-dimensionality is a powerful factor, associated with navigation. It is important to mention that the correlations might have been different if the virtual environments would be populated by other people and the technology had not affected participant’s virtual performance through factors such as motion sickness.

The focus now shifts to the structure of the navigation paths for the separate layers of the museum. In the real Ashmolean, half of the people, upon entering the building, turn left to the Cockerell axis and half to the main axis (Figure 5) (Lazaridou and Psarra, 2015). The percentages in the virtual world A are 56% for the users choosing the Cockerell axis and 44% for the main axis. This difference is possibly associated with the presence of numerous exhibits along the Cockerell axis compared to the main axis or the fact that in the real museum the natural light is stronger, entering from the skylight of atrium A. In contrast, in Condition B the navigation paths present a different distribution as follows: the majority of the subjects (64%) move towards the Cockerell axis, 24% use the main axis and 12% turn to the right (Figure 5). There seems to be a degree of similarity between real and virtual movement in Condition A compared to Condition B, where the atria are closed off and the three-dimensional views are obscured. Moreover, from the outset, it seems as if atrium A in Condition A, acts as a significant attractor regarding the initial route choices people make, also supporting the effect of the third dimension being significant when people enter a building. In other words, the absence of atria in Condition B directs people along the Cockerell axis. This confirms the hypothesis that in the real world and Condition A users are attracted by atrium A and three-dimensionality.

Focusing on users who follow exploration pattern ‘a’ (main axis towards atrium A) on the ground floor across all scenarios, it is seen that the paths in Condition A are visually more similar to the observed real movement compared to those in Condition B (Figure 5). This shows that the existence of atria on the entrance level of the museum, attracts and enhances navigation around them and also motivates users to explore its deeper parts (75%) compared to Condition B, where people concentrate in the front galleries (62%). On the other hand, the exploration pattern ‘b’, in Condition B, shows more similarity to the real exploration pattern ‘b’, than in Condition A (Figure 6). This signifies that once users choose to follow the sequential galleries, their movement is prescribed by the outline of the floor plan with the tendency towards peripheral movement, clearly shown in Condition B. In this case, the atria, do not play a significant role in navigation, since the sequential circulation structure overrides the role of the third dimension. The fact that the exploration pattern ‘b’ in Condition A is not so similar with the real traces supports the idea that the stage in which users encounter the atrium in their journey is an important factor. In Condition, where users reach the atria upon entering (exploration pattern ‘a’), they mostly concentrate around the core of the building, compared to the latter case (exploration pattern ‘b’), where the atria are introduced later and do not affect their movement significantly (Figures 5, 6).

Moving on to the two exploration patterns ‘a’ and ‘b’ on the rest of the floors, it seems that they create opposing exploratory patterns (Figures 5, 6). In Condition A, participants move mostly around the core of the building and in between the atria using the wide views and re-orientating themselves. They use the integration core of the building together with the three-dimensional views to create their own journeys. On the contrary, in Condition B, they use the peripheral galleries and the whole extent of the spatial layout to gradually increase their perceptual awareness about their spatial positioning, since they are deprived of wider views. Therefore,
the absence of the third dimension drives people to the most segregated spaces, following the sequential galleries, depriving them of the information needed to make their own choices.

Next, focusing on the 'return to the entrance' task, we see that 68% of the participants in Condition A use atrium A to reach the ground floor, compared to atrium C (33%). In contrast, in Condition B, 57% use atrium A and 43% atrium C. This signifies that the existence of panoramic views in Condition A, and the centrally situated and integrated atrium A, attract almost double the number of users compared to Condition B. Atrium A clearly acts as an orientation and reference point. However, when it is closed off, it loses its strong role within the three-dimensional system and people choose whichever vertical connection they find next to their location. Atrium C, on the other hand, in Condition A, does not attract a lot of movement. In Condition B, despite not providing views, its integrated position means it is chosen by more users. Overall, three-dimensionality presents a stronger impact on navigation than the two-dimensional spatial configuration of the museum but once the third dimension is eliminated, the two-dimensional spatial configuration becomes the dominant influence on exploration.

Figure 5 - Exploration pattern 'a' showing real and virtual traces (Conditions A and B) in the Ashmolean Museum. Paths initiate from the main axis on the ground floor and atrium A on the rest of the floors. The table shows the percentages of people based on their route decisions upon entering the environments on the ground floor.
Figure 6 - Exploration pattern ‘b’ showing real and virtual traces (Conditions A and B) in the Ashmolean Museum. Paths initiate from the Cockerell axis on the ground floor and atrium C on the other levels.

The average rate of people changing level is higher in the real museum and in Condition A than in Condition B. On the ground floor, 60% of subjects change floor level upon reaching an atrium in Condition A compared to 46% in Condition B. In the latter scenario, where the voids are enclosed, the fact that the staircases are located in them enhances vertical circulation. Further, it is interesting to note that in the real environment, three-dimensionality affects navigation to a greater extent as visitors ascend in floor levels. On the contrary, in the virtual worlds, the effect is stronger on the ground floor and weaker on the other levels. The reason for this may be that users, once accustomed to virtual navigation, prefer to move first horizontally to cover the majority of spaces and later vertically to the other floors. They are also given the task to cover many spaces and they seem to proceed so as to move efficiently.

An important finding refers to the correlations between the spatial properties and the virtual paths. In terms of VGA visibility, the $R^2$ reaches 0.36 ($p<0.01$) on the ground floor of Condition A compared to the real environment ($R^2=0.14$, $p<0.01$) (Table 1). This could be associated with the presence of other factors in the real environment, such as the internal climate, attractions,
special exhibitions, light, noise, presence of people, separately from the purely configurational characteristics. On the upper levels of Condition A, the correlations become weaker. This is explained by the fact that three-dimensionality is introduced, attracting people’s movement away from the gallery spaces. Another similarity between Condition A and real paths is that VGA visibility measures correlate better with the real traces than permeability ones.

Next, the strongest correlations appear when calculating the spatial properties against the virtual paths of Condition B. In particular, VGA permeability reaches $R^2=0.47$ ($p<0.01$) on the first floor (Table 1). VGA visibility values show strong correlations on the lower levels but weaker ones on the upper floors, something in contrast to what happens in real life and the virtual Condition A. This clearly illustrates that the effect of atria and three-dimensionality seem to have a stronger impact on users’ navigation than the two-dimensional configuration on its own.

Finally, when agent patterns (Turner and Penn, 2002) are correlated with the virtual paths, it is observed that the r-squared values between the agents and virtual paths are relatively weaker compared to their correlations with the real paths (Figure 8). This happens because in the virtual scenarios, exploration is three-dimensional, with continuous level changes and returning visits, which is not the case with the two-dimensional agents. However, it is clear that Condition B shows better correlation values than Condition A (Table 1). In addition, the upper levels in Condition A, present no correlations (close to zero), which can be possibly attributed to the existence of panoramic views.

<table>
<thead>
<tr>
<th>Correlation $R^2$</th>
<th>Agents/Traces</th>
<th>VGA perm (HH)/Traces</th>
<th>VGA visib (HH)/Traces</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Real Ashmolean</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basement</td>
<td>0.10 ($p&lt;0.1$)</td>
<td>0.09 ($p&lt;0.01$)</td>
<td>0.13 ($p&lt;0.01$)</td>
</tr>
<tr>
<td>Ground Floor</td>
<td>0.41 ($p&lt;0.01$)</td>
<td>0.17 ($p&lt;0.01$)</td>
<td>0.14 ($p&lt;0.01$)</td>
</tr>
<tr>
<td>First Floor</td>
<td>0.36 ($p&lt;0.01$)</td>
<td>0.09 ($p&lt;0.1$)</td>
<td>0.03 ($p&lt;0.1$)</td>
</tr>
<tr>
<td>Second Floor</td>
<td>0.02 ($p&lt;0.1$)</td>
<td>0.14 ($p&lt;0.1$)</td>
<td>0.34 ($p&lt;0.01$)</td>
</tr>
<tr>
<td><strong>Condition A</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basement</td>
<td>0.38 ($p&lt;0.01$)</td>
<td>0.26 ($p&lt;0.1$)</td>
<td>0.38 ($p&lt;0.01$)</td>
</tr>
<tr>
<td>Ground Floor</td>
<td>0.06 ($p&lt;0.1$)</td>
<td>0.29 ($p&lt;0.01$)</td>
<td>0.36 ($p&lt;0.01$)</td>
</tr>
<tr>
<td>First Floor</td>
<td>0.04 ($p&lt;0.1$)</td>
<td>0.18 ($p&lt;0.01$)</td>
<td>0.04 ($p&lt;0.1$)</td>
</tr>
<tr>
<td>Second Floor</td>
<td>0.09 ($p&lt;0.01$)</td>
<td>0.21 ($p&lt;0.1$)</td>
<td>0.14 ($p&lt;0.1$)</td>
</tr>
<tr>
<td><strong>Condition B</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basement</td>
<td>0.16 ($p&lt;0.1$)</td>
<td>0.25 ($p&lt;0.1$)</td>
<td>0.28 ($p&lt;0.01$)</td>
</tr>
<tr>
<td>Ground Floor</td>
<td>0.06 ($p&lt;0.1$)</td>
<td>0.28 ($p&lt;0.01$)</td>
<td>0.47 ($p&lt;0.01$)</td>
</tr>
<tr>
<td>First Floor</td>
<td>0.29 ($p&lt;0.01$)</td>
<td>0.47 ($p&lt;0.01$)</td>
<td>0.03 ($p&lt;0.1$)</td>
</tr>
<tr>
<td>Second Floor</td>
<td>0.24 ($p&lt;0.01$)</td>
<td>0.27 ($p&lt;0.01$)</td>
<td>0.02 ($p&lt;0.1$)</td>
</tr>
</tbody>
</table>

Table 1 - Correlations between the spatial variables and traces in the real Ashmolean and the virtual conditions.
Figure 8 - Agent-based models for the Ashmolean Museum. Red areas show high movement rates and blue ones low. The circles signify the areas where differences are observed with real movement. 50 agents are released with standard properties (Turner and Penn, 2002): a walking pace of about 1.5 ms⁻¹, three steps to decision and a field of view of 170°.
The fact that there is a weaker correlation between simulated and human movement in Condition A and a stronger one in Condition B is a significant result. In addition, agents, as presently calculated in the Depthmap software, do not produce very high correlations and are not able to take into account all the properties that can affect human exploration.

To summarise, the existence of a significant correlation between the real paths and condition A (Figure 4) implies that VR technology can be regarded as a valuable tool in predicting movement. Moreover, the presence of other people inside the virtual worlds might have had a significant impact on the virtual explorations. However, the absence of additional virtual users may have helped participants to focus on the spatial properties of the environments. Additionally, it is interesting to notice that, although the two observation methods were different (real: on-site observations, virtual: pre-programmed script), there still seems to be a strong correspondence between the analyses. In particular, the differences, in terms of movement, in the R² values between the two Conditions, signify the effects of the existence or absence of atria.

Further, through the analysis of the observed and virtual paths, it can be argued that the most visited is atrium A, by virtue of its integrated position and its vistas, compared to atrium C. This finding confirms that it is not solely the integrated values of a space that attract movement, but also its three-dimensional properties. In addition, the voids enhance and attract exploratory movement but also provide global orientation. On the contrary, the absence of three-dimensional views, especially upon entering a building, direct people towards sequential routes that guide them through integrated or segregated spaces. In the first case, where visitors move towards the atria, they navigate using their own spatial thinking and global understanding, without exhaustively moving through all of the spaces in the museum. In the latter scenario, where they follow the sequential routes, their movement is directed by small scale actions and decisions that result in aggregate patterns highlighting the peripheral galleries of the building.

### 6. ENGAGING WITH THREE-DIMENSIONALITY

This section goes into more detail regarding users’ head orientation and gaze direction as they navigate in the virtual museum. Figure 9 shows the participants’ visual activity in Conditions A and B, using arrows to illustrate the direction of sight. It is interesting to notice the visual and numerical differences between the two datasets. Users, in Condition A, turn their head horizontally mostly on the platforms next to atria A, B and C, as well as at the intersection point between the Cockerell and the western axis (Figure 9C). In contrast, in Condition B, users engage more with their surroundings, with their visual activity being dispersed throughout the floor. This clearly shows that in Condition A, users orientate themselves and take their spatial decisions in fewer spaces than in Condition B, due to the existence of three-dimensionality.

This is why the concentration points of gaze direction are adjacent to the voids, double-height spaces or intersections in Condition A. On the other hand, in Condition B people seem to be turning their head more frequently seeking direction and orientation (243 times in total) compared to Condition A (183 times). Condition B appears to be a more difficult environment for people to navigate since users need to constantly check their position in relation to their previous and next steps. Overall, we see that in Condition A people engage visually with their surroundings in panoramic areas and in locations where route choice decisions need to be made. In contrast, in Condition B, they look around more frequently while moving (not only at the intersections) because the nature of the environment does not provide orientation and makes decision-making more complicated.
Figure 9 - Head movement (horizontal axis) in Condition A (left) and Condition B (right).
Moving a step further and looking at head movement along the vertical direction, the data indicate that subjects seem to engage with the third dimension in multiple ways using a full range of the head movement. Users in Condition A engage more with three-dimensionality compared to the ones in Condition B. Specifically, the times they look up and down in Condition A is more than double (≈ 2.44 times) compared to Condition B. The viewing points are clearly differentiated between these two worlds (Figure 10). This suggests that the more intense the radial distribution is, the more people seem to be attracted by the adjacent location and also the more time they potentially spend browsing the panoramic views.

Specifically, in Condition A, the areas next to the atria A, B, C and D show extensive browsing activity compared to Condition B, where the concentration is identified at the entrance point on the ground floor and the intersection of the Cockerell and western axis (Figure 10, circled points). This happens because in Condition A the three-dimensional views attract users around the atria. In contrast, in Condition B the views are obscured and viewers are restricted to taking route decisions at main intersections points, such as the Cockerell with the western axis. Thus, the absence of panoramic views encourages more route decisions to be made at spacious intersection points.

To sum up, a significant finding arises from the analysis which identifies the difference between the horizontal and vertical gaze direction. In particular, in Condition A, participants do not use horizontal browsing so extensively but scan the vertical dimension, unlike the subjects in Condition B, who act in the opposite way. This happens because the first environment provides a global understanding of the three-dimensional space. It further eases navigation, motivates users to admire the views, orientate themselves and plan their next steps. The latter condition guides users to a sequential layout that provides local cues with discontinuities in the visual field, resulting in users’ disorientation and a need to constantly engage with the horizontal dimension in the absence of the vertical one. In other words, it seems that the intense engagement with the horizontal dimensions is an indicator of seeking orientation while navigating.

Figure 10 - Head movement of all the participants overlaid on the 3D section of the Ashmolean, using the output data from the virtual tracking.
7. CONCLUSIONS

To overview, the paper has captured the effect of atria and three-dimensionality on users’ exploration in real and virtual environments. Initially, it is important to note that the navigation patterns in the real Ashmolean and in the virtual Condition A present a high degree of correlation. This shows that VR technology can be used as a competent tool to examine, evaluate and research complex environments. However, to achieve the best results, the virtual representations should be designed to simulate the target reality as closely as possible. Therefore, it seems that virtual worlds can be used to gather data, simulate real movement and predict phenomena.

Further, the atria seem to perform a dual role, being both expressive and functional in terms of navigation and spatial cognition. They allow natural light to enter the building, facilitate horizontal and vertical circulation, enhance cross-visibility, provide the potential for the creation of social interaction and act as three-dimensional orientation and reference spaces for visitors. The absence of voids impacts on navigation illustrated through the lower correlations between the real and virtual paths of Condition B compared to Condition A. The existence of atria, on the other hand, motivates visitors to explore all the spatial layers of a building. Further, the voids attract users by offering global visual cues to the surroundings. In other words, when atria are included in the design, visitors seem to be better oriented and move in more selective and critical ways. On the contrary, when the architectural design does not contain any atria, people appear more disoriented, get lost and exhaustively pass through all of the segregated spaces in the building. The outcomes show that the three-dimensional layout has a stronger influence on navigation than the two-dimensional spatial configuration.

In addition, the visual engagement with the third dimension is more intense when atria exist inside a building environment. Extended head movement on the vertical dimension illustrates the need for orientation but also attraction to the wide views from the three-dimensional voids. In contrast, the intensity of visual activity on the horizontal plane illustrates users’ need for orientation and understanding of their global positioning in space. These concentration points capture the decision making areas, being at the intersection points of the galleries.

Finally, simulated movement (agent-based models) shows a stronger relationship with the navigation paths in Condition B, where the three-dimensionality is obscured ($R^2=0.29$, $p<0.01$). Thus, agent analysis can be applied on sequential layouts and provide useful information for predicting movement wherever the permeability structure of a layout is identical to the visibility. This analysis reinforces the argument regarding the significant impact of three-dimensionality on exploration in museums and overall in building environments.

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CALATRAVA’S CASTLE: Morphogenesis as “beautiful problem”

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ABSTRACT
Colleges and universities increasingly offer a combination of formal and informal learning spaces, which perform multiple didactic, individual and group study and socializing functions, as a method of enriching students’ educational experiences. This inquiry contributes to the study of these new-model educational buildings through an analysis of Santiago Calatrava’s recently completed Innovation, Science & Technology Building (IST) on the campus of Florida Polytechnic University. This paper explores the IST’s spatial configuration characteristics and their role in contemporary educational processes using space syntax analysis, combined with Bill Hillier’s framework of morphogenesis, and through the overarching analogy of a chess game. Much as chess rules are learned and executed by silent players, spatial configurations reflect a predetermined, “pre-linguistic” set of social conventions articulated by the architect and acted out by and upon users, who perform the dual roles of agent and piece. In spatial design, as in chess, rules and randomness interact to produce both known outcomes and new outcomes—or morphogenesis. The author discusses the spatial structure of Calatrava’s building as a combination of rules-governed and randomization-supporting spaces, which restrict or liberate movement, behaviours, and interactions in the building. The propositions that first emerge suggest that immeasurable variations (i.e. piece placements and relationships) derive from a small suite of simple, local moves. As the rules become too many or too global, the generative process tends to break down, informality diminishes, and orderliness and uniformity of encounters increase. Second, although rules may govern the movement of pieces, they do not govern the specific decisions that players make. Within the building, users simultaneously strategize and enact their chosen strategy through a complex suite of moves, actions and encounters. The processual nature of users’ experiences is key to this exploratory examination of Calatrava’s IST and how its design may inhibit or sustain the game of learning.

KEYWORDS
Educational Building, Spaces, Morphogenesis, Chess, Movement

1. INTRODUCTION
In today’s shared-experience-based economy, interpersonal communication and collaboration are crucial for the creation and consumption of new knowledge. Contemporary pedagogies of educational environments go well beyond the rote, cognitive mechanics of students’ brains (with bodies in chairs facing lecterns), integrating non-discursive, non-cognitive experiences and events, including movements, patterns, visual accessibility, transitions and sensations (Ellsworth, 2005). These are student-centred, experiential approaches to education, where knowledge is not handed down from master to apprentice, but constructed through a combination of traditional, social and media-based methods. It is in part for this reason that new
educational spaces are increasingly complex, multifaceted social and material environments reflecting a motley of pedagogical intentions. It is, however, an open question how effective or qualitatively different these spaces are in implementing these pedagogies.

Space syntax focuses on social aspects of built environments and their interrelationships with spatial configurations. Interest in educational environments among space syntax scholars has risen in recent years (e.g. Sailer, 2015; McLane, 2015; Koch, Bergstrom and Marcus, 2012). This paper seeks to contribute to the discussion via the exposition of one new educational facility through the lens of chess as a metaphor for space syntax-illustrated morphogenesis.

2. DATASETS AND METHODS

This study provides the first syntactic analysis of the Innovation, Science and Technology Building (IST) designed by Santiago Calatrava on the campus of Florida Polytechnic University in Lakeland, Florida (Figure 1). The IST was designed to be a symbol of the university and its commitment to future-oriented ‘experiential’ learning, innovation and research (Florida Polytechnic, 2016). It incorporates 26 classrooms, 11 science and computer labs, a library, meeting and study spaces and faculty and administrative offices.


This paper presents results from the exploratory phase of the study. Data were obtained from building plans utilizing space syntax methods (VGA and all line axial map graphs generated by UCL DepthmapX (2014) and from on-site observations. A subsequent phase will include additional field observations, behavioural mapping, interviews with space users (students, faculty, and administrators) and analysis of additional syntactic measures of permeability and visibility.

Hillier’s short/long spaces model (2007) served as the conceptual framework for the study and was instrumental in the analysis of syntactic structure of the IST. Short model spaces have fewer rules that frame their configuration and user behaviour patterns, allowing for greater randomization of movement, visibility and socialization, while long model spaces are more strictly regulated by rules and act (inadvertently or by design) to minimize random movement and user interactions.

The metaphor of chess appeared to be particularly fitting for describing the relationships between the configurational properties of Calatrava’s building and users’ patterns of movement and encounters. As posited by the anthropologist Robert Desjarlais (2011), chess is an “ever-shifting tangle of neural networks, bodies, social relations, perception, memory, time, spectators, history, narratives, computers, databases” (p. 8). This quote echoes much of the multivalence of the social / physical / behavioural inquiries at the root of space syntax.
Proceedings of the 11th Space Syntax Symposium

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3. RESULTS

From the outset, university administrators, campus planners and the architectural team conceived the IST as a “campus within a building.” This approach is reminiscent of the medieval castle as safehold and multipurpose centre of civic life. The IST is situated within a lake—literally encircled by a moat and accessible via two bridges on opposite sides of its mirrored hemicycle. A screened promenade on the lower level and terrace on the upper level provide outdoor spaces for formal or informal socializing, walking, sitting or studying. Programmatically, the interior is divided into two areas: classrooms and laboratories on the ground floor, and a library and office spaces on the upper floor.

3.1 SPATIAL ANALYSIS: GROUND FLOOR

The ground floor is organized around two curved double-loaded corridors and three secondary corridors running perpendicular to the main corridors (Figure 2). The circulation pattern extends symmetrically from the two entrances and is defined by four rings formed by the intersections of the pathways. These intersections function as navigational decision points, and provide ready access to the main classroom and lab spaces. This is a shallow configuration with a maximum depth of three syntactical steps. The VGA integration map suggests that most spaces have a medium level of integration, with the corridors being the most integrated.

Figure 2 - IST building ground floor: all line axial connectivity map and VGA integration.

The geometry of the space, however, plays a deceptive game on the users: the curvature cuts lines of vision short, thus precluding the formation of a cognitive image of the building as a whole. The building reveals itself only as one progresses along the corridor; there are new routes, openings, angles of approach that cannot be discerned until the user makes his or her next move. The two grand staircases at the entrances provide access to the second floor and reveal what is above only gradually, as one ascends to the next level.

The analysis of these syntactic measures suggests that the IST building’s ground floor configuration is a long model with elevated levels of movement and visibility control. This model reflects the traditional educational paradigm of student–instructor interaction in formal classroom settings (the direct interplay of juxtaposed pieces with assigned roles) joined by freer-form entrance and intersection areas (a comparatively open field in which to experiment with tactics and strategies for interacting with faculty and student peers).
3.2 SPATIAL ANALYSIS: UPPER FLOOR

The upper floor configuration combines elements of long and short model spaces, with opportunities for greater randomization of movement and encounters. Its central part is defined by the vast “commons” area reminiscent of the great hall of a castle. This is the main campus library (which provides only electronic resources and does not contain a single printed book in its collection) and individual and group study spaces, but could easily be reconfigured for other functions. Similar to the ground floor, the commons is flanked by two curved double-loaded corridors that provide access to faculty and administrative offices, making this part a long model configuration, which in this instance reflects the social status of faculty members and regulates interactions between faculty members and between faculty and students (Figure 3). The all axial line and VGA analyses show this as the most accessible area in the building, with the greatest potential to become a space of “requirement” in Hogwarts fashion (Rowling, 2004). This is a short model space, in which restrictions are minimized, user co-presence is visual and physical and relationships are defined by local rather than global connections. The space supports random movements and encounters and enables user agency in the form of purposeful being (space holding) and navigating (space claiming). As the tightly gridded chessboard is inhabited by pieces that move differently and serve diverse functions, compressed space in the IST is counteracted by the numerous user types defined by discipline (pieces) and diverse research and educational aims to which common areas may be put (tactics and strategies to the endgame of knowledge creation and communication).

Figure 3 - IST building upper floor: all line axial connectivity map and VGA integration.

On-site observations revealed that open access to the faculty corridor and proximity to the study/library area do add an informal, serendipitous element to encounters and interactions. In a sense, the entire board can be surveyed at a glance. Students in the study area see the professors and professors see the students. Such openness helps to reduce psychological barriers that could inhibit students from approaching and talking with their professors.

4. CONCLUSIONS

4.1 MORPHOGENESIS AS “BEAUTIFUL PROBLEM”

The IST embodies a blend of short and long models, respectively restraining and liberating movement and visual accessibility depending on one’s location within the building. Returning to Hillier’s (2007) view that morphogenesis, or the creation of unprogrammed outcomes, may result from combining local rules and randomness, the researcher is left to wonder if the IST will become a hub for experiential learning in a qualitatively different manner than its counterparts at other universities, both old and new. Its thoroughgoing castleness (complete with crenellations, moat, grand staircases, great hall and chamber-like classrooms and labs), reflects a quite conventional, if grandly aestheticized, monastery, the original architectural template for campus plans. This is in no way to say that the IST will not enable new knowledge formation, just that it may be more conventional than futuristic.

Chess is a game of conventions and most games are won by the player best equipped to employ those conventions through a complex suite of patterns, preordained moves and serendipitous openings to the endgame. To quote Marcel Duchamp: “I always loved complexity. With chess one creates beautiful problems” (as cited in Shenk, 2006, p. 185). Chess is a window for grasping
complex systems. Much as chess rules are learned and executed by silent players, spatial configurations reflect a predetermined, ‘pre-linguistic’ set of social conventions articulated by the architect and acted out by and upon users, who perform the dual roles of agent and piece. Akin to chess, design may be “solely purposive,” yet, as Benjamin Hale has observed, “even strategic arrangements share a formal presupposition with nonstrategic arrangements” (p. 159). Rules govern the movement of pieces, but not the specific decisions that players make, leaving room to strategize and choose between moves. This processuality (rather than outcome) is key to this initial examination of the participatory parallels in Calatrava’s IST.
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SYNTACTIC STUDY OF THE OLD AND THE NEW DOUIRET VILLAGES.
Study of the new homes spatial reconfiguration generating process in the new village of Douiret

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ABSTRACT
This paper aims to make a comparative syntactic study on a former Tunisian troglodyte Berber village that has undergone a massive “dislodging” operation of its population of Berber culture, the former “Douiret” on one hand and, on a newly built village, “the new Douiret “, with the same dislodged population, on the other hand.

In 25 years’ time span, this population has triggered a process of distortion and reconfiguration of the resettlement areas in the new village. The latter was remodelled and reshaped by numerous and undeniable curiously different formal transformations of their original habitat in the old Douiret.

We explore in this study the generating process of these changes. The comparison aims to find a hypothetical relationship between the ancient cave dwellings and the new housing units after their modification. Our hypothesis is that between the two areas, the old and the new, and beyond their very different physical conformations, there would be a relationship governing the structural reorganization of the new homes. We seek through our comparative study to show that the spatial reconfiguration follows in fact a morphogenesis process in a topological organizational structure inspired from old ancient structures found in older homes.

With Space syntax we first of all have found that there are similar types of structures in the houses of two villages. Thus, residents have corrected and readapted their living spaces by restructuring them along the same organizational process. The space syntax tools allowed us to find that these transformations, seemingly anarchical, are actually organized according to types of a configurational order.

This study also allowed us to find a representation that we called “permeability pathways” (PPs) embodying the topological organization in each type of pattern. Comparing the “permeability paths” belonging to the same types revealed a recurrence in the configurational topology found in different physical conformations.

KEYWORDS
Spatial reconfiguration, comparative syntactic study, topological organization, permeability paths
1. INTRODUCTION

Douiret, a hundred-year-old troglodytic dwelling Berber village located in the mountainous area of southern Tunisia, juxtaposes another village, newly built in 1990, called “the new village of Douiret”. The former is in a state of ruin and abandonment whereas the latter appears anarchic and disordered.

In reality, in the context of urban renewal, entering into the process of “modernity” as seen thought and undertaken by the political leaders of Tunisia in the mid-1980s, large-scale relocation operations were applied urgently to several tissues considered as archaic, unhealthy and very “traditional” in the eyes of politicians. These operations aimed at curing all the disorders and the dysfunctions identified in these old tissues were applied without any real operational strategies of intervention.

These approaches become even more important when they investigate specific human settlements of the built heritage: such as our case study: the vernacular village of Douiret. A village long neglected and abandoned by the authorities and which, due to lack of maintenance, witnessed a long process of deterioration. These vernacular dwellings housed a homogeneous Berber community, jealous of its particular socio-cultural traditions in a country which has been “arabised” for hundreds of years and which bears marked traces of French colonization both socially and architecturally. These inhabited spaces represented much more than simple boxes for the population: they organized a whole way of life (André, L., 1975).

During these operations, this entire population was displaced, forced to leave its ancestral village the “former Douiret”, and relocated to a new village specially built for her, some 2km from the old one called ‘The new Douiret’.

In the 25 years span, the new village has changed its morphological aspect. The population has undeniably reshaped the new habitation fabric. There are extensions and transformations and a striking mutation in the forms of the initial units of the dwellings, which are obviously different from their original habitat found in the former Douiret.

Over time, this operation became an antagonism between the concepts of the developer, expressed by their programs and execution, and the practices of the relocated, expressed by the remodelling and reshaping of the buildings originally conceived. There is even a tendency to speak of a “degradation of the new village”.

Our study proposes to go beyond the visible and the hasty and subjective interpretations on a purely formal observation. We question the importance of the mental representation of the spaces and the links that the sub-spaces can have in their composition of space. Is there a hidden order in an apparent disorder?

Morphologically different, would these houses hide in their configurational organisations a link with the old vernacular dwellings of the “old Douiret”? What links can these transformations have with the spatial characteristics of old homes?

Through a comparative study of the structural organisations between the ancient troglodytic dwelling of the old village and the new habitation transformed by the inhabitant in the new village, we explore in this study the generating process of these transformations.

2. DATASETS AND METHODS

2.1. PRESENTATION OF THE CASE STUDY

Our work explores a specific human settlement, the Berber community of a mountain in the Tunisian South, with the specific social and cultural context, and the characteristics of the old village of Douiret: a troglodytic village belonging to the Tunisian cultural heritage.

Our study site is located in a mountainous area at the gates of the desert. It is composed of two villages: on one side the ancient village of Douiret, troglodytic, built by the population itself over time for hundreds of years, now in a state of ruin and abandonment located on the flank;
On the other hand, the new village at the foot of the same mountain, some 2 km from the first, built by the State through a state body in 1990 to house all the displaced community of the old village. In order to take into account the new spatial transformations and update the graphic documents, a comprehensive survey was carried out in 2015.

2.1.1. THE FORMER BERBER TROGLODYTIC VILLAGE OF DOUIRET

The singularity of the old village of Douiret lies in its location, and in the techniques and building materials used, so it seems to form part of the mountain and the surrounding environment.

The troglodytic houses of Douiret appear similarly ordered. It is a century-old vernacular architecture that reflects the material and ideal needs of its inhabitants. The dwellings are generally composed of several rooms dug horizontally in the rock (ghar), in front of the hollow ghar extends a raised and discovered terrace (doukkana) connected by stairs to a sort of patio (bawh). A stone built part in front of the rooms stands between the street and the patio, in which there are cells serving as family granaries (ghorfa), a kitchen (matbakh), sometimes a livestock barn (zriba), and chicane (skifa) mark the separation between the street and the interior of the dwelling. These walls are at the same time partitions and ramparts and are built in materials from the mountain itself (the rocks extracted from the caves). The number of ghar cells grows as the family grows. [Figure 1]

2.1.2. THE NEW VILLAGE OF DOUIRET:

In order to improve its living conditions, the population was granted social housing a few kilometres down from the old village, a new settlement called “the new village of Douiret”.

The process of dislodging and reintegrating the inhabitants of the former village into the new village took place over a five-year period (1985-1990).

The initial urban development plan (1990) contains six variants of the same typical plan. The difference between the variants lies in the dimensions of the spaces and the type of roofs (flat or vaulted). The typical house is simple in shape with rudimentary spaces for a lower cost. It is 12m/9m and composed of a room of 4m / 3m juxtaposed with a kitchen of 3m / 3m overlooking a court of 6m/7m containing a toilet of 1m / 1m [Figure 2]. The urban plan is composed of several

Figure 1 - Views, plan and section of the troglodytic house of the old village of Douiret.

Figure 2 - Views of the typical house of the new village of Douiret.
blocks; a block is constituted of semi-detached houses in parallel strips. The strips are formed by two or more juxtaposed houses.

At the beginning and for the implementation of this work we carried out in a methodical and organized way the updating and the reconstitution of the urban development plan of the agglomeration in 2015 (Menaja Bessioud, 2015). A systematic and meticulous in-situ survey of all the dwellings (208 specimens) and the equipment (7 specimens) was carried out by the all available documents (plans, facades, photographs). All the dwellings were listed in individual sheets including: plans, facades, photographs, location and composition in terms of spaces. We then successively superimposed the new plans on a mass plan dating back to 1995 that was provided to us by the Ministry of Equipment. The work obtained is an updated development plan which contains all the dwellings of the new village as they are in 2015, carried out in an exhaustive manner. [Figure2].

According to the same principle observed in the ancient dwellings, the family structure that occupies these houses is generally extended; it is composed of the family nucleus (parents + children) with the grandparents and paternal uncles. The extension of the house allows for the newly married children (sons) to settle in private rooms while sharing common spaces (kitchen, pantry, storeroom, zriba, garage, and toilet). For larger families and due to the lack of space, some married children settle in independent houses but always close to the family home.

Figure 2 - Comparison of the house initially built and after transformation and the Urban Development scheme updated in 2015.
2.2. METHODOLOGY

Morphologically, the new transformed dwellings of the new village of Douiret are different, on one hand between each other-in fact the modifications made are not similar and each house is singular in relation to the other- and on another hand, compared to the old troglodytic dwellings where visible and formal disparities become obvious.

But beyond a comparison of the purely formal aspect, we thought of finding deep links between spaces: a spatial-configurational structural organisation which, despite the multitude of possibilities of spatial conformations and their geometrical and plastic characteristics, would be stable both in the new dwellings between them and on between the new houses and the old troglodytic dwellings.

This has led to the choice of the method of analysis, namely Space syntax (Hillier, Hanson, 1984). A method that investigates relationships and spatial links between elements and sub-elements that constitute a system (the object of study) and that allows to represent and describe them in terms of types of relationships and neighbourhood ties that allow characterizing them and identifying the organizational structures they make up (Hillier, 1996). A method that remains morphological because it allows us to have spatial measurements that are very sensitive to any morphological variations of spaces at the level of the dwelling; able to describe the socio-spatial properties of spaces and the syntactic relations between them. This may lead us to discern the expression of a spatial organization and from there to find a certain configuration structure. Finally, it is a method that allows us to correlate spatial organization and social behaviour but in terms intrinsic to the architectural discipline. All of the results obtained lead to a deciphering of the spatial organization of the whole system and make it possible to establish and represent an organizational structure in a configurational sense (Hillier, Hanson, 1984).

A spatial and syntactic analysis has been carried out on, firstly the troglodytic houses of the old village of Douiret and secondly the houses transformed in 2015, that is to say 25 years after their occupation by the population and the changes brought to them by the inhabitants. This enabled to identify types, patterns and syntactic characteristics of each house, and look for matches between types and which comparisons can inform us about the forms of stability that may exist.

The work was carried out on several levels

- 1. The codification of the spaces throughout the corpus and the matching between the spaces in the troglodytic dwellings and the modified houses.
- 2. A syntactic spatial study on the ancient and the new transformed dwellings to reveal types, subtypes and spatial-syntactic characteristics of each subspace.
- 4. Identify analogies between types between old and new dwellings.
- 5. Find the stability of the organizational structures of spaces between analogous types.

3. RESULTS

3.1. DIACHRONIC COMPARATIVE ANALYSIS BETWEEN THE OLD TROGLODYTIC DWELLINGS AND THE NEW TRANSFORMED DWELLINGS

3.1.1. THE CODIFICATION OF SPACES

A space coding table was developed, a letter has been assigned for each space, and a letter with an index number (its number) if there are several spaces with the same name. This table is applicable to the whole corpus: the old troglodytic dwellings and the transformed houses surveyed. (Menaja Bessioud, 2015). This makes it possible to compare the structures between the different corpuses in all objectivity. The coding takes into account the different nomenclatures and toponyms of the spaces in the different houses of the corpus. Indeed, the names attributed by the inhabitants can sometimes vary to designate only one space, depending on whether it is
a former dwelling or a new house: there is a linguistic mutation identified even in the dialect of the douiri inhabitants (Arabisation, Modernisation, cultural influences ...). This coding made it possible to have a better and objective reading of the spaces forming each house, to visualize their typological relationships and to identify possible patterns and structures. The structure thus obtained is an objective form which does not take into account the often subjective plastic descriptions. [Figure 3]

**3.1.2 SPATIAL-SYNTACTIC ANALYSIS OF ANCIENT DWELLINGS**

The purpose of this study is to identify the organizational principle of the spatial structure of the troglodytic dwelling, to understand the relationships that can occur between the subspaces of the same house and to find a principle or structure that governs these dwellings.

In this section the different structures of the dwellings will be looked at in order to detect a possible recurrence between them.

The elaboration of the justified graphs and the resulting syntactic calculations allowed us to classify and compare the spaces according to their syntactic characteristics. We recorded the RA (Relative asymmetry) values of all the subspaces of all the dwellings that we classified in ascending order in each dwelling. We then associated with each value the code of the space that corresponds to it. We thus obtained coded structures for each dwelling. Spaces with the same value are represented by their juxtaposed codes without separation (they form a section) and the passage from one value to another is marked by a (-) link. The observation and comparison of the coded structures revealed a form of stability between the specimens located at the distribution spaces: the courtyard (C) and the skifa (B). The number and organization of these spaces in relation to one another will determine in our work the construction of types. A table of types is thus drawn up.

Subtypes are subsequently identified in the types, according to the composition and the positional variations of the sections relative to each other, and in particular in this case of study, according to the position of the street (A) compared to other spaces. We thus obtain a first table. By comparing them we have grouped the dwellings with the same coded structure: patterns are therefore identified.[Figure 4]

We observe in this first work that 2 specimens can have the same coded structure and therefore the same principle of spatial and configurational organisation without necessarily having identical geometric appearances.

The analysis of the corpus of the former Berber dwellings of the ancient village of Douiret reveals the presence of 3 types of structural organisations in which all the old troglodytic dwellings of the corpus studied can be grouped together. These types are determined by the number of distribution spaces, their mutual relations and with the rest of the spaces. We note...
that for type1 and type2 we have the same type of graph and yet at the level of the syntactic calculations the values of RA differ, which implies a difference at the level of organisational structure.

3.1.3 SPATIAL-SYNTACTIC ANALYSIS OF NEW MODIFIED DWELLINGS

In the first place, we carried out surveys on social and spatial practices in the modified houses (Menaja Bessioud, 2015). We found that many spaces were added to the original plan. These additions make it possible to fill the lack of spaces for the practice of certain specific and important domestic activities in the daily life of the inhabitants. The number and the nature of these spaces vary according to several factors: the number and the composition of the families, their work, their economic level, the size of the spaces reserved for extension ... etc. [Figure 5]

However, we also noticed that beyond the material need in living spaces, the inhabitants make changes in the relationships between spaces: doors, courtyards, passages ... thus, the relations between the spaces within each house can undergo numerous evolutions and attempts at modelling and remodelling, reflecting dissatisfaction with the spatial organisation in the practice of space emanating from a desire to modify the circuits of passage and circulation from one space to another.
We then systematically calculated the post-occupation spatial-syntactic properties in all the spaces of all the houses (208 specimens). In the first place, we have elaborated the justified graphs making it possible to highlight the links of permeability between the different spaces of each house. The development of types in the new houses follows the same process used in the design of the types of old dwellings. Once the graphs were constructed we computed the syntactic calculations and classified the RA (Relative asymmetry) values in each specimen in ascending order.

From there, the same coding (used in the old houses) is applied which allowed the construction of structures comparable with those of ancient dwellings and the revelation of the principle of organisation of the spaces of each specimen in an objective way. We then made comparisons on the same principle as the comparisons already made in the previous section, in order to identify the patterns. We first identified and grouped together the specimens with the same structures. In a second step, we compared the coded structures of the specimens of our corpus; we were able to identify the existence of patterns (forms of stability between the specimens). We note that the most integrated space and which therefore occupies the first place in all cases of the study is the distribution space: a buffer space which can be the court or the skifa (the chicane) or both together. These spaces can be single or multiple and can have the same values or have consecutive values.

Thus all the possible combinations detected between these two spaces (C and B) help us to identify the types of our corpus: according to their nature, their number, their organisation and their links. The result is a table that highlights the structures found.

In this section let us remember that the letter represents the code of the space, each set of spaces having the same values is considered as a section. The sections are separated by a (-) connection: this marks the passage from one RA value to another. Two juxtaposed letters without hyphens mean they have the same RA value. The relation of the distribution spaces (in this case the court (A) and the Skifa (B)) with the street (A) determines these subtypes. [Figure 6]
### Table of Classifications of Coded Structures of Specimens of New Dwellings and Identification of Types

<table>
<thead>
<tr>
<th>Types</th>
<th>Composition</th>
<th>Abbreviation</th>
<th>Coded Structures</th>
<th>Numbers of Specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td>TYPE 1</td>
<td>C-</td>
<td>ST4</td>
<td>C-EFGL</td>
<td>49-55: 62-126-164-247</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ST3</td>
<td>C-EFGAD</td>
<td>209-215</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ST4</td>
<td>C-EFGALD</td>
<td>12-162-167-249-449</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ST5</td>
<td>C-AD-FLG</td>
<td>36-60-38-103-161-121</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ST6</td>
<td>C-A-EGF-D</td>
<td>10-11-30-71-141-180-163-372</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ST7</td>
<td>C-A-FLG-D</td>
<td>99-106</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ST8</td>
<td>C-A-IEFG-D</td>
<td>45</td>
</tr>
<tr>
<td>TYPE 2</td>
<td>CC-</td>
<td>ST45</td>
<td>C-AM-EFLMG</td>
<td>129-145</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ST46</td>
<td>C-AM-EFLDL</td>
<td>151-81-156</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ST47</td>
<td>C-AM-EPH-D</td>
<td>189-166</td>
</tr>
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<td></td>
<td></td>
<td>ST10</td>
<td>C-C-EFLG-D</td>
<td>7-35-75-78-337-440-174-152-259-207-229</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ST11</td>
<td>C-C-EFLG-D</td>
<td>84-134</td>
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<tr>
<td></td>
<td></td>
<td>ST12</td>
<td>C-C-EFLG-D</td>
<td>115-485-593-150-126-13-87</td>
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<td></td>
<td>ST13</td>
<td>C-C-EFLG-D</td>
<td>6A-48B-187</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ST14</td>
<td>C-C-EFLG-D</td>
<td>222-43</td>
</tr>
<tr>
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<td>ST15</td>
<td>C-C-EFLG-D</td>
<td>200-120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ST16</td>
<td>C-C-EFLG-D</td>
<td>17</td>
</tr>
<tr>
<td></td>
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<td>ST17</td>
<td>C-C-EFLG-D</td>
<td>135</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ST18</td>
<td>C-C-EFLG-D</td>
<td>122-123</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ST19</td>
<td>C-C-EFLG-D</td>
<td>126-64</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ST20</td>
<td>C-C-EFLG-D</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ST21</td>
<td>C-C-EFLG-D</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ST22</td>
<td>C-C-EFLG-D</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ST23</td>
<td>C-C-EFLG-D</td>
<td>223-220-220-228</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ST24</td>
<td>C-C-EFLG-D</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ST25</td>
<td>C-C-EFLG-D</td>
<td>305-21-23</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ST26</td>
<td>C-C-EFLG-D</td>
<td>190</td>
</tr>
<tr>
<td>TYPE 3</td>
<td>C-C-</td>
<td>ST27</td>
<td>C-AM-EPH-D</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ST28</td>
<td>C-AM-EPH-D</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ST29</td>
<td>C-AM-EPH-D</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ST30</td>
<td>C-AM-EPH-D</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ST31</td>
<td>C-AM-EPH-D</td>
<td>34</td>
</tr>
<tr>
<td>TYPE 4</td>
<td>CB-</td>
<td>ST32</td>
<td>C-AM-EPH-D</td>
<td>34</td>
</tr>
</tbody>
</table>

Figure 6 - Table of classifications of coded structures of specimens of new dwellings and identification of types
The spatial-syntactic study of modified houses established that despite the multitude of possibilities of spatial conformations of houses and their very different geometric and plastic characteristics, we can detect forms of organizational stabilities that emerge in the spatial configurations.

3.1.4. ANALOGY BETWEEN THE TYPES OF OLD HOUSES AND NEW HOUSES IN DOUIRET

For the rest of the work we took into account only the specimens which represent the houses which are no longer under construction, that is to say, the houses which will no longer undergo new transformations and whose owners, after investigation, expressed their satisfaction. We found that all specimens of houses with stabilized structures belong to type2, type3, type5 and type6.

We therefore began our comparative work with a first comparison between the types found for the modified houses with stabilized structures and the former Berber dwellings. The following table sets out this work:

<table>
<thead>
<tr>
<th>Types of old houses</th>
<th>Structures of new post-occupation houses with stabilized structures</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1 (ancient houses)</td>
<td>CC-</td>
</tr>
<tr>
<td>T2 (ancient houses)</td>
<td>C-C-B-</td>
</tr>
<tr>
<td>T3 (ancient houses)</td>
<td>C-B-</td>
</tr>
<tr>
<td>T6 (new houses)</td>
<td>C-C-</td>
</tr>
<tr>
<td>T5 (new houses)</td>
<td></td>
</tr>
</tbody>
</table>

This table highlights many results:

- All the typological structures of the former dwellings are included in all the types of new dwellings with stabilized structures. [Figure 8]
- Analogies can be made between the types of old and new houses based on the coded structures representing each type, as follows:
  - T1 (ancient houses) → T2 (new houses)
  - T2 (ancient houses) → T6 (new houses)
  - T3 (ancient houses) → T5 (new houses)
- A first very important result emerges from our study: beyond the physical conformations, the analogy between the types already allows us to trace a relationship between the old troglodytic dwellings and the new modified houses with stabilized structures.
- This very important result in itself will allow us to carry out research on the common points that may exist between the organizational structures in terms of spaces and spatial links between old dwellings and new dwellings, by type.
- We have therefore translated the types of the former Berber dwellings and the new modified houses with stabilized structures found in the previous table into topological structures expressed in terms of spatial links. Thus, each structure is expressed in terms of links between sections and each section in terms of “group of functions”, and this for each type. The comparison of spatial organisations in each group of similar types will serve as a comparative basis by a set of similar types to reveal the organizational principles re-adopted by the inhabitants in their process of re-designing their living spaces.
### Comparative Table of Topological Structures and Matches

<table>
<thead>
<tr>
<th>House Type</th>
<th>Structure</th>
<th>Structural Organisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ancient House</td>
<td>CC-X-AM</td>
<td>Distribution area - Distribution area2 - Service area - Living area - The Khanaa</td>
</tr>
<tr>
<td>New House</td>
<td>CC-AI-X</td>
<td>Distribution area - Service area - Living area - The street - The garage</td>
</tr>
<tr>
<td>New House</td>
<td>CC-X</td>
<td>Distribution area - Service area - Living area - The street</td>
</tr>
<tr>
<td>Ancient House</td>
<td>C-C-B-XD-A-M</td>
<td>Distribution area - Distribution area2 - Service area - Living area - Stable (Ziba) - The Khanaa</td>
</tr>
<tr>
<td>New House</td>
<td>C-C-B-XD-A</td>
<td>Distribution area - Distribution area2 - Service area - Living area - Stable (Ziba) - The street</td>
</tr>
<tr>
<td>New House</td>
<td>C-C-B-XA-D</td>
<td>Distribution area - Distribution area2 - Service area - Living area - Stable (Ziba) - Shop</td>
</tr>
<tr>
<td>Ancient House</td>
<td>C-B-XD-A-M</td>
<td>Distribution area - Distribution area2 - Service area - Living area - Stable (Ziba) - The Khanaa</td>
</tr>
<tr>
<td>New House</td>
<td>C-B-X-AM</td>
<td>Distribution area - Distribution area2 - Service area - Living area - Stable (Ziba) - The Khanaa</td>
</tr>
<tr>
<td>New House</td>
<td>C-B-X-A</td>
<td>Distribution area - Distribution area2 - Service area - Living area - Stable (Ziba) - The street</td>
</tr>
<tr>
<td>New House</td>
<td>C-BD-X-A</td>
<td>Distribution area - Service area - Living area - Stable (Ziba) - The street</td>
</tr>
<tr>
<td>New House</td>
<td>C-B-X-AD</td>
<td>Distribution area - Service area - Living area - Stable (Ziba) - The street</td>
</tr>
<tr>
<td>New House</td>
<td>C-BI-X-A</td>
<td>Distribution area - Service area - Living area - Garage - The street</td>
</tr>
<tr>
<td>New House</td>
<td>C-B-A-X</td>
<td>Distribution area - Service area - Living area</td>
</tr>
</tbody>
</table>

**Figure 8** - Comparative table of the topological structures of the old dwellings and their matches in the new dwellings.
• We note here that the space of the Khazna (assigned the M code) belonging to the former dwellings and acting as a safe for the valuables has been suppressed in all the new dwellings and replaced by a piece of furniture: A wardrobe or a safe.

• This work made it possible to find organizational stability in the spatial configurations in terms of topological structures and spatial links between the new houses with stabilized structures and the former Berber dwellings of the former village of Douiret.

3.1.5. COMPARISON OF SYNTACTIC CHARACTERISTICS BETWEEN NEW DWELLINGS AND NEW HOUSES BELONGING TO THE SAME TYPES

The following table shows a comparison of some syntactic features between old houses and new ones that belong to the same types.

| Types      | Habitations | RRA  | Depth | MD  | Rings | SLR | BDF 
|------------|-------------|------|-------|-----|-------|-----|-----
| CC-        | H1          | 0.97 | 5     | 2.61| 0     | 1   | 0.99
|            | M146        | 0.91 | 4     | 2.25| 0     | 1   | 0.99
| C-C-B-     | H2          | 0.99 | 5     | 2.61| 0     | 1   | 0.98
|            | M34         | 0.98 | 4     | 2.24| 0     | 1   | 0.95
| C-B-       | H3          | 0.94 | 4     | 2.17| 1     | 1.22| 0.92
|            | M195        | 0.94 | 3     | 2.13| 1     | 1.1 | 0.86

Figure 9 - Comparative table of syntactic characteristics between specimens of the same type

The syntactic characteristics between the specimens are homogeneous in all types. It is noted that the values of the BDF (Base difference factor) vary between 0.86 and 0.99, which shows that these systems are non-rigid and consist of interchangeable subspaces. Depth levels and MD values show that these spaces are moderately deep. In general, the structures tend to be integrated with RRA values varying between 0.91 and 0.99. With a value of SLR (Space Link ratio) = 1, the majority of the systems are in tree and denote a rather closed space. Only a few specimens express systems which tend to be distributive and ringy, with higher values but which remain close to 1.

3.2. SPATIAL-ORGANIZATIONAL COMPARISON BETWEEN OLD DWELLINGS AND NEW POST-OCCUPATION HOUSES WITH STABILIZED STRUCTURES AND PERMEABILITY PATHWAYS

In this work we try to find the points of stability between the organization of spaces and circuits as they are found and represented in old houses with those found in new houses with stabilized structures.

We therefore carried out a comparison by group of two: in each type we took an old house and a new house, which represent the type. We have developed new graphs which spaces are coloured according to the functions to facilitate the comparison in terms of spatial organization according to depth levels.

In order to highlight the circuits followed by the inhabitants during their movements in the house to pass from one space to another, we have developed a process called «permeability pathways”. These are circuits established on the bottom of the graphs, which describe the successions of spaces necessarily borrowed by the inhabitants as they move from the entrance of the house to the objective space.
In our study, we detected the existence of four (4) possible pathways of permeability (PPs):

- PPs leading to living spaces (rooms).
- PPs leading to the service areas (kitchen, pantry, wc)
- PPs leading to the barn (zriba)
- The PPs leading to the shop

Each circuit is distinguished by a different colour, allowing us to have descriptions of the number of passing choices to reach the objective space, the types of traversed spaces, the number of borders to pass, and Depth in the system. In addition, comparing the circuits of the corpus houses with each other allows us to visualize the aspect of the stability and permanence of certain circuits. Thus, it is possible to verify whether, during the process of spatial reconfiguration, the inhabitants would give importance to the direction of movements from one space to another (materialized by a stability of the PPs in all the houses) and the passage required by a space for to reach another. [figure10]

<table>
<thead>
<tr>
<th>types</th>
<th>Elements</th>
<th>Example of Old houses</th>
<th>Example of New modified houses</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC-</td>
<td>Spatial-organizational characteristics</td>
<td><img src="image1" alt="Chart" /></td>
<td><img src="image2" alt="Chart" /></td>
</tr>
<tr>
<td></td>
<td></td>
<td>H_1</td>
<td>M_{151}</td>
</tr>
<tr>
<td>CB-</td>
<td>Spatial-organizational characteristics</td>
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<td><img src="image4" alt="Chart" /></td>
</tr>
<tr>
<td></td>
<td></td>
<td>H_4</td>
<td>M_{66}</td>
</tr>
<tr>
<td>plan</td>
<td></td>
<td><img src="image5" alt="Plan" /></td>
<td><img src="image6" alt="Plan" /></td>
</tr>
</tbody>
</table>

SYNTACTIC STUDY OF THE OLD AND THE NEW DOUIRET VILLAGES.
Study of the new homes spatial reconfiguration generating process in the new village of Douiret
Figure 10 - Comparative table of spatial-spatial characteristics and pathways of permeability in old homes and new houses belonging to the same types
This table has yielded important results regarding the stability and mutation in spatial organizations between old houses and new houses belonging to the same types: paths tend towards reorganization close to the ancestral model.

First of all, we emphasize the suppression of the space of the Khazna in all the new houses; and the creation of two new spaces, the garage and the small shop, in margin with the demands of modern life. These changes resulted in the removal of a level of depth in the graphs of the new houses, which was reserved only for the Khazna in the old houses, and the appearance of two spaces (the garage and the small shop) adjoining both the street and inside the house in the graphs of the new houses.

- In all the houses, whether old or new, living spaces are always represented in the graph at the deepest level.
- The permeability path (PP) of the living spaces must imperatively pass through all the distribution spaces composing the house.
- Living spaces should not be directly attached to the skifa. It is a form of stability that is found in the interpretation of the relations that spaces must have with each other to pass from one space to another.
- If you are in the presence of 2 courts in the type, all the living spaces open on the 2nd courtyard. The first courtyard, which adjoins the skifa, is reserved only for service areas.
- In all cases of study it is necessary to cross at least two spaces of distribution in order to reach the spaces of life.
- The permeability path (PP) of the service spaces can occur in the same graph at two levels of different depths. This shows that these spaces can be distributed on two levels of different depths. Conversely, the PPs of the living spaces must imperatively lead to the same level of depth: the last.
- The path of permeability of zriba, shops and garages never reach the last level of depth.
- In almost all specimens, there is no living space or service that opens directly onto the skifa, it is a space of passage. The only exceptions are the probability of finding the zriba (in both houses) or the garage (in the case of new dwellings) adjoining the skifa.
- The kitchen space is always at the same level of depth as the living spaces.
- A single node can be found in the graphs of all specimens.
- Nevertheless, it is remarked that in the old houses the street never participates in the nodes. By cons in the new houses the street can participate in the nodes and this in several specimens. These nodes are related especially with the new spaces created and which are the garage and the small trade.

4. CONCLUSIONS

The elaboration of syntactic calculations resulting from morphological measurements has made it possible, in addition to informing us about the spatial characteristics of the components of the houses, to find forms of stability (patterns) at the level of the structural configurational principles between the different specimens collected and to construct structures revealing spatial organizations by classifying and comparing the values of each space in each specimen. These patterns detected in houses despite their different formal appearances confirm the presence of a non-apparent order that governs the inhabited space in the village inscribed in the form itself. The confrontation of patterns, spatial characteristics and pathways of permeability reveals a spatial configuration inscribed.

The presence of circuits imposed on users of space, which are imperceptible when travelling within houses, and organizing the movements of the inhabitants, means that the practice of space is embedded in form and that it is of importance for the inhabitants who have reproduced
them through the transformations of the new dwellings in an intuitional way. These circuits and the creation of certain spaces in the new dwellings persist in certain cultural values of Douiri society. We cite respect for privacy and this by relaying and aligning all intimate living spaces to the last level of depth through the creation of Skifa-type buffer spaces or a 2nd courtyard between the living spaces and the outside. The creation of distribution spaces (courtyard and skifa (chicane)) has, on the one hand, preserved certain values (separation of public and private areas, strong control over passage to the rooms for safety reasons) and on the other hand to perpetuate certain traditions linked to the daily domestic life of the inhabitants and their subsistence.

Indeed, it is in the courtyard, become private and away from the street (thanks to the creation of a skifa or a 1st courtyard), that various activities take place: washing and drying of the linen, reception of guests, preparation the bread and, on a seasonal basis, preparation of the main sources of their food for their preservation (provisions for wheat kernels, bread semolina and drying figs, olives and dates for storing ) The activity of weaving (a know-how and an important economic activity for the Douiri society which begins with the preparation of the wool and ends with the making of the carpets) is also taking place there. The creation of the zriba, the pastoral activity being the main one for the population because it is a source of income, food and wool, also allowed continuing an economically important activity for the Douiri society.

Thus, the interpretation of the comparative spatial-syntactic analyses of the houses of the two villages of Douiret, allowed finding that the modification process taken over by the population relocated in the new houses, describes a morphogenetic process that follows a topological organizational structuring inscribed in the old troglodytic dwellings.
SYNTACTIC STUDY OF THE OLD AND THE NEW DOUIRET VILLAGES.
Study of the new homes spatial reconfiguration generating process in the new village of Douiret

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MODERNIST DWELLINGS IN LISBON, PORTUGAL
A Syntactic Approach to Living Use Analysis

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ABSTRACT
This paper deals with the relationship between domestic space built in the early 60’s and the users way of living in the late 70’s, which is assessed by analyzing public housing apartment in Lisbon and the switch-over made by the users.

The study is based upon the differences between the built apartment layouts and the modified apartment’s layout that result from different ways of living or use(s) proposed by the occupant families as a reflection of their space needs. The paper analyzes five different apartment typologies and respective user modifications, having based the apartment plans (both original and modifications made by the users) in the Inquérito à Habitação Urbana, organized by Laboratório Nacional de Engenharia Civil (LNEC), in the late 70’s, which aim was to ascertain dwelling tendencies and to create a basis for future designs. The results of this research were based on a comprehensive analysis of family structure, previous dwelling, house activities, family member characterization, apartment typologies distribution in the building and the apartment interior layout.

The concepts and methods used in this paper are based on the theory of social logic of space. The analysis aims at understanding the extent to which some attributes of society redefined families’ social behavioral patterns, particularly their ways of living and use of house spaces and how these impacted the apartments’ spatial layout. Syntactic measures, namely those of integration and depth will be analyzed to better understand how the modifications made by the families best serve their ways of living and spatial needs. Apartment layouts will be analyzed by means of justified graphs. Visual graph analysis will also be carried out as a comparative assessment as a mean of validation of the former’s results. This comprehensive analysis will help understand why the modifications took place and how they reflect the occupants’ effective use of space and needs.

The paper discusses how the original dwellings do not seem adequate to families ways of living and use but also that in the majority of the analyzed apartments the interior spatial adaptations seem to be more appropriate to the their needs and patterns of living.
KEYWORDS
Housing, Dwelling Adequacy, Space Use, Spatial Adaptation, Visual Graph Analysis

1. INTRODUCTION

This paper proposes an analysis of housing units through space syntax theory. The proposed analysis consists on the study of housing units, carefully selected, examining the project design and two different user’s modifications (functional, spatial or both) of each case-study. These modifications were observed by Valente Pereira and Corrêa Gago, published in Inquérito à Habitação Urbana, in 1971, by Laboratório Nacional de Engenharia Civil (LNEC).

The buildings that support the case studies are a part of Olivais Sul housing development, an important plan in Portuguese architecture, being the first formal application of modernist principles expressed by the Athens Charter in housing design. It is also notable by the array of architects invited to design new building’s for the plan, the most significant at the time. Developed by public funding, this plan was designed to accommodate social housing and is considered to be (...) the biggest social housing ensemble (...), ‘neighbourhood’ to house almost 50000 people in Lisbon (...), and a real collective domestic design school to many professionals (…) (Almeida and Fernandes, 1993, p. 153).

Intended to serve different households (in both economical and sociological aspects), the plan proposed a total of 6458 units, to house 31000 inhabitants. The selected units were analyzed in the Inquérito à Habitação Urbana carried out a decade later by Valente Pereira and Corrêa Gago. This document illustrates plans of the units and plans that show users modifications and, more importantly, attests for user satisfaction towards the lived-in dwelling.

By selecting case-studies that have been previously analyzed and having access to inhabitants’ uses and opinions about the dwellings, as described in the Inquérito à Habitação Urbana, a more substantiated and supported investigation is allowed.

2. DATASETS AND METHODS

As mentioned previously, space syntax is the chosen methodology, defined as ‘(...) a set of techniques for the representation, quantification, and interpretation of spatial configuration in buildings and settlements (…)’ (Hillier, Hanson and Graham, 1986, p. 363). As per Hanson (1998), the first studies in housing using this theory support the notion that there is a correlation between spatial configuration and space use, stating that because of its complexity Housing is fundamental in Space Syntax.

The main goals of this paper are, on the one hand, the assessment of the housing unit as designed with the lived-in housing unit (two different uses) in order to understand the differences between design plan’s and effective use and also which solution – original design or use – enables better living conditions for the family; and on the other hand, the analogy between the results of the Inquérito à Habitação Urbana and the outcomes of the space syntax analysis, so to identify if both methodologies document the same conclusions or, if not, what relevance could this theory have in the analysis of housing typologies.

In order to achieve these goals, some space syntax methods were considered relevant – convex maps, justified graphs and Visual Graph Analysis (VGA) – as well as output calculations

1 Author’s free translation from ‘(...) o maior conjunto de habitação social (...), ‘bairro’ para alojamento de quase 50000 pessoas em Lisboa (...), e verdadeira escola do projeto doméstico colectivo que foi para muitos profissionais (...)’ (Almeida and Fernandes, 1993, p. 153).
regarding qualitative features of depth\(^2\), integration\(^3\) and choice\(^4\). Two different softwares were used in this research – Depthmap\(^5\) for VGA and AGRAPH\(^6\) for justified graphs.

As case studies, five units were selected intended to be as diverse as possible, with typologies ranging from a two bedroom to a four-bedroom unit. It was also important to analyze all the units in the Inquérito à Habitação Urbana (Vol. I and Vol. II) and choose the ones which had been modified by the inhabitants. The identification (ID) of the case studies is the same as the one found in the Inquérito à Habitação Urbana (Vol. II) so that it is easier to make a direct relation between the apartments' design plan and better compare the results.

As aforementioned graphic elements to be used in this research are simplified design plans, convex break-ups, VGA representation and justified graphs. The latter are considered paramount for they allow for a clearer reading and analysis and more validated results.

When analyzing the justified graphs it was important to identify the dwelling layout – compartment layout and functional sector (social, private and service) layout. According to space syntax theory it is possible to encounter two different layouts – tree-like layout and ringy layout. According to Hanson (1998), tree-like layout is the most common in several cultures' dwellings and it is the one that enables a greater control of inner movement and movement in relation with the exterior, making them more predictable. Apart from that, ‘(...) tree-like domestic space arrangements produce strongly programmed forms of domestic space arrangements (...)’ (Hanson, 1998, p. 278). Unlike the tree-like, a ringy layout allows for choice, or route choice, and the spaces where the rings intersect tend to be the more important ones where the more important functions and people are based (Hanson, 1998).

When drawing the graphs, options were made that can influence the results: it was decided that there should be an outer space (IN) as root of the graph, as the entrance to the dwelling; transition spaces were deemed relevant as mediators (as classified by Amorim, 1997). Hanson (1998), and, Hillier, Hanson and Graham (1986) characterize them as such:

*Transitions have the effect of insulating spaces from one another (...). (...) Strong arguments have been adduced that link the use of transitions in houses with the intent to assure that social separations within the home are strictly maintained. (Hanson, 1998, p. 285)*

*The transition space type works by more uniformly segregating interior functions through a central transition space which controls both interior relations and relations with the outside. (Hillier., Hanson and Graham, 1986, p. 385)*

Amorim (1996, p.18.11) validates these affirmations, stating the following:

*It seems that mediator units were introduced to compose different configurations, assuring one or another requirement, as segregating sectors (...) or integrating systems (...). As a joker in some card games, mediation spaces assumed different roles, according to the interest of the player, but under the general rules of the game.*

---

2 *Depth*, among a set of spaces always expresses how directly the functions of those spaces are integrated with or separated from each other. (Hillier, Hanson and Graham, 1986, p. 365)

3 (…) the distribution of integration gives a rather good account of the relative organization of the plan. (Hanson, 1998, p.43)

4 (…) the existence or otherwise of alternative routes from one space to another. (Hillier, Hanson and Graham, 1986, p. 364)

5 DepthmapX is a multi-platform software platform to perform a set of spatial network analyses designed to understand social processes within the built environment. Available at https://varoudis.github.io/depthmapX/

Apart from the dwelling layout, this study contains graphs that illustrate integration (absolute and relative) and depth of compartments and functional zones. Depth was analyzed under two different lights: using the entrance as root and the living room as root (this space was chosen above all the others because it is the backdrop of family life and the social gathering space).

2.1. THE RESULTS OF INQUÉRITO À HABITAÇÃO URBANA

Being an exemplary and ground-breaking study, the *Inquérito à Habitação Urbana* was able to assemble countless information and present important conclusions, analysing various housing facets and dwellers satisfaction, also intending to correctly social characterize the latter. In the instructions given to the interviewers some objectives are made clear: ‘(…) characterize and interpret the different modes of inhabiting a dwelling through the knowledge of who are the people (…), how they inhabit the dwelling (descriptions and interpretation of the unit’s use) and which unit they inhabit (project design characteristics) (…)’ (Valente Pereira and Corrêa Gago, 1984, p. 245).

This paper focuses in a few of those information and conclusions that are relevant to the proposed analysis. Thus, it is paramount to reference the aspects that cause dislike and that the inhabitants most stated as not satisfactory. Firstly, compartment distribution (18%), being also important the mention to the entry of the dwelling (12%), living room crossing (5%) and violation of the living room in relation to the interior (4%) (Valente Pereira and Corrêa Gago, 1984, p.110). It is essential to highlight that the primary complaint is compartment distribution, result supported by space syntax analysis namely in types 23 and 25 in which the original layout plan unit does not present the best functional layout. Living room crossing and its violation with relation to the rest of the dwelling were also pointed out in type 25 and partly in types 23 and type 28B, where the living area is treated as a transition space to one of the bedrooms. Another question relates to modifications having been registered a percentage of 42% of modifications to the initial design (Valente Pereira and Corrêa Gago, 1984, p. 112)\(^8\). Of these 38% corresponds to the creation of new compartments (as seen in Type 21 - Use 02, the creation of a compartment – home office – by reducing kitchen area, and in Type 25 – Use 01, the creation of a new transition space by reducing and enclosing one bedroom). One of the appointed motives for altering the initial layout was poor plan distribution (10%), also being stated, though less representatively, isolation and privacy (4%)\(^9\) (Valente Pereira and Corrêa Gago, 1984, p. 112). Poor layout plan distribution is also substantiated by space syntax analysis, especially in types 23, 25 and 28B.

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7 When applying “Colour by RA” for comparing different graphs, the “Colouring by RA, absolute” is useful. If analysing only one graph the “RA-relative” is better as this gives a larger range of colour and thereby a more differentiated information. (Manum, 2009, p. 3)

Relative integration can also be denominated Relative Asymmetry: The Relative Asymmetry (RA) describes the integration of a node by a value between (or equal to) 0 and 1, where a low value describes high integration. RA is calculated by the formula RA=2*(MD-1)/(k-2). (Manum, 2009, p. 2) The RA-value is defined to be 0 when a node is as integrated as possible. (…) Contrary, RA is defined to be 1 when a node is as segregated as possible. (Manum, 2009, p. 6)

In AGRAPH, warmer colors (reds) equate to values of more integration (RA near or equal to 0) and colder colors (blues) to those of less integration (equal to or near 1).

Absolute integration (i) is said to be the opposite of RA, the highest the value, the more integrated. This is the integration value of RA. Integration might be defined as the inverse of other asymmetry parameters than the RA. The most usual is to invert the RRA, the Real Relative Asymmetry, as described by Hillier and Hanson, 1984, p.111-113. (Manum, 2009, p. 6)

8 Of all these answers, only compartment distribution and dwelling entry were given as choices, the rest were referred freely by the inhabitants (vide question 64 of the inquest that, combined with question 63, reflects the Opinion of the Dwelling. Important to infer judgement on the dwelling (Valente Pereira and Corrêa Gago, 1984, p.253)).

9 Also mentioned by the inhabitants, not given as possible answer (vide question 20; along with question 19 explains the reasons for alterations that have been made to dwelling project and that are to be registered in plan (Valente Pereira and Corrêa Gago, 1984, p. 251)).
The need for isolation and privacy was largely studied in depth and integration graphs being noticeable that types 23, 25 and in some degree type 28B are the units that present greater problems with regards to bedroom privacy, specifically original layout plan unit 23 (and to some extents Use 01 of the same type) and original layout plan unit 25.

It is important to consider these findings when conducting and reading the space syntax analysis that follows, in order to better compare the two methodologies and their scopes and potential.

3. ANALYSIS AND RESULTS

Five apartment units, from the Inquérito à Habitação Urbana (Vol.II) (Valente Pereira, Corrêa Gago and Lopes, 1984), were selected and analysed as case-studies – Type 19, Type 21, Type 23, Type 25 and Type 28 – having also been selected two different user modifications per each type, except for Type 28 where two project variations and two uses of each variation were analysed.

The graphic representation of these units is presented in both simplified plans (Fig. 01) and convex maps (Fig. 02), depicting the changes from the project unit to the two uses. These alterations can be either spatial or functional, or in some cases, both.

In Type 19, a two-bedroom small unit, the noticeable modifications in Use 01 are spatial – the asserted adjoining of the two living areas – and functional – the specialization of these living areas, dividing them functionally into living room and dining room; in Use 02 the alteration is carried out in the opposite direction – the once part of living area is closed off and created a bedroom and one existing bedroom is transformed into a living area.

Type 21, a three-bedroom dwelling, is modified in Use 01 in the following way – the closing of one of the living room entrances and the conversion of a bedroom into a home office; and in Use 02 the making a home office by reducing the kitchen area. In both Uses, the kitchen ceases to have two accesses, remaining the one furthest from the dwelling entrance.

Type 23 is a four-bedroom unit, with a three-bedroom unit variation. In Use 01 the alterations lie on the closing of the bedroom adjoining the living area and, also the closing of the visibility between the kitchen and living space. Use 02 corresponds to the three-bedroom variation and displays the same modifications.

Type 25 is again a two-bedroom unit which modifications occurred only in the spatial sense and regarding the bedroom near the entrance – Use 01 encloses the bedroom but allows for the existence of a circulation and transition space, whereas Use 02 enlarges the same bedroom by enclosing it near the entrance transition space.

The last case, Type 28a and 28b are both two-bedroom units. Use 01 of 28a consist of the removal of the connection between the living area and the kitchen support area; Use 01 of 28b preserves this link but ends the one between the living area and the circulation and transition space near the dwelling’s entrance.
### Figure 1 - Simplified plans of all dwellings types

<table>
<thead>
<tr>
<th>Project Unit</th>
<th>Use 01 Unit</th>
<th>Use 02 Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type 19</strong></td>
<td><img src="image1.png" alt="Type 19 Use 01" /></td>
<td><img src="image2.png" alt="Type 19 Use 02" /></td>
</tr>
<tr>
<td><strong>Type 21</strong></td>
<td><img src="image3.png" alt="Type 21 Use 01" /></td>
<td><img src="image4.png" alt="Type 21 Use 02" /></td>
</tr>
<tr>
<td><strong>Type 23</strong></td>
<td><img src="image5.png" alt="Type 23 Use 01" /></td>
<td><img src="image6.png" alt="Type 23 Use 02" /></td>
</tr>
<tr>
<td><strong>Type 25</strong></td>
<td><img src="image7.png" alt="Type 25 Use 01" /></td>
<td><img src="image8.png" alt="Type 25 Use 02" /></td>
</tr>
<tr>
<td><strong>Type 28 (a)</strong></td>
<td><img src="image9.png" alt="Type 28 (a) Use 01" /></td>
<td><img src="image10.png" alt="Type 28 (a) Use 02" /></td>
</tr>
<tr>
<td><strong>Type 28 (b)</strong></td>
<td><img src="image11.png" alt="Type 28 (b) Use 01" /></td>
<td><img src="image12.png" alt="Type 28 (b) Use 02" /></td>
</tr>
</tbody>
</table>

- L - Living Area/Room
- K - Kitchen
- BR - Bedroom
- WC - Toilet
- DR - Dining Room
- HO - Office
- KSA - Kitchen support area
Figure 2 - Convex break-up of all dwellings types

L-Living Area/Room
K-Kitchen
BR-Bedroom
WC-Toilet
DR-Dining Room
HO-Office
KSA-Kitchen support area
Figure 3 - Depth justified graphs by dwelling rooms

- L: Living Area/Room
- K: Kitchen
- BR: Bedroom
- WC: Toilet
- DR: Dining Room
- HO: Office
- KSA: Kitchen support area

Gradation:
From Red (first level) to dark blue (furthest from root).
Figure 4 - RA justified graphs by dwelling rooms
Figure 5 - Depth justified graphs by functional zone (social, private, service and work)
Figure 6 - RA justified graphs by functional zone (social, private, service and work)

S-Social
P-Private
Sv-Service
W-Work

Gradation:
From Red (more central and integrated) to dark blue (most segregated).
Figure 7 - Visual Graph Analysis (VGA) using DepthmapX software
Figure 8 - Visibility justified graphs (RA)

(It is interesting to notice that in Type 25 apartments the accessibility graph is the same as the visibility graph, as is Type 19 – Use 01 apartment, indicating less complex interiors.)
To better analyse all the units, and the design layout plans unit and uses of each case study, it
is firstly important to read the justified graphs, being proposed different analysis using this
method – depth and integration (relative asymmetry – RA) concerning dwelling spaces (Figs.
03/04) and, also depth and integration (RA) concerning functional sectors (Figs. 05/06). It is
also proposed a Visual Graph Analysis, illustrating visual integration by means of isovists (Fig.
07) and justified graphs considering relations of visibility and not only accessibility (Fig. 08), as
proposed by Griz and Amorim(2015).

When analysing each type unit and comparing the design layout plan unit with the modified
dwellings it is possible to understand which layout apparently better serves familiar way of
living in this context and time.

Regarding the apartment Type 19, Use 01 seems to be the one that better organizes the
dwelling spaces, by centralizing the living area and segregating the private spaces. Both the
original design layout plan Unit and Use 02 place part of the social area in a segregated space,
thus not enabling in full its social character. In these two units, part of the living area is not only
segregated but also on of the deepest levels in the dwelling, which equates (?) to visitors having
to enter in these deeper and traditionally more private levels, which takes away some of the
bedrooms’ privacy.

When reading layout, depth and integration results of apartment Type 21 it is possible to state
that of all solutions the design layout plan unit is the one which better organizes functional
sectors allowing for privacy to the spaces to which it is inherent (bedrooms) and a social
caracter to social spaces (living areas and services). With regards to the two uses, several
criticisms can be observed: in Use 01, the social area is the most segregated (lowest RA value)
even though it is the most accessible from the entry (on the one hand it doesn’t allow for privacy
in the living room in relation to the outside, on the other hand, since it functions as a gathering
area its location and lack of privacy can be positive); in Use 02 it is evident the lack of privacy of
the bedrooms in relation to the living room (a social and gathering space) and also the fact that
they constitute the most segregated compartments.

Looking at apartment Type 23, Use 02-Unit is the one with less difference between
compartments: it presents only two integrated spaces (both of them transition spaces, highly
integrated) and four segregated compartments (social, service and private sectors, all equally
and highly segregated, at the same level as the outside). When comparing this case with Use 01-
Unit it is possible to state that the existence of the fourth bedroom (adjacent to the living room)
has an integrating role regarding the system as a whole, allowing all the spaces to be more
integrated, with more degrees of integration/segregation. In this unit, the transition spaces
are the most integrated, followed by the dwelling social area (living room; level 1), the private
sector 1 (level 3), the service sector and exterior (level 4) and lastly private area 2 (bedroom
adjacent to the living room; level 5). It is note-worthy that the compartment responsible for
global integration is the one that is more segregated in the system. In the design layout plan
unit it is relevant the greater integration of the compartments that compose the ring, being the
social sector the second most integrated of the system, followed by the service and private area
1 (both in level 3). The rest of the private area shows a gradation of integration: private area 2 is
less integrated that private area 1 but more integrated than private area 3. In this unit, the most
segregated space is the exterior of the dwelling which demonstrates a more evident separation
inside-outside, or family-visitors, than the other two cases. It is also interesting to note that
comparing the original design layout with the modifications, one of the latter (end of visual
connection between the kitchen and living room) acts as a segregating factor by dissolving
an integrating ring-layout that linked transition, social and service areas, whereas the other
(definition separation between living room and bedroom) contributes to the increased privacy
of the private area.
As for apartment Type 25, reading layout and depth results, it is possible to infer that both Uses correspond to a better hierarchized interior, improving interior functional distribution and establishing increasing levels and degrees of privacy which signifies that a progressive infiltration inside corresponds to access to increasingly private spaces. Comparing these, the original layout plan unit places part of the intimate area in an intermediate level, which leads to it being less private, more vulnerable to the outside. Of the two uses, Use 01 is the one that better organizes interior circulation, foreseeing transition spaces between entry hall and bedrooms and living room and bedrooms, differing from Use 02 in the fact that it doesn't treat the living area as a circulation space that acts as a transition space, allowing for a better use of the living area and its furnishing. Concerning global integration, there is a difference between the units of apartment Type 25 as opposed to the previous case-studies: the transition spaces are not the most integrated in all units. In the original layout plan unit the most integrated (central) spaces are a transition space and the social area; in Use 01 the transition space of the entry hall is the most central; in Use 02 the social area reappears as the most integrated node of the graph. In all units, the private area appears as more segregated than the exterior of the dwelling, thus reinforcing its intimate character. Integration analysis supports the findings of the previous ones: inhabitant's uses are more appropriate to standard family life, allowing for greater privacy to the private areas (bedrooms) and centrality to social spaces.

Lastly, Type 28A and 28B, when compared, the most visible difference, and an important one, is the separation of the private area into two in type B, being one of these areas accessible only through the living area (in Use 01B, it implies a first access through the kitchen), without a transition space as seen in type A. In Use 01B there is also a division of the social area, also into two areas, each one near the private areas. Integration analysis of type A units demonstrates that the social areas (common living room) is the most integrated, i.e., central of the system in both cases. The ring in the original layout plan unit A has also an integrating character regarding the service area (namely the service support space). In Use 01A, the dissolution of the ring results in a lesser integration of the service area (almost at the same level as the exterior). In both units, the private sector is the most segregated, therefore, more intimate. Being more complex than type A units and having been altered spatially and functionally, type B units suggest more dissimilarities between them. The most integrated spaces are in both cases two different transition spaces: in original layout plan unit a transition space that takes part of the ring layout and connects the entry hall, the living area and the bedrooms; in Use 01B the entry hall (where the dwelling layout bisects). In original layout plan unit B the social area is the second most central, followed by the entry hall and the service areas (all of which compose the ring layout). The private areas and the exterior are the most segregated, although bedroom 3 (adjacent to the dining room) consist in the most segregated of all spaces, being the furthest from the most central space10. In Use 01B, without the existence of the ring, the bisection determines the integration of the different spaces: the service areas and the bedroom transition space are in level two of centrality, followed by the part of the social area. The second social space – the formal living room – lies in the third level of centrality, as does the bedroom adjacent to it. The bedroom contiguous to the common living area is the most segregated of the system.

It is thus possible to state that original layout plan unit A is the one that appears to serve family life better by integrating in a ring-like layout the most social areas (entry, living and service) and segregating and therefore protecting the bedrooms as the most private compartments. The alteration in Use 01A has little impact in the system apart from a lesser integration of the service areas.

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10 This should indicate that this is the most private space of the dwelling when in fact this statement is fallacious when considering that the only access to it is one of the most central and integrated (more public) compartments – the common living area.
Comparing original layout plan unit A and original layout plan unit B the latter due to the division of the private area seems less appropriate: the bedroom adjacent to the primary living area is greatly vulnerable to social activities and thus less private and intimate, as it should. The alterations in Use 01B aggravate the dwelling's functioning: by abolishing the access to the social area through the entry, the bedroom adjacent to the living room is placed further from the other bedroom and the toilet facility, the problem of its privacy regarding the living area persisting. Furthermore, the functional alteration (the creation of a formal living room in a bedroom compartment) causes integration issues: the living area is not central in the system causing the visitors to enter deep in the dwelling to access it, which also conflicts with the need for privacy of the contiguous bedroom.

4. CONCLUSION

4.1. CASE-STUDIES

The previous examination of all dwelling types, both original layout plan units and Uses-Units, demonstrates unity between VGA and Graph analysis. In general terms, it is important to emphasize that the transition space (or spaces) appears to be the most integrated in the system, especially in the present case-studies that consist of smaller dwellings where a single or a couple of transition spaces are paramount in the distribution of the entire dwelling. Moreover, if one disregards these transition spaces, the social area tends to be the most integrated and central in the dwelling, more so in some units than in others nonetheless. This is especially made clear by the VGA analysis that allows for a more immediate reading. Which leads us to highlight the difference between the VGA and the Graph analysis: the former by implying integration through visibility and not only a physical link allows for an enhanced centrality of some spaces, which could prove to be misleading.

In general terms the analysis also supports that the ring layout has an integrating effect on the compartments and functions that compose it, whereas the tree-like layout tends to stratify and hierarchize dwelling interiors, creating increasingly deeper and more private levels.

When comparing the original layout plan units to the Uses-Units the findings differ from one case-study to another, a general result being inexistent: original layout plan units of Type 21 and Type 28 appear to be the ones that better serve the needs of social activities and privacy of the family in terms of compartment distribution and layout; Use-Units of Types 19 (Use 01 only) and 25 (both Use 01 and Use 02) seem more appropriate to family living; in Type 23 none of the units fully serves said needs. This assessment is based upon the level of segregation of the private area, i.e. the bedrooms, and the level of integration/centrality of the social area, i.e. the living area, being considered that the privacy needed in the bedrooms is consistent with higher levels of segregation and the social functions of the living area with higher levels of relative integration (RA). Whenever the modifications made to the dwellings or the original layout plan unit itself didn’t hierarchize functions and areas according to this premise they were considered less adequate.

4.2. COMPARISON WITH THE RESULTS OF INQUÉRITO À HABITAÇÃO URBANA

Comparing the two different methodologies and the results made possible by each it is noticeable the coherence of conclusions, as aforementioned. Although the Inquérito à Habitação Urbana has a broader scope in what relates to dwelling layout its analysis is confirmed by the space syntax analysis presented in this paper. The later methodology allows for a more objective and analytic investigation of dwelling layout, hence permitting an ample and extensive reading of

11 A space syntax analysis’ scope is the investigation of design and layout aspects, not taking into account dwellers’ opinions and their needs satisfaction.
its functioning as a whole and the relation between the various compartments. The advantage of this methodology (Space Syntax) is the possibility to review and equate the adequacy of alternative solutions and designs\textsuperscript{12} and immediately verify their validity. As a further and more extensive development it would be beneficial a Post-Occupancy Evaluation as the work developed by Sungur and Çagdas\textsuperscript{13} (2003), that would serve as an additional investigating methodology by adding information regarding dwelling use and inefficiency in terms of user satisfaction.

\textsuperscript{12} As stressed by Mustafa, Hassan and Baper (2010, p.157) when mentioning that data obtained by space syntax analysis should be used as project auxiliary in future processes.

\textsuperscript{13} Effects on Housing Morphology on User Satisfaction
REFERENCES


#18

THE DYNAMIC NATURE OF CAREGIVER COMMUNICATION NETWORKS AND SPATIALISED WORK PROCESSES IN HOSPITAL WARDS

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ABSTRACT
This paper presents an empirical study of four hospital wards in two UK hospitals. Of interest are caregiver communication networks and behaviours because they form an important part of care provision. Space syntax research argues that the spatial configuration of buildings has an effect on social behaviours. However, only few notable studies investigate how inpatient wards influence work processes and relationships amongst caregivers. The dynamic nature of this work environment is particularly challenging to observe. Therefore, this study focuses on spatial layouts and dynamically evolving communication networks and behaviours adopting a set of complimentary methods to disentangle the complex and dynamic social processes in hospital wards.

The two case studies are situated in London and were specifically selected to contrast in their setup and spatial organisation. Two corresponding inpatient departments in each hospital were chosen for a comparison – the intensive care unit and one medical ward. Space syntax was used alongside a staff survey including social network analysis to assess communication networks amongst caregivers. The survey was carried out for four consecutive days and asked about communication partners on each particular day to capture snapshots of everyday communication that could explain the dynamics of social networks. Sociometric sensors developed at MIT were run for eight consecutive days and provided information about frequency and duration of conversations. The dynamic nature of the workflow was captured by shadowing caregivers and recording digitally type and durations of sequential activities and locations.

The study offers several contributions by bringing together spatial analysis, observational data, self-reported surveys and sensor data. Results indicate that the structure of communication networks of doctors and nurses became less hierarchical to keep the network stable when a key role was missing. It was also shown that distance influence the frequency and duration of conversations in the intensive care unit assuming that caregivers are fixed to their assigned beds. However, for the general nursing ward, a different methodology to model distance is required as one caregiver takes care of several physically dispersed patients. Finally, it was shown that...
nurses spent a great proportion of their time in various activities in different locations pointing towards the dynamic nature of the workplace. The outcome of this study generates insights into everyday life in hospital wards and how spatial practices play out.

**KEYWORDS**

Space syntax, social network analysis, hospital ward layout, communication networks, sociometric sensors

**1. INTRODUCTION: THE DYNAMIC NATURE OF HOSPITAL ENVIRONMENTS**

Hospitals operate in a fast-paced 24/7 service economy. By arranging various user groups through elaborate routines and work patterns and a flow of materials and people into large spatial configurations, they form complex, diverse and multi-layered environments. Complexity could be argued to arise from three main factors: process dynamics, interface dynamics and organisational dynamics.

Firstly, the way processes play out in the physical environment of hospitals is dynamic as they accommodate a variety of building usage patterns. Sailer (2015) argued that buildings are dynamic settings that accommodate a range of different uses for example a hospital is not just a place for curing the ill, but also a workplace for clinicians. The author showed how the nature of usage patterns in libraries is dynamic by taking into account the diversity of user groups as well as the temporal unfolding of behaviours. Similarly, hospitals are dynamic settings because they accommodate a multitude of functions as well as a variety of user groups – consultants, doctors, students, matrons, nurses, nursing assistants, porters, cleaners, pharmacist, physiotherapists, patients and visitors whose day-to-day tasks and activities vary across days. To add to this complexity, there are several different levels of nurses as well as doctors (Figure 1) resulting in different responsibilities and usage patterns. For example the matron or the nurse in charge of a ward has a managerial role while the nurse educator is responsible for the continuous professional education of nurses. None of these roles takes care of patients.

![Figure 1 - NHS nurse and staff uniforms](image-url)
Another investigation of work process and routines in a university hospital was conducted by Koch and Steen (2012a, 2012b). The authors used the concept of spatial practice to 'de-compose' work programmes. The concept represents the interaction between spatial configuration, organisational configuration and configuration of work processes and routes. The authors chose cases with similar general workflow principles and argued that similar tasks and roles were realised in space differently and that similar tasks and roles were also realised in time differently. These differences add another layer of complexity to the space usage patterns in hospital wards.

Secondly, two main interfaces exist between visitors and inhabitants of a hospital: caregiver-patient and caregiver-caregiver interface (Hanson and Hillier, 1984). However, as the inhabitants are not just caregivers but various different types and levels of caregivers, the resulting interfaces are much more complex and dependent on the daily regimes of the various user groups. How and where inhabitants and visitors interact depends very much on the type of the user group. For example, a haematology nurse may need to take care of a patient in pulmonology because the patient requires their expertise. This would result in deviation of the nurse from their usual daily regimes and interactions with the members of staff in the new ward.

Thirdly, hospitals are dynamic organisations since the workload of caregivers is organised around multiple shifts that involve a considerable flux of personnel. This means that the composition of professionals may vary greatly from one day to another, resulting in unstable teams. To study the dynamic nature of work environments in courts, Lazega et al. (2009) coined the term 'relational turnover' to describe changes in the network structure of judges regardless of the turnover of its individual members. The idea was that a role in the network remains stable, but the person filling the role changes. It was found that the hierarchy of status remained relatively stable regardless of members’ turnover while role relationship and division of work showed that the relational turnover was high.

Valentine and Edmondson (2015) studied a similar process but in hospitals. The researchers investigated the redesign of an emergency department – both organisationally and physically, and showed how the work dynamics can be controlled to improve patient throughput time. Prior to the redesign, individuals coordinated work in a role-based structure where interactions occurred in unstructured groupings. After the redesign, the ED implemented new organisational structures that bounded small sets of roles and gave them shared responsibility for a group of patients. The authors labelled these as team scaffolds because they acted as a stable structure that helped extremely fluid groups to act like a team. The hospital ED also implemented a spatial redesign dividing the large unit into four pods. A pod was a physical location with dedicated computers, supplies and patient beds acting as a stable structure that persisted over time but the individuals staffing each pod changed constantly.

Despite its dynamic workplace environment, it could be argued that hospitals still operate similarly to buildings where the work force is less mobile e.g. offices. For example, in a seminal study Allen (1975) investigated communication patterns amongst engineers and found that the longer the distance between their desks the less like they were to talk to each other. This is obviously a static way of looking at the workplace, however it is still valid in office buildings despite workforces becoming more flexible (Sailer 2010, Catalini 2016).

Therefore, the interest of this paper lies in measuring and spatialising the dynamic nature of hospital wards, drawing on both quantitative and qualitative empirical data sets collected in four hospital wards in 2016. In detail, the research questions are:

1. With regards to organisational dynamics, does the structure of the communication network of doctors and nurses change when a key role is missing?
2. Does the distance-communication frequency relationship often found in workplaces also hold in hospitals despite a more mobile work pattern?

The aim of the paper is to generate insights into the everyday life of hospitals and to more accurately describe and depict the role of the layout in shaping communication patterns and care processes.
The paper continues with a review of the space syntax literature in hospital wards and discusses how researchers have investigated the relationship between the spatial layout and caregiver processes and communications. Next, the four case studies and methodology used are described in detail. Then, we present the results from the analysis of how distance influences communication in hospitals. Conclusions, limitations and future work are presented in the final sections of the paper.

2. THE SPATIALISATION OF CAREGIVER WORK ACTIVITIES AND COMMUNICATION

The application of space syntax in hospital environments is relatively new, however a growing number of studies have looked at how the configurational properties of a hospital affect work processes and communication networks among caregivers.

In a study conducted in an intensive care unit, Lu, Peponis and Zimring (2009) investigated how visibility affected providers’ activities and communication. They found that nurses and doctors were tuned to different features of the environment. Doctors’ patterns correlated better with generic visibility, which is the standard analysis of visual field calculated from all visible points to all other points in space. On the other hand, nurses’ activities were tuned to a new spatial measure developed by the researchers and called ‘targeted visibility’. The measure was calculated as visibility directed towards a number of pre-selected foci of attention that are visible e.g. patient beds.

Sailer et al. (2013) conducted studies in outpatient clinics in two hospitals using social network analysis and space syntax. They found that the distance between clinics in one of the hospitals measured in axial steps influenced the communication intensity between caregivers across clinics. The relation was not linear but logarithmic meaning that in close proximity small increases in distance made a bigger difference than for larger distances. However, no relationships between communication intensity and distance across clinics in the second hospital were found.

Trzpuc and Martin (2010) explored how visibility and accessibility in three medical-surgical units influenced nurses’ communication and subsequently perceived social support that helped to protect staff from high stress levels and increase job satisfaction. Yet nurses’ perception of visibility and accessibility did not consistently match anticipation from the floor plan analysis. The authors concluded that there was a gap in our knowledge of how the nursing units affected nurses’ behaviour.

The above studies either found no correlations between various user categories and different space syntax metrics pointing towards what Trzpuc and Martin expressed as a concern: our understanding of how the hospital layout affects caregiver behaviours is rather limited. To study this gap in knowledge, this research aims to explore how dynamically evolving communication networks and work activities of caregivers can be measured and spatialised.

Three different space syntax measures were selected for the present study – metric, visual and angular distances. Metric distance was used because past research showed that the longer the distances between people the less likely they were to communicate with each other (Allen 1975, Sailer 2010, Catalini 2016). Visual distance was chosen because studies indicated that the visibility of a ward layout was highly correlated with density of interaction of doctors (Lu et al, 2009). Finally, angular distance was selected because it has been proved that people tend to prefer straight routes (Dalton 2003).

Hendrich et al. (2009) studied nursing units and based on their data described two overall strategies of nurse mobility patterns affected by the spatial qualities of nurse assignments: fewer, longer visits versus more frequent, shorter visits. This led to the following hypothesis:

H1: The longer the metric (H1a), visual (H1b) and angular (H1c) distance between HCW (healthcare workers), the less likely they are to communicate frequently and the longer the duration of their conversations.
3. CASE STUDIES

This paper draws on data collected in four inpatient wards in two different hospitals. Both institutions belong to the same NHS Trust and are situated in central London. Hospital A was purpose-built and first opened in 2005. Hospital B occupies a building from 1885 and was expanded in several stages hence it consists of a few interconnected buildings.

The intensive care unit (ICU) and one medical ward in each hospital were selected for the study. Table 1 provides an overview of the selected cases. The layout typology of the wards in Hospital A is called ‘racetrack’ (Thompson and Goldin, 1975) where the core of the building, that contains lifts and staircases, is located in the middle of the floor plate and the main corridor runs around it. All patient rooms and bays are situated along the perimeter of the building to maximise the amount of daylight for patients. The layout of the wards in Hospital B has a ‘corridor’ structure (ibid). The main corridor runs in the middle of the ward and all patient and staff facilities are situated on both sides. The two wards in Hospital A are 1/3 bigger in terms of bed numbers and have more side rooms than their corresponding units in Hospital B.

<table>
<thead>
<tr>
<th>CASE STUDY</th>
<th>FLOOR SIZE</th>
<th># BEDS</th>
<th>OPEN BAYS/SIDE ROOMS</th>
<th>WARD TYPOLOGY</th>
<th>LAYOUT DIAGRAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nursing ward</td>
<td>1470 m²</td>
<td>43</td>
<td>21 / 22</td>
<td>racetrack</td>
<td></td>
</tr>
<tr>
<td>ICU</td>
<td>1515 m²</td>
<td>32</td>
<td>21 / 21</td>
<td>racetrack</td>
<td></td>
</tr>
<tr>
<td>Hospital B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nursing ward</td>
<td>928 m²</td>
<td>28</td>
<td>24 / 4</td>
<td>corridor</td>
<td></td>
</tr>
<tr>
<td>ICU</td>
<td>1380 m²</td>
<td>10</td>
<td>17 / 3</td>
<td>corridor</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 - Overview of selected case studies:

Legend:  - main corridor;  - building core;  - patient side rooms
4. METHODOLOGY

This paper combines the syntactical studies of the four wards with data collected from observations, social network analysis surveys and wearable devices. Visibility Graph Analysis (VGA) was constructed on eye level (Turner, Doxa, O’Sullivan & Penn, 2001) in Depthmap X (Varoudis, 2012) and metric, visual and angular distances from any patient bed and nursing station to any other bed and station were then calculated selecting the VGA node that coincided with the middle of the bed or the station.

A staff survey including social network analysis was conducted to assess communication networks amongst HCW. The survey was carried out for four consecutive days and asked for communication partners on each particular day to capture snapshots of everyday communication that could explain the dynamics of social networks. In this paper we used survey data from the nursing ward of Hospital A where the average number of survey participants per day was 32 with daily response rates between 62% and 93%. Communication networks on the exchange of patient-related information were constructed from the data and analysed with UCINET (Borgatti, Everett, and Freeman 2002). Betweenness centrality of individuals as well as the average degree of the networks were calculated. Betweenness shows who controls the flow of information in a network. It is similar to choice in space syntax and is calculated by summing the number of all shortest paths from every node in the system to any other node that passes through the node of interest divided by the total number of shortest paths in the network. The average degree is similar to connectivity in space syntax and shows the average number of communication partners in the network. For instance, an average degree of 5 means that all caregivers spoke to 5 other caregivers on average.

Sociometric badges developed at MIT (Olguin, 2007) were employed to provide additional information about communication behaviours. The devices were used for eight consecutive days with an average number of participants of 15-24. Volunteers were asked to wear the badges around their necks throughout the duration of their shifts. The devices contain Bluetooth and infrared sensors as well as an accelerometer that provided information about the duration and frequency of communication between participants and their body movement and posture during conversations. Data were analysed statistically and visualised with STATA 14 software (StataCorp. 2015).

Caregivers were shadowed during their daily tasks and routines to capture the dynamic nature of the workflow. The observer followed the HCW and recorded on a digital device where they were, what they did there and whom they spoke with selecting from a predefined list of activities and locations. The data provided information about sequence and duration of activities and how much time caregivers spent in certain locations. A total number of 64 caregivers were observed for an average of 45 minutes and different roles were selected including participants from medical, nursing and ancillary staff.

5. ANALYSIS AND RESULTS

5.1 ORGANISATIONAL DYNAMICS

Initially, a network survey over 4 days had to be conducted to understand the communication network of caregivers. However, it was announced that the junior doctors would go on strike a day after the survey was planned to begin. This was a rare opportunity for a natural experiment to investigate the ‘relational turnover’ (Lazega et al, 2009) of a network when the people fulfilling the roles remained the same but one key role was missing. No junior doctors worked on the strike day and more consultants (senior doctors) were present in the ward to compensate. The survey included the day before the strike when caregivers were preparing for the big day, the strike day, the day after the strike and one ordinary day during the following week. Figure 2 shows the caregiver communication networks for the four different days on the left and the distribution of betweenness centrality on the right.
On the day before the strike the most central figures in the networks were the nurse in charge, the ward administrator and one of the senior doctors. On the day of the strike, the general nurses and the pharmacist were the ones who stepped in and helped the nurse in charge with patient care (Figure 2). The betweenness centrality of the main actors on days 1, 3 and 4 was much higher than the ones on the strike day: for example, the nurse in charge, who is a main actor on days 1, 2 and 4, has a betweenness of 105 on strike day and 158 and 174 on the other days. The standard deviation of betweenness is also lower on the strike day meaning that the data is less dispersed and the values are more equal and close to each other. This shows that the distribution of importance was much more equalised on strike day, thus less hierarchical than on the other days. Average degree also varied across days (Figure 2). Average degree increased from 5.13 to 5.72 on a strike day, reached 6.46 on the day after the strike and dropped down to 4.75 during an ordinary day. This shows how on the day after the strike there was a lot more information to be exchanged resulting in a higher number of communication partners on that day.

In summary, on the day of the strike, the general nurses and the pharmacist were the ones who took control over patient care. While in the case of the court judges (Lazega et al, 2009), the hierarchy of status remained the same regardless of members’ turnover, this study found that when a key role was missing, the distribution of importance was less hierarchical which kept the network stable and enabled caregivers to cope with the critical situation. The day after the strike was busier in terms of communication as the junior doctors had to catch up with information.
Proceedings of the 11th Space Syntax Symposium

THE DYNAMIC NATURE OF CAREGIVER COMMUNICATION NETWORKS AND SPATIALISED WORK PROCESSES IN HOSPITAL WARDS

Day 3: After the strike

Response rate: 91%
Ave degree 6.46
SD Betweenness 29.33

Day 4: Ordinary day

Response rate: 62%
Ave degree 4.75
SD Betweenness 35.37

Node size: Betweenness centrality
Link: Discuss patient care more than 2 times per day

Figure 2 - Network structures of the four days of the network survey (left) and corresponding distribution of betweenness centrality per person (right)

5.2 SPATIAL ANALYSIS

This section describes the layouts of the two intensive care units in terms of metric, visual and angular distances between beds and nursing stations.

Basic statistical information and distribution of the three types of distances for each hospital are presented in Table 2. The maximum distance between beds in the racetrack layout is 62.3m, which is 13.8m longer than the maximum distance of 48.5m in the corridor layout. The mean value of the former is also higher – 34.1m compared to 20.45m in the latter, and the distribution of the data is shifted towards the higher values of metric distance indicating that there is a higher count of longer distances between beds in the racetrack layout than the corridor layout. Similarly, the racetrack layout also has longer distances in terms of visual distance with mean values of 3.5 compared to 2.1 for the corridor layout. However, both hospitals are equally deep – it takes a maximum of five visual steps to reach any space. In terms of angular distance, the distribution of the data shows that the corridor layout has more distances between beds with angular changes closer to 0. This is a result of the 85% of the beds in hospital B being placed in two adjacent open spaces (beds in the same space have an angular distance of 0) while 66% of the beds in hospital A are placed across 4 different open bays and the rest are in side rooms.

In summary, the corridor layout has overall shorter distances between caregivers in terms of metric, visual and angular distance than the racetrack layout.
5.3 INTERFACE DYNAMICS

This section tests the hypotheses H1a-c that distances affect communication. For this purpose, distances between caregivers were measured in a similar way as they would be in an office. General nurses were assigned to the bed of the patient they were taking care of. Junior and senior doctors were assigned to the nursing station closest to the patients they were responsible for as this was their workstation. The distances between all nursing stations and patient beds were calculated and assigned to pairs of caregivers. Assigning caregivers to locations was only done for the intensive care units where the nurse to patient ratio is usually 1:1 meaning that the task of assigning a caregiver to a bed is feasible. On the other hand the nurse to patient ratio in the general nursing ward is 1:4 or 1:5 which makes the task impossible and raises methodological questions not discussed in this paper.

A statistical model was used to test the relationship between communication and distance. Frequency and duration of conversations, extracted from the sociometric badges, were used as dependent variables. The three types of distances – metric, visual and angular, were used as independent variables. Gender, role and experience of caregivers served as control variables. Participants were split into male and female for gender, doctor and nurses for role and junior and senior for experience.

5.3.1 GENERAL DESCRIPTION OF THE DATA

A total number of 287 unique participants took part in the study with the badges of which 175 were in hospital A and 112 were in hospital B (Table 3). In terms of gender split, there were more female than male participants in both hospitals – 59% (HA) and 67%(HB). As for the split of roles, nurses represented a greater proportion of the study population for both cases – 64% (HA) and 88%(HB). Finally, 57% and 55% of the participants in hospital A and B respectively were junior level staff.

The distribution of frequency for both layouts is exponential where 55-60% of the communication events consisted of 1-5 conversations per day and then the number of events dropped dramatically (Table 4). The data for Hospital B is more distributed that the one for Hospital A with maximum frequency of conversations per day = 131 and SD = 22.5 compared to maximum frequency = 75 and SD = 11.7 (HA). This meant that caregivers in the corridor layout had a lot more frequent conversations than caregivers in the racetrack layout.

The distribution of duration for both case studies was exponential too with 90% probability to have a conversation for less than 5 minutes long and 80% probability to have a conversation...
that is less than a minute long. The highest duration of conversations was 125.4 minutes long in hospital A and only 52 minutes in hospital B.

In summary, a greater proportion of the participants consisted of female participants, nurses and junior level staff. There were a lot more frequent and shorter conversations in the corridor layout while caregivers in the racetrack layout communicated less but had longer conversations.

Table 3 - General information for participants in hospital A and hospital B

<table>
<thead>
<tr>
<th>Total</th>
<th>Gender</th>
<th>Role</th>
<th>Seniority</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All participants</td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>HA (racetrack)</td>
<td>175</td>
<td>71</td>
<td>104</td>
</tr>
<tr>
<td>HB (corridor)</td>
<td>112</td>
<td>37</td>
<td>75</td>
</tr>
<tr>
<td>Total</td>
<td>287</td>
<td>208</td>
<td>79</td>
</tr>
</tbody>
</table>

*Role and Seniority information was unavailable for 21 and 22 participants respectively out of the total 175 for HA.

Table 4 - General statistics for frequency and duration of conversations in hospital A and hospital B

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HA (racetrack)</strong></td>
<td><strong>HB (corridor)</strong></td>
</tr>
<tr>
<td>Max</td>
<td>175</td>
</tr>
<tr>
<td>Mean</td>
<td>7.12</td>
</tr>
<tr>
<td>Std</td>
<td>22.55</td>
</tr>
<tr>
<td>Variance</td>
<td>508.47</td>
</tr>
<tr>
<td>N</td>
<td>274</td>
</tr>
<tr>
<td><strong>HA (racetrack)</strong></td>
<td><strong>HB (corridor)</strong></td>
</tr>
<tr>
<td>Max</td>
<td>125</td>
</tr>
<tr>
<td>Mean</td>
<td>2.3</td>
</tr>
<tr>
<td>Std</td>
<td>5.3</td>
</tr>
<tr>
<td>Variance</td>
<td>29.0</td>
</tr>
<tr>
<td>N</td>
<td>1982</td>
</tr>
</tbody>
</table>
5.3.2 RESULTS FROM THE STATISTICAL ANALYSIS

The conditional variance of the two dependent variables – frequency and duration, exceeds their conditional mean for both cases, which means that the data is over dispersed (Table 4). Therefore, negative binomial regression is used for the analysis as it is a statistical model that accounts for over dispersion. Results from the regression analysis for frequency for the two hospitals are presented in Table 5a and results for duration in Table 5b. Three different models for each of the dependent variables were tested including each of the independent variables separately and all of the control variables. To compare the models within each case study the maximum log likelihood was used which examines the fit of different coefficients. Because one wants to maximise the log likelihood, the higher the value the better. Alongside the coefficients, the IRR (incidence rate ratio) is calculated only for statistically significant results, which is then used to present the findings as percentages. Predictive margins were computed from predictions from each model for different values of the covariates. They indicated how frequency and duration depend on the three types of distances in the two hospitals and the graphs on Figure 3 shows the shape of the effect.

All three distances for both hospitals produced highly significant results (p=0.000) and influenced frequency negatively meaning that with increasing distance between caregivers the frequency of their conversations decreased (Table 5a and Figure 3). The maximum log likelihood results were produced by the model containing visual distance for hospital A and metric distance for hospital B. This meant that from the three different types of measures, visual distance was the best predictor for the racetrack layout and metric distance for the corridor layout. Results for hospital A showed that if everything else was kept stable, with every one metre increase in distance, there was a 3% decrease in communication frequency; with every one increase of visual step depth there were 39% fewer conversations; and with every one increase of angular step depth there were 45% fewer conversations. The results for hospital B are similar and show that if everything else was kept stable, with every one metre increase in distance, communication frequency dropped by 6%; with every one increase of visual step depth there were 50% fewer conversations and with every one increase of angular step depth there were 45% fewer conversations. It can be concluded that the corridor layout had a slightly bigger impact on frequency of communication than the racetrack one.

Of the control variables, only seniority of caregivers in hospital A gave highly significant results and thus had an effect on frequency of conversations. It was found that junior doctors were more likely to communicate with other junior doctors while senior doctors were more likely to speak more often to junior doctors. None of the control variables in hospital B produced highly significant results.

Similarly, all three distances for both hospitals produced highly significant results (p=0.000) and influenced duration (Table 5b). However, differences were found between the two layouts. While distances in the racetrack layout influenced duration positively meaning that with increase of distance, the duration of conversations increased, on the other hand, distances in the corridor layout influenced duration negatively meaning that with increase of distance between caregivers the duration of their conversations decreased (Figure 3).

This phenomenon will be explored in future studies as it could be equally a result of the management of the hospital, the daily routines and regimes of caregivers or the spatial layout.

The maximum log likelihood results were produced by the model containing metric distance for both layouts meaning that physical distance measured in metres was the best predictor for duration of conversations. Results for hospital A showed that if everything else was kept stable, with every one meter increase in distance, there was a 1% increase in duration; with every one increase of visual step depth there was a 16% increase in duration; and with every one increase of angular step depth there was a 13% increase in duration. The results for hospital B showed that if everything else was kept stable, with every one meter increase in distance, the duration of conversations decreased by 2%; with every one increase of visual step depth there was a 22% decrease in duration and with every one increase of angular step depth there was a 13% increase in duration.

IRR is the ratio of the incident rate for two values of x one unit apart – easier to calculate percentages.
17% decrease in duration. Again, the corridor layout had a slightly bigger impact on duration of conversations than the racetrack one.

Gender and role of caregivers influenced the duration of conversations in hospital A. Results showed that females were more likely to have longer conversations with other females than with males while males were more likely to have shorter conversations with other males than with females. Nurses were more likely to have longer conversations with doctors than with other nurses while doctors were more likely to have longer conversations amongst themselves than nurses would do. Only the role of caregivers in hospital B had an effect on the duration of interactions. There were no recorded conversations amongst doctors. Results showed that similarly to hospital A, there was a higher probability of a nurse to have a longer conversation with a doctor than with another nurse.

The conclusions from the analysis in this section are used to reflect on the stated hypotheses and are summarised below. With increase of distance in the racetrack layout, communication events decrease and the duration of conversations increases meaning that caregivers have shorter and more frequent conversations in close proximity and longer but less frequent conversations when distances increase. On the other hand, with increase of distance in the corridor layout, the communication events decrease but also the duration of conversations i.e. caregivers have more frequent and longer conversations in close proximity.

<table>
<thead>
<tr>
<th>HYPOTHESIS</th>
<th>Racetrack</th>
<th>Corridor</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1a: The longer the metric distance between clinicians</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>A) the less likely they are to communicate frequently</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>B) the longer the duration of their conversations</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>H1b: The longer the visual distance between clinicians</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>A) the less likely they are to communicate frequently</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>B) the longer the duration of their conversations</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>H1c: The longer the angular distance between clinicians</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>A) the less likely they are to communicate frequently</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>B) the longer the duration of their conversations</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
### Table 5a - Results of negative binomial regression for duration for hospital A and hospital B

<table>
<thead>
<tr>
<th>Metric DIST</th>
<th>HA (racetrack)</th>
<th></th>
<th></th>
<th></th>
<th>HB (corridor)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>coeff.</td>
<td>p. value</td>
<td>IRR</td>
<td></td>
<td>coeff.</td>
<td>p. value</td>
<td>IRR</td>
<td></td>
</tr>
<tr>
<td>f-f</td>
<td>-0.168</td>
<td>0.016</td>
<td>0.85</td>
<td></td>
<td>0.055</td>
<td>0.147</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>m-m</td>
<td>1.008</td>
<td>0.000</td>
<td>2.74</td>
<td></td>
<td>0.055</td>
<td>0.477</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>n-d</td>
<td>-0.159</td>
<td>0.018</td>
<td>0.85</td>
<td></td>
<td>0.259</td>
<td>0.000</td>
<td>1.30</td>
<td></td>
</tr>
<tr>
<td>d-d</td>
<td>-0.319</td>
<td>0.000</td>
<td>0.40</td>
<td></td>
<td>omitted</td>
<td>0.047</td>
<td>0.536</td>
<td>-</td>
</tr>
<tr>
<td>j-j</td>
<td>-0.124</td>
<td>0.224</td>
<td>-</td>
<td></td>
<td>-0.054</td>
<td>0.235</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>s-s</td>
<td>0.003</td>
<td>0.964</td>
<td>-</td>
<td></td>
<td>0.047</td>
<td>0.536</td>
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<td></td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-3116.80</td>
<td></td>
<td></td>
<td></td>
<td>-3656.36</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Visual DIST</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>coeff.</td>
<td>p. value</td>
<td>IRR</td>
<td></td>
<td>coeff.</td>
<td>p. value</td>
<td>IRR</td>
<td></td>
</tr>
<tr>
<td>f-f</td>
<td>-0.168</td>
<td>0.016</td>
<td>0.85</td>
<td></td>
<td>0.066</td>
<td>0.871</td>
<td>-</td>
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<td>m-m</td>
<td>0.876</td>
<td>0.000</td>
<td>2.40</td>
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<td>0.030</td>
<td>0.664</td>
<td>-</td>
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<tr>
<td>n-d</td>
<td>-0.192</td>
<td>0.005</td>
<td>0.83</td>
<td></td>
<td>0.241</td>
<td>0.000</td>
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<tr>
<td>d-d</td>
<td>-0.359</td>
<td>0.000</td>
<td>0.38</td>
<td></td>
<td>omitted</td>
<td>0.052</td>
<td>0.453</td>
<td>-</td>
</tr>
<tr>
<td>j-j</td>
<td>-0.055</td>
<td>0.580</td>
<td>-</td>
<td></td>
<td>-0.052</td>
<td>0.453</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>s-s</td>
<td>0.070</td>
<td>0.333</td>
<td>-</td>
<td></td>
<td>0.048</td>
<td>0.527</td>
<td>-</td>
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<tr>
<td>Log likelihood</td>
<td>-3113.39</td>
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<td>-3656.38</td>
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<table>
<thead>
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<th>Angular DIST</th>
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<th></th>
</tr>
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<td></td>
<td>coeff.</td>
<td>p. value</td>
<td>IRR</td>
<td></td>
<td>coeff.</td>
<td>p. value</td>
<td>IRR</td>
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<tr>
<td>f-f</td>
<td>-0.151</td>
<td>0.030</td>
<td>0.86</td>
<td></td>
<td>0.184</td>
<td>0.000</td>
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<tr>
<td>m-m</td>
<td>0.861</td>
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<td>2.37</td>
<td></td>
<td>0.071</td>
<td>0.063</td>
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<tr>
<td>n-d</td>
<td>-0.186</td>
<td>0.007</td>
<td>0.83</td>
<td></td>
<td>0.066</td>
<td>0.933</td>
<td>-</td>
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<tr>
<td>d-d</td>
<td>-0.356</td>
<td>0.000</td>
<td>0.38</td>
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<td>omitted</td>
<td>0.235</td>
<td>0.000</td>
<td>1.26</td>
</tr>
<tr>
<td>j-j</td>
<td>-0.012</td>
<td>0.901</td>
<td>-</td>
<td></td>
<td>-0.027</td>
<td>0.456</td>
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<tr>
<td>s-s</td>
<td>0.114</td>
<td>0.112</td>
<td>-</td>
<td></td>
<td>-0.062</td>
<td>0.411</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Log likelihood</td>
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<td></td>
<td></td>
<td>-3688.92</td>
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Table 5a - Results of negative binomial regression for duration for hospital A and hospital B
### Table 5b - Results of negative binomial regression for frequency for hospital A and hospital B

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<tr>
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<th>IRR</th>
<th>coeff.</th>
<th>p. value</th>
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<td>0.000</td>
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<td><strong>m-m</strong></td>
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<td>-</td>
<td>-0.435</td>
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<td><strong>n-d</strong></td>
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<td>0.591</td>
<td>-</td>
<td>0.266</td>
<td>0.451</td>
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<tr>
<td><strong>d-d</strong></td>
<td>0.647</td>
<td>0.090</td>
<td>-</td>
<td>omitted</td>
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</tr>
<tr>
<td><strong>j-j</strong></td>
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<td>0.043</td>
<td>0.72</td>
<td>0.230</td>
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<td>-</td>
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<tr>
<td><strong>s-s</strong></td>
<td>0.463</td>
<td>0.004</td>
<td>1.59</td>
<td>-0.263</td>
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<td><strong>Log likelihood</strong></td>
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<td></td>
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<th>Visual DIST</th>
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<th>p. value</th>
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<tr>
<td><strong>f-f</strong></td>
<td>0.217</td>
<td>0.129</td>
<td>-</td>
<td>-0.149</td>
<td>0.414</td>
<td>-</td>
</tr>
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<td><strong>m-m</strong></td>
<td>0.234</td>
<td>0.333</td>
<td>-</td>
<td>-0.539</td>
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<td>-</td>
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<tr>
<td><strong>n-d</strong></td>
<td>0.100</td>
<td>0.470</td>
<td>-</td>
<td>0.125</td>
<td>0.580</td>
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<tr>
<td><strong>d-d</strong></td>
<td>0.951</td>
<td>0.020</td>
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<td><strong>j-j</strong></td>
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<td>0.098</td>
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<tr>
<td><strong>s-s</strong></td>
<td>0.367</td>
<td>0.038</td>
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<td><strong>Log likelihood</strong></td>
<td>-.789 51</td>
<td></td>
<td></td>
<td>-.547 04</td>
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</table>

<table>
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<th>Angular DIST</th>
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<th>p. value</th>
<th>IRR</th>
<th>coeff.</th>
<th>p. value</th>
<th>IRR</th>
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<tr>
<td><strong>f-f</strong></td>
<td>0.195</td>
<td>0.180</td>
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<td>-0.072</td>
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<tr>
<td><strong>m-m</strong></td>
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<td>-</td>
<td>-0.575</td>
<td>0.066</td>
<td>-</td>
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<tr>
<td><strong>n-d</strong></td>
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<td>0.261</td>
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<td><strong>d-d</strong></td>
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<td>2.73</td>
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<td><strong>j-j</strong></td>
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<td>0.68</td>
<td>0.270</td>
<td>0.184</td>
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<td>0.318</td>
<td>0.047</td>
<td>1.37</td>
<td>-0.413</td>
<td>0.126</td>
<td>-</td>
</tr>
<tr>
<td><strong>Log likelihood</strong></td>
<td>-.795 88</td>
<td></td>
<td></td>
<td>-.554 57</td>
<td></td>
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</tr>
</tbody>
</table>

Table 5b - Results of negative binomial regression for frequency for hospital A and hospital B
5.4 PROCESS DYNAMICS

To investigate the dynamic nature of work process in hospitals further, results from the observations in the four units are presented in Figure 4. The pie charts show the amount of time nurses spent in various activities. For the two intensive care units, nurses spent 23% and 19% of their time in pure patient care in hospital A and hospital B respectively. For the general nursing wards, the percentages are 23% and 14%. These results show that nurses spent a great proportion of their time in other activities, which further emphasises the problem of assigning caregivers to fixed locations.

The presented analysis where the ward environment was considered as static and caregivers were assigned to beds and nursing stations was done in the intensive care units of the two case studies where providers took care of one patient or group of patients. It was impossible for the study to be reproduced in the general nursing wards where one care provider was responsible for several usually spatially dispersed patients. This means new methods need to be developed in further work.
THE DYNAMIC NATURE OF CAREGIVER COMMUNICATION NETWORKS AND SPATIALISED WORK PROCESSES IN HOSPITAL WARDS

6. CONCLUSIONS

This paper brings together spatial analysis, observational data, self-reported surveys and sensor data collected in four inpatient wards. Of interest was how organisational, interface and process dynamics influenced communication and work processes of caregivers. On an organisational level, it was shown that when a key professional role – junior doctors – was missing the resulting communication network was less hierarchical which was important to keep the network stable and cope with the critical situation. Instead, the nurse in charge was supported by the other nurses and the pharmacist, which were usually less central to the network. It was also shown that the distance-communication frequency relationship that was often found in workplaces was also present in hospitals. Two different ward layouts were investigated – racetrack and corridor, and it was shown that with increase of distance in the racetrack layout, communication events decreased and the duration of conversations increased while with increase of distance in the corridor layout, communication events decreased but also the duration of conversations. These inconsistences could be a result of either differences in management, regimes and processes or the spatial layout and future studies will investigate this further. As for process dynamics, results showed that contrary to common thinking that nurses spend most of their time with patients, they actually spent a great proportion of their time in various other activities in different locations.

Although very rich data was gathered for the present study some limitations should be noted. First, inaccuracies may have occurred since observations may suffer from biases introduced by the human observer. Also, caregivers were sampled and not everyone was followed. Second, the self-reported survey on communication may have suffered from recall bias since the survey was conducted at the end of the shift when caregivers were already tired. Third, more cases could be analysed to test and extend the argument further. Finally, with regards to the sociometric badges 1) they were not enough to cover all caregivers in the ICU of Hospital A while the ICU in Hospital B was smaller and almost every care provider wore a badge; 2) some of the caregivers did not wear the badge around their neck because the device was either too heavy for them or they felt that they looked weird to walk around the ward with a blinking...
device. Those caregivers placed the badge either in their front or back pocket, which could have affected the quality of the data; 3) some of the devices broke during the study which was only discovered at the end of the data collection period causing missing data from key actors; 4) it is not always clear what a single conversation event is for the device and when a conversation starts and ends.

In future work, the authors will look at other possible ways to model space in dynamic hospital wards. One way will be to take the actual work paths of caregivers from the observational data and look at the overlapping paths between providers on a dyadic level (Kabo, 2013). It will be tested whether the integration of the overlapped paths is a better predictor for duration and frequency of communication. It could be hypothesized that the higher the integration of the overlapped paths, the shorter and more frequent the conversations are. Additional data from a third case study will be added exploring the ward layout typologies further. Differences between badge data and reported network data will be also explored. The gathered data will be cross-referenced with quality of care metrics to better understand the implications of the ward layout on healthcare.

In conclusion, the main contribution of this paper is the idea of a hospital ward as a layered, dynamic and changing environment organisationally, procedurally and in terms of interfaces rather than as a static and definite entity that works in one particular way.
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ABSTRACT

When Frank Lloyd Wright designed the Solomon R. Guggenheim Museum in New York City (1943-59) he defined and activated space simultaneously because the movement of bodies - suggested in his words before sketches existed - configured the space. Activation referred to the user’s experience, which was utilized by Wright since his Taliesin Fellowship (1931) where students learned through embodied knowledge by focusing on their receptive and experiential basis. The main goal of this paper is to evaluate to what extent the extension by Gwathmey Siegel and Associate Architects, in 1992, altered Wright’s original concept for the building. Museums are complex structures whose spatial layouts seem to have a probabilistic effect upon patterns of visitors’ movements, which consequently affect awareness and encounter. In tune with these aspects, we argue that Wright adopted three main premises to design the Guggenheim: influence how people moved through its layout; consider the configuration of galleries as differentiated social spaces, and assure the organization of spaces and artwork a decisive role in the experience of the visitor. We utilized configuration analysis of floor plans and field observations, including recording static activities in the atrium, tracing 12 pedestrian flows, and counting number of visitors in relation to their chosen means of ascending the space. Besides comparing the original 1959 layout with its later addition, this paper brings some of Wright’s ideas for the emblematic building to light, to find out, in agreement with the architect, that the system is highly intelligible due to its key design feature, the atrium. Oppositely, interpersonal interaction and copresence are weaker away from this space, where concave isovists are recurrent. Despite alterations intended to strengthen its connection with the main gallery, the segregation of the old monitor in relation to the main gallery is maintained as thought by Wright. On the other hand, some findings also point towards discrepancies: Contrary to Wright’s idea of visitors floating upwards in the elevator and descending through the ramp (main gallery), we found that the majority of visitors used the ramp to ascend in

1 This paper is part of an on going doctoral research and results from approaching its central object of study, The Solomon R. Guggenheim Museum designed by Frank Lloyd Wright. The analyses discussed are subsidiary to the thesis’ main focus: the connection between neuroscience and space syntax utilized towards the understanding of the way museum visitors engage with the building and the artwork.
space. Consequently a greater interaction with the artwork happened during the ascending movement, as on the way down visitors had little or no interaction with the art, establishing regular contact with the atrium instead. Findings also challenge the emblematic study by Peponis (1993) in regards to the museum’s circulation being impeditive of probabilistic effects in the layout on exploration and encounter, as visitors frequently stopped to take pictures of the space, themselves and their peers, even while located at different ramp levels.

KEYWORDS
Space syntax, museum architecture, museum studies, morphology

1. INTRODUCTION
The goal of this paper is to discuss from a syntactic perspective the singular spatial configuration conceived by Frank Lloyd Wright for the Solomon R. Guggenheim Museum, in New York City, by comparing its inaugural 1959 layout to its later renovation and addition, in 1992, by Gwathmey Siegel and Associate Architects. The study encompasses historic documents, on-site observations and configuration analysis of ground and main gallery floor plans (Figures 1 and 2).

Space Syntax studies have shown that spatial layouts seem to have a probabilistic effect on the patterns of people’s movement and encounter. This theoretical field is interested in the analysis of general functions that surpass a particular building type and has proved to be very helpful in understanding movement patterns, consciousness and users’ encounters, aspects rarely privileged at the initial phases of a project (Peponis, 1993, p.54). We argue that, contrary to this, Wright designed the Guggenheim under the concept that movement and visual interaction of bodies ought to define space.

We begin by contextualizing the museum building and the Guggenheim itself, which sets the basis to investigate these three issues in Wright’s layout. Following, we present and discuss the analysis through convex, axial and visibility maps, isovists, photographs, and tracking of museum visitors, and then reach some conclusions.

Figure 1 - 1959 Ground and main floor plans (Weston, 2011, p.89, edited by author)
2. THE MUSEUM AS A SOCIAL OBJECT

For King (1984), as society grows differentiation takes place, leading to the growth of institutions. Furthermore, socialization and culture, with their associated activities of education or the creation, storage and distribution of knowledge, give rise to schools, universities, libraries, laboratories and museums. Holanda (2013) notes that buildings have attributes that can be captured directly from their configuration, from their syntax (i.e., they are more or less permeable to movement or transparent to vision, have certain dimensions and proportions, simple or complex volumes, etc.). On the other hand, labels (home, school, factory, hospital, museum) that delimit a social domain overlap with this physical structure, guaranteeing semantic attributes, not directly legible from this structure.

Markus (1993, p. 171) classifies museums as buildings of collection that represent visible knowledge, arguing that these are based on three organizing components: programs of use and circulation, shapes and texts. While the first serve classification, the shape of the building contributes to its organization through floor plans and volumes and by itself, when it often unites the container and the contents. As for texts, besides instructions and textbooks, inventories, lists, guides, indexes and catalogues may be part of the whole collection.

Hillier and Tzortzi (2011) suggest the use of the spatial syntax theory and methodology in the analysis of museum layouts as configurations of related spaces, stating that layouts can be used to research the social functioning and cultural significance of museums. They argue that museums are structures with the potential of both a pedagogical device to communicate knowledge and narrative, and a transmitter of non-narrative meaning in the form of a spatial and social experience.

Museums are structured around continuous spaces that follow some kind of narrative. In the Guggenheim, the narrative is movement that embodies Wright’s ideal of space and material continuity (Siry, 2009), therefore narrative enters architecture by the way in which space is structured to achieve specific effects on users’ experience and perception. The architect utilized a circumcentric pattern of vertical spiralling movement, independent of the actual experience of the subjects who would use space, but, on the other hand, he organized it from his point of view as an observer. Getting closer to the core of the architect’s conception implies in understanding the space he created from the sequential unfolding of information as bodies move in that environment (Psarra, 2009).
If circulation can be considered as a kind of skeleton that forms the supporting structure of a building, an organizational mechanism in its layout, reflecting overall spatial organization (Jiang and Liu, 2010), it plays a key role in understanding the Guggenheim museum as a social space. As shown in Wright’s earlier accounts, circulation guides the concept of the building, materializing itself in continuous vertical spiral galleries, which become a hybrid of exhibition spaces and circulation. The efficiency of a circulation depends on how much it evidences destinies for the user that, because of this, can move towards its objectives. Thus, circulation can effectively reveal how spatial patterns and configurations affect these users through movement (Natapov et al, 2015).

2.1 WHY LOOK BACK?

As buildings are historical events that have precedents which relate to time and space, we turn briefly to the origins of the Solomon R. Guggenheim Museum for clues on Wright’s peculiar design choices, specifically his take on the relationship between art exhibition, movement of people and social encounters. This relationship connects with some of the questions raised by Hillier and Tzortzi (2011) that we intend to investigate: Does space influence how people move through its layout? Do galleries work as a significant social space? Does the sequential organization of spaces and placement of artwork in space have an important role in the visitor’s experience?

In regards to design, Peponis (1993) refers to three desirable spatial considerations in museums, also important in our approach to Wright’s concept: linkage between exhibit spaces and the building as a whole via foyers and major circulation routes; balance between the appreciation of the architectural object and effective exhibitions; and the interface between building scale and the varying scales of the exhibits.

2.2 A BRIEF HISTORY OF THE BUILDING

Following the fin de siècle tradition, when private clients began hiring architects to design buildings for their newly compiled collections, the Solomon R. Guggenheim Museum (1943-1959) was meant to house the artworks of the eponymous businessman, one of the first American collectors of abstract art. The building referred to by Wright as a modern gallery (Levine, 1996), originally intended to be a memorial for its founder, displaying the paintings he had acquired with the help of the German consultant and future director of the Guggenheim Foundation, Hilla Rebay, whose connections with Europe’s avant-garde abstract art and her major influence both in Solomon’s collection and his soon to be, as she intended, museum-temple.

The design process was long, with four major versions named schemes A through D, and a series of revisions to scheme A. From June 1943 to early 1944 ideas remained in writing, with the presentation of the first preliminary studies taking place after the building site on 5th Avenue in Manhattan was acquired, in March 1944. According to Levine (1998, p. 323), these schemes “were all based on the same parti; only their geometries and brightly colored marble exteriors differed. One was hexagonal, the other three variations on a circle... The key element was an approximately eight-story ‘tower’ occupying the right half of the site” where galleries were located around an open atrium topped with a glass dome. Scheme “A”, further developed and approved by the client in July 1944, showed two main circular volumes - galleries and atrium at South, and the administrative tower at North - and a third, smaller cylinder containing an elevator that protruded outwards, West of the gallery tower (Levine, 1998; Pfeiffer, 1986; Siry, 2009; The Guggenheim, 2009). (Figure 3)

In a press conference in 1945, in New York City, a model on display showed a major change to scheme “A”: the two towers were switched in North-South direction and the smaller cylinder was rotated by 30 degrees. Surrounded by a slower ramp, the elevator was probably the most integral part of the design. Several revisions took place after this presentation, notably the return of the two main volumes to the original N-S orientation.
After the death of Solomon Guggenheim in 1949, the remainder of the building site was purchased and the Foundation started changing directions, which led to Rebay’s resignation and the hiring of James Sweeney, a former curator for the Museum of Modern Art (MoMA), in 1952, the same period the overall layout that would end up being built was established. As changes in the museum policy and program continued, Wright and Sweeney disagreed on issues especially regarding the way paintings were hung. After a few more revisions, construction began in 1956. Wright died in 1959 prior to the museum’s opening later that year.

Figure 3 - Solomon R. Guggenheim Museum various schemes from 1944 through 1952 (Levine, 1996, edited by author)
2.3 SEARCHING FOR MOVEMENT

Wright was formally hired in June 1943 and before the building site was defined, he wrote a letter to Rebay on January 20, 1944 in which we identify similarities with some of the aspects mentioned by Hillier and Tzortzi (2011) and Peponis (1993): ‘A museum should be one extended expansive well proportioned floor space from bottom to top — a wheel chair going around and up and down, throughout. No stops anywhere and such screened divisions of space gloriously lit within from above...’ (Pfeiffer, 1994, p.6). The idea of movement of people is evident, emphasized by the presence of a wheelchair moving with ease in a spatial layout with partitions detached from ceilings, conforming a unified well-scaled space where exhibitions and building are linked continuously.

In June 1958, he emphasized a curvilinear three-dimensional space (in a spiral), the visitor’s movement and the relationship of this type of circulation with artwork viewing: ‘Walls slant gently outward forming a giant spiral for a well-defined purpose: a new unity between beholder, painting and architecture. As planned, in the easy downward drift of the viewer on the giant spiral, pictures are not to be seen bolt-upright as though painted on the wall behind them. Gently inclined, faced slightly upward to the viewer and to the light in accord with the upward sweep of the spiral, the paintings themselves are emphasized in themselves and not hung “square” but gracefully yield to movement as set up by these slightly curving massive-walls.’ (Pfeiffer, 1994, p.7)

The notion of the museum as a social space is in Wright’s reference to the type of activity (see paintings yield to movement) and social gatherings (spectators moving in a continuous space (subject to interpersonal encounters) that a spatial layout can facilitate. The words also suggest a balanced appreciation of architecture and artwork, although privileging the scale of the building in relation to the varying scales of exhibition spaces.

Besides the circulation layout Wright envisioned, the interior is extremely controlled, having visitors almost entirely removed from visual contact with the outside and placed in a self-contained world removed from the public space of the street, a strategy similarly implemented in the VC Morris Gift Shop (San Francisco, 1948-1949), the only previously built project by Wright with a similar circular two-deck ramp (Siry, 2009).

If a labelled space can reproduce specific types of social relations and power amongst various categories of users (Markus and Cameron, 2002), the monitor, a tower housing offices, staff rooms and (subsequently removed) apartments for Solomon and Hilla, certainly did so. After the renovation in 1990s when former offices were converted into exhibition spaces and store, maintaining its central void, the previous vigilance of higher hierarchy staff at top floors over those working below was replaced with that of security guards and staff over the visitors on ground level store, also attracting potential shoppers from upper galleries. (Figure 4)
3. THE GUGGENHEIM SYNTAX

3.1 SOME IDEAS ON SPACE SYNTAX

Two basic notions pervade the Spatial Syntax theory regarding space: it is an intrinsic aspect of human activity and experience and it works not only according to the properties of this or that space, but to the relationships between all the spaces that conform a layout. A spatial structure can be represented in convex, axial and isovist dimensions, as people move in axial lines, interact in convex spaces, and see visual fields that change as they move through built environments (Hillier and Vaughan, 2007, p.3). Using graph theory to describe layout configurations makes it possible to investigate the correlation between space configuration and social behaviour.

Intelligibility, a correlation coefficient between connectivity and integration, helps identifying how easy it is for someone in a local position to understand the overall structure (Dalton et al, 2015; Al-Sayed et al, 2014). According to Hillier and Hanson (1984), an intelligible system allows people to find their way in a complex building, as a function of the relationship between local and global spatial properties. In an intelligible environment immediate visual stimuli can provide clues about what is outside the immediate visual field. In contrast, in an unintelligible environment, local visual cues do not relate to their larger spatial structure or may be deliberately misleading.

Visibility graph analysis (VGA) refers to the visual properties of a layout, specifically to the intervisibility between each pair of points in relation to the visual configurations of the environment. Three topological VGA measures are relevant: clustering coefficient, integration and control. The first one indicates how much visual information is lost when someone moves from one location to another, so that convex isovists have a high clustering coefficient, whereas pointed isovists have a smaller one. Integration computes the fewest number of connections or steps that need to be traversed to reach one node from another and control relates the area of the neighbourhood to the area of the immediate vicinity, indicating those in which visitors can have a wide view of the space (Al-Sayed et al, 2014)
3.2 MEANS AND METHODS
We used the DepthMap (Turner, 2007) and JASS software platforms to generate maps and justified graphs. During the months of December 2015, January and April 2016, we also employed unobtrusive site observations, tracked 12 museum visitors, counted number of people that opted for ramp or elevator as main means of ascending the space, and captured static photos to register patterns of occupancy in the ground level atrium.

3.3 RESULTS

3.3.1 CONFIGURATION ANALYSIS
In the Guggenheim’s 1959 and 1990s plans the most integrated spaces are located in or around the atrium, confirming its structural condition within the system. When the annex was added (1990s) and previous offices and bridge connecting these to the main floor galleries became exhibition spaces, the ring-like integration core was maintained and new integrated exhibition spaces emerged off of the atrium, increasing the spatial adjacency in previously segregated spaces. In both sets of plans the semi-circular elevator hall also presents a high degree of integration, coinciding with Wright’s emphasis on such element. Except for a couple of distribution halls, there are fewer integrated service spaces, all located further from the atrium.

Figure 5 - Convex, axial and visibility maps of 1959 (left) and 1990s (right) layouts measured by integration.
1959
GROUND FLOOR
1. Exterior
2. Entry vestibule
4, 10 e 20 - Atium
4 - (bottom of ramp)
5 - Admission counter
22 - Elevator lobby
23 - Elevator
29 - Staircase hallway
40 - Monitor vestibule
41 e 46 - Monitor lounge
77 - High Gallery entry
78 e 79 - High Gallery

2nd LEVEL - MAIN GALLERY
77 - High Gallery entry
78 e 79 - High Gallery
100 - Elevator lobby
101 - Elevator
102 - Staircase hallway
119 - Main gallery ramp
109 - Ramp balcony
150 - Library entrance vestibule
125 a 126 - Room closet
130 a 144 - Library
144, 147 a 154 - Monitor offices

1992
GROUND FLOOR
1. Exterior
2. Entry vestibule
7, 9 e 34 - Atrium
7 - (bottom of ramp)
8 - Admission counter
23 - Elevator lobby
24 - Elevator
30 - Staircase hallway
86 a 92, 94, 102 a 102 - Store
93 e 104 - Store vestibules

2nd LEVEL - MAIN GALLERY
206 - High Gallery entry
307 e 308 - High Gallery
245 - Ramp balcony
333 - Staircase hallway
335 - Elevator lobby
336 - Elevator
371 - Main gallery ramp
372 - J.K. Thannhauser entrance vestibule
255 a 261; 272 a 280; 282 a 287 - J.K. Thannhauser collection
90 e 205 - Aya Simon reading room

Figure 6 - Justified graphs of 1959 (left) and 1992 (right) layouts.
In the 1959 layout the monitor tower and main galleries around the atrium were separated with a void on the ground floor and a bridge at upper levels, as Wright’s goal was to emphasize the propulsive and sculptural nature of the bipolar arrangement between the two volumes conforming these spaces. That is why two separate maps were used for the 1959 ground floor plan. This segregation remains on the ground floor even after the monitor’s function shifted from offices to store. On the 1990s first floor plan, though, segregation was diminished with the addition of new exhibition spaces, both in the monitor and in the new annex.

Prior to the major 1990s renovation, in 1974, the garage entrance below the ramp between the two towers (monitor’s and main galleries) was enveloped with glass to house a bookstore and a tea room and what might seem like a discreet addition, eventually put a negative emphasis on Wright’s idea (Newhouse, 2006). In fact, since 1960s there had been attempts to broaden the connection between these two elements. In 1965 the Justin K. Thannhauser collection was added to the museum and following William Wesley Peters’ design (former architect at Wright’s Taliesin), a new exhibition space was placed on the main floor bridge between the rotunda and the monitor, where Wright’s 1959 layout showed a library. This alteration gave a static character to the experience of seeing art that Wright had sought to avoid, interrupting the continuous flow of the spiral by cutting an arch through a wall adjacent to the main ramp to give access to this new collection.

The convex maps show that the change of function was not able to fully modify the structural properties inherent to these spaces, implying that there is pertinence in considering space as an independent medium capable of suggesting certain social relations in themselves. (Figure 5)

Even though the spiral-like museum, washed by a highly controlled light source coming from the atrium’s dome, as conceived by Wright, is maintained, the justified graphs of the 1959 layout in comparison with 1992’s show that the transition from administrative function to exhibition space of the monitor created two major spaces with different scales which generate distinct experiences for the museum visitor. While in the main galleries the space is continuous and offers almost no route option other than following the flow imposed by the ramp, in the other there is a sequence of relatively connected exhibition spaces with more route alternatives. (Figure 6)

Axial analyses are based on the smallest number of longer walkable lines covering all convex spaces of a layout and its connections. Lines that have more connections to their immediate neighbours will have higher connectivity values and those with fewer connections will have lower degrees, indicating the potential occupation of a space by visitors. Thus, more integrated lines tend to provide social gatherings and more intense flow of people. The ground floor axial maps show highly integrated lines in the atrium. Overlapping photographs of the atrium taken from level 6 with the most integrated lines in that space confirms this condition as they illustrate the gathering of people in such locations. Contrarily, both monitor and service spaces have low degrees of integration, ratifying the segregation originally intended by the architect. (Figure 5 and 7)

Although axially the configuration was not changed drastically, with the removal of former office partitions, the 1990s renovation added a new cluster of longer integrated lines linking the main tower to the monitor. The Aye Simon Reading Room, designed by Richard Meyer in 1978 in a former archive turned broom closet, seems to be the space taking most advantage of this new condition. Although it is entered from a very small punch through the main gallery wall, as visitors come out of the permanent exhibition into the adjacent space, probably walking along such lines, they all seem compelled to enter the small room, where books and digital media are available for consultation.
In museums the intelligibility of a space is intricate as it becomes accessible to the exploration, and its content more available to searching (Wineman et al., 2015, p.2). Highly intelligible environments facilitate navigation because most routes lead towards or through central locations. Low intelligibility indicates that central locations depend on fewer routes, which are less connected (Natapov et al., 2016, p.5). Considering .50 as a threshold for intelligibility (Hillier and Hanson, 1984), when correlation is greater than it, the system is intelligible; when it is lower it is unintelligible. Using the Spearman’s Correlation Coefficient formula, the 1990s ground floor layout scored .68, indicating its high intelligibility, due mostly to the circular configuration designed by Wright.

Isovists and maps of visibility also help understanding spatial cognition from a certain position, because ‘In museums visual fields and spatial structures modulate patterns of movement and associated modes of seeing and understanding.’ (Wineman et al. 2015, p.48). The importance of this type of analysis, highlighted by the concept of copresence is emphasized by Choi (1997, p.5): ‘The extended pattern of copresence, which includes people visible from a space, however, is related not only to the visual connections between spaces, but also to the integration of spaces in the layout as a whole. Thus, the spaces which integrate the building most powerfully may not have more people in them but they make more people visible. The awareness of other people becomes related to the experience of spatial structure. This seems to suggest a different form of virtual community, which may be based on visual encounter rather than encounter that is bonded in individual spaces.’

Overlapping the spaces of greater visual integration from VGA maps with axial maps, they coincide with locations where clusters of very active lines cross each other. As these active nodes tend to provide social gatherings and more intense flow of people, they facilitate the condition argued by Choi (1997) that more people visit spaces that are more integrated. We also observed some of the structural spaces in the 1959 ground and 1st floor plans through their isovists, including: entry vestibule, ticket counter, centre of atrium, bottom of ramp, elevator and stairway halls, and store (ground floor); outside High Gallery, inside High Gallery, balcony at ramp, elevator and stairway halls, main gallery ramp, library’s entry vestibule, library and monitor offices (1st floor). Isovists on ground floor close to the atrium proved to be mostly...
convex. On the 1st floor, the more convex isovists are located at the High Gallery, main gallery on ramp and in the library. As convex isovists have a high clustering coefficient, little visual information is lost when visitors move in these locations. (Figures 7 and 8)

As we look at spaces further from the atrium on both floors, isovists become more pointed, allowing for more visual information to be lost, therefore, making it more difficult for interpersonal encounters or copresence. Taking these considerations to the 1990 layout, if on the ground floor this segregation could be considered positive, as there are two different functions (store and gallery/admission ticketing), on the upper floors, almost fully occupied by exhibition spaces, it is negative in relation to the spatial experience conceived by Wright and the purposes we consider fundamental in the design of a complex building: movement, encounter and consciousness, which ratifies the idea that the architectural project ‘operates against some background of legality and that this legality is itself rooted in the properties of form’ (Peponis, 1993, P. 54).

3.3.2 FIELD OBSERVATIONS

We performed random observations during several site visits and three specific procedures: Following 12 subjects in different hours of museum operation; counting of visitors at a gate located at the bottom of the ground floor ramp to verify the type of vertical circulation (elevator or ramp) chosen to initiate their visit, and caption of static photographs from a fixed point located on level 6 (the highest level accessible to the general public) overlooking the atrium at ground floor, where 23 images were recorded, with an interval of 3 minutes between each. As for the first, we followed 12 individuals (alone or in pairs) without predefined selection criteria, recording each route with photographs and simplified floor plans that indicate ascending and descending movement in space. The counting was performed at two times during a weekday, lasting 12 minutes average each. 241 people walked by the established gate, in a flow of 10 individuals per minute (Figure 9).

Even though choices might need to consider some filters – age, profile (tourists or locals) and free admission days - a key aspect in the understanding of the routes was the option to initiate the visit via ramp or elevator. Wright conceived the galleries based on the idea of movement in the spiral as a drift downward, wishing that visitors would rise with the elevator, floating vertically towards the glass dome above. We found that, even if not by a large difference, the majority of visitors (58%), in disagreement with the architect’s prediction, used the ramp to ascend in space. However, the idea of the rapid descent thought by Wright was somehow present, as most subjects descended faster than going up. The average observation time - which often coincided with the subjects’ total visiting time - for those who took the elevator was 50 minutes and 82 minutes for the ones that opted for the ramp.

A greater interaction with works of art seemed to happen at longer stops, during the ascending movement of those who took the ramp. These, in turn, established little or no interaction with the art as they moved downwards, having more regular and direct contact with the atrium, when they frequently stopped to take pictures of the space, themselves and their peers, even while located at different ramp levels. Although such interaction may indicate that ‘the direction
of viewing is centripetal when one looks at the building and centrifugal when one looks at the paintings’ (Peponis, 1993, p. 59), it challenges criticism regarding the idea that ‘the major flow of circulation leaves no room for probabilistic effects of the layout over exploration and encounter’ (Peponis, 1993, p. 59). (Figure 10)

Coinciding with the major integration core on the convex map encompassing the continuous gallery ring, it indicates that the building was designed not only as a place for education and culture, typical in other museums of the period, but also as a social space that facilitates co-awareness and copresence, influential aspects in many cultural buildings to follow the Guggenheim later in the century through today.

Figure 9 - Maps and photographs used for tracking visitors, subject is a couple of tourists, aged 60-65, recorded from 11:27am through 1:27pm.
4. CONCLUSION

Although the Guggenheim interiors remain white as the modernist museums of the time - actually a change pushed by the museum direction that differed from the creamy tone imagined by Wright - its spiral ramp evolving around a central atrium that serves both as circulation and gallery space is an antithesis to the paradigmatic open spaces of MoMA or Mies van der Rohe's Museum for a Small City.

Even if the linearity and ceremonial character of this configuration relates to 19th century museum layouts, the Guggenheim's singular shape and dynamics of visitors' movement offer a spatial experience that is unlike any other museum, providing a unique context as people move around and observe the artwork through the continuous sloped plane of the ramp and, simultaneously, interact with each other far beyond the low parapets of the ramp that enclose the voided high-ceiling atrium.

According to Zevi (2010), the Guggenheim refuses the inert mechanism of juxtaposed rooms, each enclosed in itself without continuity, proposing, instead, a walk through art, a path similar to a parking garage that wraps itself in an open spiral. Thus, the usual circulation connecting in-line galleries or long corridors in between them is replaced by a unique configuration that began to change the social implications of art, replacing the traditional box with a continuous spiral and paving the way for the museum as an environmental art that would be established two decades later with the Centre George Pompidous. (Newhouse, 2006)

It is true that Wright was not the first one to experiment with spiral schemes. Le Corbusier was working on similar ideas since 1920s that were built in the Museum of Western Art in Tokyo, which opened shortly before the Guggenheim. There are morphologic similarities between the two, especially in relation to the central hall of Corbusier’s project - in Tokyo a high ceiling square-shaped floor plan with two semi-enclosed balconies, also used for exhibitions, overlook the main exhibition spaces on the ground floor, where a ramp allows for modified views of both, and a skylight tops the sculpture galleries. Both museums mark – perhaps more the Guggenheim than the other - an intention to step away from the rigid box of conventional architecture, aiming to create a sense of continuity between space and time by eliminating formal walls and floor plans.
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ABSTRACT

During the Portuguese post-revolutionary period in the 1970’s public housing policies were restructured, resulting in the organization of public housing development in three groups; direct state development, state co-subsidized housing co-operatives and construction of private housing for organized ill-housed populations in the city centre. The latter solution gained disciplinary and media attention at the time, and remained an important reference to contemporary approaches to participatory design processes. However, marked by projects of little urban impact and of mainly punctual action, it has proved unable to respond to real housing needs, comparatively encompassing a very small percentage of the population. It has gained exceptional relevance in the historiography of Portuguese architecture due to its participatory nature, and the resulting typologies have remained, in opposition to the large-scale top-down projects directly promoted by the state, connected to democratic values in the dominant architectural discourse. In order to challenge this notion, syntactic analysis’ tools are used to examine six neighbourhoods from the post-revolutionary period in Porto, Portugal, representative of the set of built projects in each group. The paper examines the relation between type of housing development and design process with the configurational relations between functional spaces of the produced typologies, both at the domestic and neighbourhood levels.

KEYWORDS
Social Housing, Portuguese Architecture, Citizen Participation, Domestic Space

1. INTRODUCTION

1.1. SOCIAL HOUSING POLICIES IN THE PORTUGUESE POST-REVOLUTIONARY PERIOD

The years after the revolution were a particular moment in the history of Portuguese social housing, both for the multiplicity of typological and morphological solutions which emerged from intense research, multiple programs and experiments, and for the particular relevance it had in the city. Corresponding to a momentary extinction of the real estate market, all these new residential areas of state development had great impact in the city’s growth, and, benefiting from infrastructures and public services’ planning in the long term, are in great part responsible for the current urban configuration of Porto and its adjacent cities.

While the dictatorial regime which preceded the revolution had always recognised both the necessity and the usefulness of a public housing program, it failed to provide a solution for the ongoing housing crisis. The enterprises it developed were often directed at public
employees with middle class incomes and, working as devices of governmental control, the process of admission for new families was difficult and highly monitored (Borges Pereira, 2011). Consequently, when the regime was overthrown in the early seventies, the city of Porto still suffered from long-lasting overcrowding issues and lack of proper housing conditions.

In this context, the revolution of 1974 brought a necessary restructuring of the existing institutions and public housing policies. The state department of social housing, FFH (Fundo Fomento da Habitação in Portuguese), which had been created five years prior to the revolution with the objective of integrating a new national housing policy with urban planning by centralising both in a single organic structure, remained the main housing developer. Benefiting from an increase in financing and with a practice that was, during the post-revolutionary period, highly connected to the normalisation of constructive processes, development of social studies, data collection and statistical procedures, the FFH developed a series of different solutions in policies, urban morphology and domestic typology which were highly innovative in the national context, and reflected contemporary housing experiences worldwide.

Within the FFH, public housing was organised in three different programs with different objectives. On one side, there was direct state development, working with the city council for the construction of new housing enterprises.

While the state and municipality made an effort towards a lower segregation of the working class in the city suburbs and adjacent cities through thorough planning, a different programme was created in an attempt to keep the existing populations in the city centre, SAAL (Serviço Ambulatório de Apoio Local in Portuguese). Its main objective was to promote the initiatives of ill-housed communities by creating incentives through the municipalities to their collaboration in the transformation of their own neighbourhoods, through direct discussion between architects and neighbourhood associations.

Finally, the housing co-operatives, which has existed since the late 19th century, were also vastly restructured and integrated in the FFH. Having functioned before mostly as a mechanism for facilitating gradual middle class access to private housing, cooperatives benefited during this period from the technical, juridical, social and financial support of the State. Furthermore, fruit of the initiative and organization of future inhabitants, they had a say in the selection and acquisition of sites and development of typologies. (Fleming and Magano, 1992).

As the particular conditions in which they appeared, the new housing programs, responsible for great part of the production of social housing in Porto, were short-lasting. The SAAL program was extinct in 1976, having lasted only two years, and the financial aid to co-operative housing was cut down in 1978. The FFH lasted eighteen years before its extinction in 1982, in a political and social context very different from that in which it had emerged. From this point on, these programs have been majorly forgotten in the study of Portuguese architecture, housing production and urban growth. Porto, which has become the symbol of the country’s architecture, is a blatant example of this.

1.2. THE POST-REVOLUTIONARY PERIOD IN THE HISTORIOGRAPHY OF PORTO’S ARCHITECTURE

"The SAAL remains, in the School’s imaginary, as corresponding to the Modern Movement’s heroic period - its foundation, unforgettable, unrepeatable. “ (Jorge Figueira, 2007, p.67)

The SAAL program was not the first concretization, the sole or the most productive in number of built homes, of the participatory and highly political movement which emerged from the restructuration of social housing policies. In fact, the period immediately after the revolution of 1974 was characterized by a series of different strong social movements reclaiming the right to proper housing. It was this constant popular pressure, supported by brief favourable political and ideological conditions that made it possible to create state structures which allowed for organised ill-housed communities to have an active role in the production of proper housing.

However, particularly in Porto, this program became a key point, and often the only reference, of a multiple process. It is tendentiously through SAAL projects by renowned architects that the post-revolutionary period makes an appearance in the historiography of Porto’s architecture.
While this was a moment of particular activity which had major impact both in Porto’s urban configuration and in the development of new standards for contemporary living, the multiplicity of the housing program is often reduced to particular examples of the SAAL and brief mentions of enterprises developed by housing co-operatives in the existing literature (Ruivo and Tenreiro, 2014).

It is interesting to analyse why it might be so. If it may be questionable that, as Figueira (2007) proposes, this program was the founding point of the movement known as School of Porto, it is true that the set of aesthetic and ideological principles it had been developing since the 1950’s is deeply present in a majority of SAAL projects in Porto. Furthermore, the period of the program’s activity coincided with the moment when Porto’s architecture, and in particular Álvaro Siza’s work, started being recognised as an international reference.

While the actual impact of the SAAL’s role in the School’s newly gained visibility been argued in recent years (Costa, 2014; Bismark and Domingues, 2014), this program continues to be deeply connected to a set of principles which remain the base of Porto’s architecture identity. In this context, the impact of the overall housing production in Porto during the post-revolutionary period has been undervalued by the discipline of architecture. It seems pertinent then to draw a comparative analysis of the three models of housing development in order to shed light, in the context of Porto’s architecture and urban development, on other programs which, not less relevant or architecturally pertinent, may add to the typological model and of urban morphology of the SAAL, which has been consistently presented as the victorious materialization of architecture in the post-revolutionary process.

2. METHODOLOGY

While some historical and socio-political reasons have been advanced here which for the prominence of the SAAL program in the historiography of post-revolutionary housing, it is outside the scope of this paper to attempt to thoroughly explain them. Instead, this study aims to contextualize its projects within the housing production of this period, analysing the spatial characteristics of each program. This will be done in light of a set of objectives which was transversal to all.

In fact, the development of public housing in the post-revolutionary period was directly connected to intense research conducted by the national laboratory of civil engineering (LNEC). It encompassed various fields of action, from the development of new construction techniques to anthropometric, ergonomic and sociological studies (Portas, 1969). Within the latter some major concerns stand out:

(1) The importance of a shift in the understanding of the woman’s role in the household;
(2) How a growing intensification of the time spent at home reflects in a changing attitude towards children;
(3) The importance of neighbourhood relations, focusing on the ways of interaction and mutual aid systems - this particularly in the case of the housing co-operatives, which aimed at fostering a feeling of familiarity and community;
(4) The degree and relative value of the relationships established between the family and other groups - this particularly in the case of the SAAL projects, concerned with the integration of lower class populations in the city.

These were reflected in a set of design regulations and guidelines for the overall quality of life and development of desirable social interactions in the domestic space (Portas, 1969) and neighbourhood (Redol, 1985), regarding the design and composition of functional spaces.
Three main variables were defined for the quality of the domestic environment:

(a) Domestic activities: those necessary to foster domestic interaction and good neighbourhood relations;

(b) Configuration: the disposition of the private and collective spaces where activities took place within the overall configuration and their influence on the family life (Redol, 1985; Pereira, Gago and Lopes, 1984);

(c) Areas: In order to generate what were considered good conditions for living and sociability, ideal areas for each functional space were suggested which were different from the minimum areas commonly researched during that period (Portas, 1969).

The adopted methodology aims at studying how the differences and similitudes of the variables (a), (b) and (c) at the domestic and neighbourhood levels of the three different types of housing development above mentioned, acting as social and spatial mediators, translate the main social concerns indicated in (1), (2), (3) and (4).

(a) Which domestic functions and functional spaces: The existence or non-existence of each of the functions considered necessary by the LNEC in each case was examined, as well as which of those are located, according to the labels on the projects, in the same room or perceivable space. At the neighbourhood level, the existent rules and regulations are much vaguer, focusing mostly on a systematic suggestion of the necessity of designing spaces for collective social use, such as public equipments and services like schools, sports facilities, social centres, shops, restaurants, and public spaces like gardens and squares. At this level, areas planned to house collective functions were taken into account.

(b) Spatial Configuration: The spatial configuration of the studied cases was analysed with recourse to syntactic analysis’ tools, mainly justified permeability graphs, and the syntactic properties of depth and integration were calculated.

Functional spaces have been used instead of convex spaces in several studies of the domestic space (Chatzichristou and Kranos, 2014; Hadjichristos, 2003; Monteiro, 1997). Following this approach, each area destined to a specific activity was counted as one, regardless of its shape, unless there exists a major division (in the form of steps, difference in height, or other separations such as fixed furniture) between areas meant for different activities.

(c) Areas: The areas of the examined projects are analysed in light of the exhaustive research work conducted in this period for the definition of minimum and ideal areas for functional spaces and the home. As these areas were defined always as the possible best within the reduced budget of social housing, lower, but not higher, values than those determined by the LNEC were considered to be less propitious for the creation of favourable social interactions.

3. ANALYSIS AND RESULTS

Following the discussed methodology, the analysis will begin by studying (4) “the degree and relative value of the relationships established between the family and other groups”, through an examination of the patterns observed for each of the studied programs in their location in the city, in regards to more or less integrated areas and connection to main infrastructures.
Integrating a housing program concerned with keeping existing communities in the centre, the small scale participatory SAAL projects are normally settled in or around the best integrated areas of the city. However, as shown in figure 2, often situated inside existing city blocks and resorting to complex pathway structures in order to adapt to the site’s form and topography, these neighbourhoods present the highest depth values for the houses in relation to the main street system. With houses situated five steps deep from the exterior, these neighbourhoods are invisible from outside the blocks, and so from the main city arteries.
In contrast, state and municipal social neighbourhoods appear in areas that were, at the time of their construction, mostly un-urbanised. These are today mostly areas of medium integration, well connected with the main built fabric of the city.

In most cases, buildings turn their back on the existing streets and there exists a secondary pathway system as shown in figure 3. Both apartment buildings and public infrastructures lead to complex sidewalks which often place their entrances three steps away from the street network interior to the neighbourhood. While the same design logic is followed in larger scale cooperative projects, there is a big part of cooperative enterprises, dependent on available urban land, which is small and integrates the existing city fabric.

Figure 3 - Neighbourhoods (c) (Aleixo, state development) and (d) (CETA, co-operative development), large scale enterprises with public equipment and facilities.

In these cases, buildings tend to follow the existing urban design, often opening directly to the sidewalk. In this aspect neighbourhood (c) presents a different approach. Organized directly around the main street, apartment buildings are positioned according to solar orientation, with its accesses facing north. While houses and public equipment are both more integrated in the city fabric than in other cases, they show a lower relation with each other.

Usually located near the city limits, with only a few more central exceptions, housing cooperatives developed the least integrated neighbourhoods of the three groups. Not as articulated in urban planning strategies as state and municipal housing, the co-operatives’ need for cheap terrains, its inability to conduct expropriations and a systematic fall-through of the construction of designed infra-structures, seems to result in a discrepancy between the needs of lower class populations and the resulting enterprises. These end up being directed mostly by lower middle class, which can afford to be mostly dependent on personal transportation. Even though these neighbourhoods mostly follow the same design principles state and municipal neighbourhoods, the interior of the apartment often appears to reflect class differences between their respective inhabitants.
The houses’ total internal useful area is larger in these cases than in any of the others, sitting at around ten square meters above the legislated minimum. This reflects into a higher percentage of the apartment’s area being assigned to the kitchen and bedrooms over living areas, with the first being significantly larger than in other studied enterprises.
In fact, housing co-operatives are the only cases in which living spaces such as the living and
dining rooms are neither the largest nor the best integrated, displaying higher integration values
on bedrooms and particularly on the kitchen. This seems to happen to the detriment of exterior
spaces. In place of well-integrated areas in close relationship with either the living room or the
house's entrance present in other cases, the housing co-operatives have small segregated semi-
exterior utilitarian spaces which are accessible through the kitchen. This reflects a different take
on the role of these areas from the other two types of housing development. While the smaller
scale single family houses also have relatively large kitchens, these are less integrated and
establish a closer relationship with the exterior, to which they are the closest functional area.

State and municipal enterprises, which seem to be more strictly concerned with the development
of minimal areas, it was possible to identify two different approaches to the issue: the minimal
kitchen, designed according to minimum regulated areas and showing low integration in
relation to the rest of the house; and the overall negation of the kitchen as an autonomous area
and its integration within the living or dining room.

Area economy seems to be the major point where state and municipal enterprises converge,
resulting in small to non-existent kitchens, fewer and smaller transition spaces within the house
and below-standard areas in bedrooms. In contrast to what was verified in housing co-operatives,
the combination of high levels of integration and large areas in the sector living room, dining
room and exterior seems to indicate a definition of these spaces as the collective areas of the
house. An opposition seems to exist between the assignment of the major social role to the
living room or the kitchen among all cases, and the definition of a social pole encompassing
both areas appears to be rare. Only in two cases are the living and kitchen areas accessible
through each other, and no difference in approach could be identified between housing co-
operatives and state and municipal housing.

Figure 6 - state and municipal housing apartment typology in Ramalde do
Meio (e) and Aleixo (c), justified graph and relation between rooms' areas and
integration levels
In two storey single-family houses living areas and bedrooms are located further apart, and contrarily to other cases where the living areas and the kitchen occupy similar places in the house's configuration, the kitchen is, if not topologically shallower, at least metrically closer to the entrance than any other area. Exterior spaces have particular importance – unlike other cases they are not an extension of the living area, but an intermediary space between the interior of the house and the neighbourhood. While balconies are places of living and reunion within the family, the front yard establishes a relation from within the house with outside actors. The interior of the house reflects characteristics of the neighbourhood, both presenting particularly deep spaces which are accessible only through well-integrated social areas.

4. DISCUSSION AND CONCLUSIONS

Three types of housing development emerged in the Portuguese post-revolutionary period. Developed with different objectives, they seem to respond differently to a common set of major social concerns. While in some cases these differences are explicit and come from a conscious response to outlined principles and objectives, they are often also due to each one's particularities and consequential material constraints. A good example of the processes leading to and resulting from these differences is neighbourhood integration in the city's configuration and with the city's infrastructures.

Even though social integration in the city and the establishment of desirable relationships between resident families and social groups outside the neighbourhood was a transcendent goal to all three types of development, different tendencies could be observed between groups. Occupation of un-urbanized and industrial areas by state and municipal enterprises seems to
have resulted in the qualification of those places, creating neighbourhoods which, even when remaining removed from the consolidated city, are mostly well integrated today. Inversely, housing co-operatives seem to have been less successful in integrating neighbourhoods with city development. While both originated from the same set of principles and objectives, concerned with global urban planning and city-growth and taking into account economic constraints, the characteristics of each program resulted in differences in the integration of the developed enterprises in the city.

SAAL neighbourhoods take on forms which explicitly reflect a different approach to the idea of integration and urban planning. While urban infrastructures and accessibility are assured by the particular integration of these neighbourhoods in the city centre, it is interesting to verify how discrepancies between architects’ objectives, residents’ references and the site’s characteristics are visible in the configuration of these spaces. For example, both the design of highly integrated spaces controlling accessibility in the neighbourhood, and the way accesses reflect nearby public spaces, seem to be formal strategies developed by architects to oppose the inhabitants’ resistance to collective spaces and public equipment within the neighbourhood (Portas, 1969) and the constraints inherent to the need to occupy blocks’ interiors with no immediate contact with the main road structure.

Regarding the neighbourhood-city relation, the study encountered well-defined neighbourhood limits and enterprises located around main city-axis. Regarding neighbourhood-house relations, the hypothesis is advanced that these may shift the social relationships happening inside the house. In order to understand the effects these different strategies have in the development of neighbourhood relations and in integrating its inhabitants in city dynamics, further analysis of the neighbourhood and the relations it establishes with the home and with the city is currently being conducted. It is expected that the study of interior-exterior dynamics will make it be possible to understand, for example, whether the front yard of the analysed single-family houses extends the social areas of the house to the collective space or acts as a transition space increasing the depth of the private spaces in relation to the neighbourhood.

Regarding the domestic space, conclusions regarding explicit state concerns were possible to be drawn from the relations and relative importance of each domestic sector, as well as how each functional space seems to be perceived as either social, private or service. For example, the integration and area of the kitchen in relation to other spaces in the house may indicate different approaches to the ‘shift in the woman’s role in the household’, as presented in LNEC’s guidelines. In fact, it was verified that neighbourhoods with some sort of participation in the design process by its future inhabitants tend to have larger and better integrated kitchens. It has been indicated before that, in participatory processes, future inhabitants might be resistant to change in recognizable spatial patterns. Architects have registered a strong resistance against planned exterior collective spaces by a population used to a pre-existent type of coexistence based on the street as the main space of social interaction. Likewise, this kitchen configuration may have to do with the perpetuation of this area as the traditional main social pole of the house. In contrast, the minimum kitchen present in state-developed enterprises, if unaccompanied by this period’s shift in paradigm relating to women and household chores, seems more likely to result in a segregation of the woman in relation to a social area which is clearly intended to be the living-room. Even though both area economy and woman’s integration in family life were two of the stated objectives of social housing during this period, only one case of a kitchen integrated in a larger living room was verified. Further analysis of municipality-developed typologies is expected to contribute to the understanding of the extent to which this question was explored.

Family life seems to be a concern in these neighbourhoods. State and municipal enterprises present the better defined domestic sectors as introduced by the modern movement, with a clear separation of a private area defined by bedrooms and bathrooms, a social area mainly consisting of the living and dining room, but sometimes also of a separate dining-room and balcony, and a services area defined by the kitchen. This division in different sectors is characterized by a relatively larger and better integrated living area, while for example, co-operative housing’s focus on the kitchen as a more likely space for social interaction is counterbalanced by relatively
larger and better integrated bedrooms, which, added to a probable difference in target social classes, might suggest different family relations in housing co-operatives and other types of social housing development.

The analysis seems to make clear that the different housing programs which shaped Porto and its adjacent cities in the years after the revolution served different purposes and attempted to provide solutions for different urban and domestic questions. While the SAAL was undoubtedly notable as an institutional and exhaustive materialization of the ideals of popular participation in architecture, the place of uniqueness it has achieved in the historiography of Portuguese post-revolutionary architecture may for this very reason be detrimental both to the historical understanding of this period, and for the full reclamation of its teachings.

On the contrary, further research on the particularities of each different solutions and methodological approaches might contribute to inform the future of social housing development in the country. An analysis of how the questions of urban planning and economy of resources, which were thoroughly explored during this period but have been overlooked in subsequent theoretical production, have translated into the contemporary urban space and social dynamics, seems likely to be an asset both for housing studies in general and for a more comprehensive understanding of the highly studied participative typologies.
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TOPKAPI PALACE: 
Reflections on Social and Spatial Order

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ABSTRACT

Anatolia has witnessed many Ottoman structures, yet, Topkapı Palace may be the most 
significant one that has influenced the distribution and control of power. The Palace was built in 
the longest-term capital of the Empire, Istanbul, and reflected architectural and environmental 
features that were developing and expanding at the site for about half of the 600 years of reign 
of the Ottoman Empire. The palace is the symbol of interaction, social and spatial order, privacy 
and the territoriality affecting the overall administrational and social structure. The three-fold 
interaction between the Sultan, various chambers of administrational levels and the public is 
the key concept that the research is based on.

Although construction of The Topkapı Palace first started in 1459 after Istanbul became the 
capital of Ottoman Empire, its significant role on reflecting Ottoman ruling is undeniable. The 
transformation and expansion character of the Palace give clues for understanding how the 
order is facilitated through the governing and social issues. Therefore, in this research the 
concept of state that lie behind the tradition of ruling, its reflection to architectural space and 
the latent aspects of public-and private relations embedded in a deep hierarchy are examined 
and compared within the context of Mehmet II (Fatih) and Süleyman I (Kanuni)  eras of the 
Topkapı Palace.

The palace as the royal residence of the sultan and the centre of social issues as well as the 
centre for government, is a complex structure, settled on a large area, configured through the 
spatial hierarchy on the interfaces of four main courtyards and the relationship between the 
administrative, residential and auxiliary spaces. At its peak complexity, Topkapı Palace was
home to as many as 4,000 people, while containing many public and private facilities such as mosques, hospitals, bakeries, as well as a mint in its territory.

As the courtyards are the interface between the public and the private, through ceremonies and rituals, integration of indoor and outdoor spaces, the level of visibility through the palace complex and its effects on the spatial meaning are explored. Therefore, depending on the complex and developing physical structure of the palace a two-fold syntactic comparison is executed in this research; in order to define spatial hierarchy of spaces, public-private interfaces and the overall rationale behind the power concept. At the first stage, the configuration of the courtyards and thresholds of both periods are examined through defined reference nodes; whereas at the second stage Süleyman I era is scrutinized. The first stage gives an overall panorama on the motion flow, while the second stage focuses on the building scale.

Syntactic findings show that the effects of transformation through administrational and institutional structure from 15th century to 16th century in Ottoman Empire have affected the spatial order and meaning in Topkapı Palace, in terms of deeper hierarchy, centralization of power, and introversion. On the other hand, while the state based on traditions keep their significance within the spatial configuration, and the existence of power remains solid.

KEYWORDS
Social order, configuration, interaction, Topkapi Palace, spatial differentiation, power, spatial hierarchy

1. INTRODUCTION
In Plato’s ideal world, which was depicted in The Republic, the tripartite analogy between the soul and state is denoted as logical, spirited and appetitive classes of the society, briefly representing rulers, soldiers and workers. In this harmonious yet deeply hierarchical system where members are ranked according to their virtues and aptitudes, justice is the main key component that holds everything in divine order. Especially in ancient communities, envision of cosmos is formed within the framework of fundamentals such as human, God, and order. Values, which are innate both in institutions and traditions, are the basis of justification for societies’ thoughts and actions (Bıçak, 2004). In Turkish cosmology continuity of the state has emerged as one of the most important values since it means existence (Bıçak, 2009). In Turkish culture, state is an essential value, which also contains the concepts of justice and centralization.

In the mentioned cosmos, Tengri depicted as an eternal, powerful God, maintained its presence in all of the dialects and accepted religions of the Turkic people. Particularly, the rulers who are believed that they were given the blessing (kut), have to be in harmony with Tengri (Roux, 1994). In the determination of the duties of the state and the ruler, God’s will and the order of the universe have been used as a model. On the other hand, Kutadgu Bilig, written by Yusuf Has Hacip in 1069, as the “bible” of statecraft theoretically analyses the relationship of ruling Sultan and vizier based on the myths of Orkhon inscriptions. The book discusses the administrative problems such as protection of rulers, conditions of dominance, circumstances that will cause collapse, methods of ruling for people’s loyalty and means of keeping treasure full. When traditional understanding of the state is analyzed, power emerges as the most important concept. There are two main foundations of power; one is the blessing of God (kut of Tengri), while second one is to be skilled enough to meet the needs of the society by acting in accordance with the blessing. Justice is an important decisive factor considering the relations of the state and ruler with the people. The goodness of the laws also indicates the wisdom of the ruler. Therefore, similar to Plato’s just state, traditional Turkish thinking is established on the continuity of state and justice based duties assigned either from the kut of Tengri or the ruler himself.

Palaces as the signifiers of the central authority give us extensive information on the society, political systems, socio-cultural implications purely within the context of architecture and
spatial configuration. The collection of this information is easier if we can actually observe the daily royal life behind walls. However, when the means of power has gone through a severe transformation, architecture also loses its functional and semantic basis. As the layout of spatial configuration turns into a puzzle that needs to be solved and interpreted, we reach for the history and try to recapture the hidden rationale. Therefore, in this research the concept of state that lie behind the tradition of ruling, its reflection to architectural space and the latent aspects of public-and private relations embedded in a deep hierarchy are examined and compared within the context of Mehmet II (Fatih) and Süleyman I (Kanuni) eras of the Topkapı Palace of the Ottoman Empire.

2. REFLECTIONS OF POWER AND RITUAL ON STATE AND SPACE

Especially when analysing administrative buildings, the factor of political power as the determinant of configuration and its usage, are needed to be understood. As Šuvakovic (2014) mentioned, although sometimes its intentions are hidden, architecture is essentially a political and ideological practice; so when analysing the executive and representative effects in architecture we cannot be restricted to questions about architecture's pragmatic functions. Therefore, the practice of architecture is in its character a signifier practice and that means a material practice, in which the social and the human are produced in the struggle to structure the visible, i.e. presentable order of power, rule, governance, and existence.

The Ottoman ruling tradition goes back to initial Turkic societies. The world state realized by Oghuz Khan Legend has emerged as an archetype for the following states, even after the adaptation of Islam during the 10th century. As the legend was also used to explain the origins, it had been very influential on determining the ruler’s right to govern and the character of the state (Roux, 1994). Therefore through Oghuz Khan as the first ancestor of Turks, the descendants and generations who were connected to him could explain their origins to fulfil the requirements of claiming legitimate right on the throne. The Seljuks have acquired the right to govern the Turkish state by linking themselves to the legend, whereas Ottomans linked themselves to Seljuks. Thus, this explanation helped both the legitimacy of the state and the origin the society needed. As a result of mentioned continuity in state traditions, the relationship that Seljuks had established with Islam determined the relationship of Ottomans as well. In Ottoman state, there were two separate notions; while Oghuz Khan Legend constitutes the foundations of the state understanding, faith is formed in the framework of Islamic belief and finds expression in the person of the Prophet. This dual evolution is evident especially comparing the initial years of the empire with later stages.

Ottoman Empire had been the longest-lasting Turkish state, which had dominated a wide geography until the 18th century by maintaining its existence through balancing economic structure and transformation of social structure (Bıçak, 2009). The quality of the army, which was greatly supported by the society as required by the holy war belief, was an essential factor in state organization. Thus army was considered as the assurance of economic growth in addition to a large number of officers and professional experts. Moreover, since the Seljuk period the madrasahs have become the main institutions of education for state officers specialized especially on religious law (Bıçak, 2009). However, in Ottoman era, madrasah has been enriched in content and developed a certain hierarchy that can also be seen in the formation of palace school, Enderun. Therefore, the state was regarded as a structure rising on the foundations of law and army, based on the values of order, justice and security, where madrasahs and bureaucracy played major parts on the principles and robustness.

Additionally, the adoption of localism and self-sufficiency as a principle of central state administration has enabled the prevention of richness through capital accumulation. This economic tradition has put the emphasis on social order by secure compensation of needs and also a strong submission to state and ruler. Since society does not have a property-based class structure, equality between individuals is among the fundamental values of the social structure and superiority could only be achieved through assigned duties (Roux, 1994; Bıçak, 2009). This mindset also helped the acceptance of competences among various ethnic and religious groups.
that work in state bureaucracy. However, this bureaucracy has led a deep hierarchy reflected in spatial configuration, actually which is still present in Turkish state formation.

As for the architecture, social and spatial hierarchy forming Topkapı Palace, starting from Chinese palace tradition, to rural palaces of early Islamic rulers, to Seljuk Era, to early Ottoman palaces were all intertwined with the understanding of the state. Commercial relations with China and Byzantium inspired the pavilions and the geometric configuration with its landscape elements that reflect the Chinese architectural tradition in the east and the feudal chateaus emerged during the 6th and 7th centuries in the west. Seçkin (1990) states that early Islamic palaces of the 8th century which had fortified appearances, were composed of mosques, simple living units, baths and formal functions. 12th century Ghaznavid examples had four lywan courtyards where the northern one is reserved for reception hall, while the spaces for the official functions of the palace were arranged around small courtyards. In Anatolian Seljuks, the palace is an organic collection of different sizes and constructions of various functions within the castle, described as a “palace city”, reflecting the tent tradition of previous tribal states.

In ancient Turkic states, palace served both for private life of the ruler, and administrative affairs. In Ottoman palaces however, sultan’s private life is located in the forbidden section, such as Ghaznavid and Chinese palaces. Edirne and Topkapı Palaces as extensive settlements in wide gardens, surrounded by city walls, similarly are formed by two sections; one houses accessible official functions, while the other one is housing Sultan’s inaccessible private life. However, administrative and ceremonial functions had their own structures (Seçkin, 1990). Pavilions located in courtyards that follow each other hierarchically are also seen in these palaces as we will further discuss.

3. THE DEVELOPMENT AND SOCIO-SPATIAL RELATIONS WITHIN THE TOPKAPI PALACE

Throughout the last three decades, space syntax has imposed itself as a reliable analytical technique for quantifying specific structural properties of urban spatial networks, which have been shown to be strongly associated with a wide range of urban social and functional phenomena. The findings of the space syntax research programme led to the progressive construction of a new morphological theory of the city: one that merges objective observational knowledge of urban spatial structures, with knowledge of the human sociological and behavioural phenomena occurring therein, while trying to find systematic relations between both; and so, a theory that was able to propose cogent causal explanations for the fact of cities being like they are (Hillier 1999a, Hillier 2012).

Topkapı Palace (Figure 1), which was built in the second half of the 15th century by Mehmet II, is the product of architectural traditions accumulated through Anatolian, Middle Eastern and Mediterranean civilizations of the previous centuries. Although its formation was coincided with the period when the borders of the country were expanded, and therefore transition from the city-state to central-state system was seen, in the 15th century, Topkapı Palace was an unspectacular building that very few people actually inhabited (Seçkin, 1990). Despite this appearance, it was programmed according to a state concept that is predefined in Mehmet II’s code of laws and structured to operate predicting the improvements in the state organization.
In the traditional palaces where a keep surrounded by quadrangle walls, houses the ruler’s mansion situated on a high set. The central position of the ruler as a product of the cosmographic plan scheme, expresses dominance in four wind directions, as in Chinese and Turkic cultures. This basic configuration remained unchanged however; the Turkish palace was developed within the local conditions, and architectural characteristics of the region as seen in Topkapı Palace.

The spatial hierarchy of Topkapı Palace rests essentially on the interfaces of courtyards and the relationship between the administrative, residential and auxiliary spaces (Figure 2). Before the imperial fortress was built to enclose the huge space, Topkapı Palace had only two courtyards and one entrance (Necipoğlu, 1991), similar to the depictions of Old Palace, which is the precedent of the Edirne and Topkapı Palaces. The relationship of the buildings was based on the traditional order of the Ottoman encampment, also seen in Seljuk tents. When the land wall of the Imperial Fortress was joined to the Byzantine city walls, a new fore courtyard appended to the palace’s main core. On the wall there are several belvedere towers functioned as a link between the palace and its surroundings, signifying that the sultan was watching over the public.
Ceremonial movement is directly related with the imperial architectural representation of the palace and has a narrative dimension according to the hierarchy. Although the connection gates are not aligned, three courtyards settle the hierarchy (Seçkin, 1990; Necipoğlu, 1991). The first courtyard surrounded by gardens housed various public functions, and although some were pre-existed such as Basilica of Saint Irene, located on the left of the Imperial Gate (Bab-ı Hümayun), the buildings here are mostly functional structures with simple tectonics. As the natural extension of Hippodrome area several service functions like; a menagerie, a stable, a powder magazine, a bakery, a hospital, storehouses, workshop for painters, an archive, tailors, tent makers and other royal craftsmen were located in this courtyard. Beside the contrast between the military functioning of the second courtyard and paradisiacal tectonics of the third courtyard, the first courtyard is clearly a public extension of the city.

The buildings in the second and third courtyards were more prestigious. The second courtyard acted as a theatrical setting for ceremonies and housed administrative functions as the administrative centre of the empire. For example, Mehmet II himself was still appearing in the administrative courtyard of the palace for fifteen minutes to brace his soldiers and to accept ambassadors until he abolished this practice in his code of laws (kanunname) with the construction of Chamber of Petitions inside the residential third courtyard. (Necipoğlu, 1991). Justice Tower (see Figure 1), which was the landmark of the palace and Council Hall as the main administrative space, are both located in this courtyard. Vestibules, porticoes, halls and kitchens on the right are other important service structures located in second courtyard, as modelled from the traditional tent-palaces of the previous Turkish rulers, where the administrative enclosure was connected to the residential courtyard. Mehmet II translated this traditional layout into a permanent architectural configuration with the administrative buildings located on the left corner.

The third courtyard was more than a royal residence with a palace school (Enderun) inside, as a reference to continuity of state, as well as the connection of state, bureaucracy and army. The threshold between second and third courtyard that passes through a monumental gate, meets the Chamber of Petitions (Arz Odası), which cuts the visual perception through the third courtyard. As an invention of Mehmet II, this building was used for the presentations of
the leading divan members. Ambassadors or officials who had once been received publicly at the second courtyard could now be received privately in this chamber. Although the sultan is invisible, this building represents his power, whereas the hierarchical setting and functioning represent the centralized imperial government. The configuration of the royal structure begins with Chamber of Petitions also known as Throne Room in some references. Third courtyard is surrounded by buildings such as palace school, dormitories, harem connection, royal baths and kiosks along with a mosque. The inner treasury also located here, has three halls open to loggia. There are private courtyards of sultan and his family in addition to an outer portico with terraces, pool, and several pavilions in hanging garden.

In the following decades, basic principles of Mehmet II were protected but the palace structure was renovated by each sultan. The main ceremonial buildings founded by Mehmet II had been rebuilt or remodelled and the private royal domain had been extended (Necipoğlu, 1991). Especially during the reign of Süleyman I, in the 16th century, because of the extension of the borders of the empire, a new structural organization in the palace was needed. The centralization of the state had a great effect on the architectonics of the palace. For example, during Mehmet II’s reign, Topkapı Palace acted as a seasonal resting stop, in between the campaigns of sultan and his courtyard. However in the 16th century, palace provided a private realm for a self-contained social organism sealed off from the world outside. The sultan withdrew into his inner household. Power of the sultan was increased and the hierarchy in the palace was deepened. The extensions built in first and third courtyard were enriched. The private third courtyard had transformed mainly with the enlargement of the harem and with addition of new pavilions to the gardens and along seashore.

These architectural transformations and the ceremonial changes are related with each other. Following earlier practice, ambassadors were admitted twice into the sultan’s presence in the Chamber of Petitions, once upon arrival, after a public audience with the viziers at the second courtyard and again before the departure. Earlier sultans had risen from their seat to honour the ambassadors. However, Süleyman I and his successors remained not only seated, but immobile (Ortaylı, 2017). This strong privacy and invisibility had a strong relationship with the architectural transformations. Even in his private quarters the sultan had contacted with a very few people, such that a sign language was first seen within the palace during this period.

4. SYNTACTICS OF THE SEMANTICS

Various syntactic and semantic layers determine the patterns of built space; and through interrelated position of these layers, Topkapı Palace with having ceremonial and administrational/institutional order as well as domestic space characteristics is no exception. Peponis and Wineman (2003) suggest that built space is to be understood as a relational pattern of distinctions, separations, interfaces, and connections; a pattern that integrates, segregates, or differentiates its parts in relation to each other. However, “social logic” in Topkapı Palace should be examined considering the interwoven nature of spatial layout that hosts the activities of daily life or special occasions interrelated with public and private in the context of a power based complex structure. The issues of perception and cognition are related with the movement patterns associated with functions and permissible visual and/or physical access within the palace system. In this deeply hierarchical system, where the institutional or imperial message of the palace related to power and privacy is clearly transmitted, the choices or the spatial experiences of the users are strictly related to the specific functions, thresholds, and interfacing zones just like the artwork and the order of spaces in relation with the content in a museum (Wineman and Peponis, 2010).

In the physical layout examination of Topkapı Palace, visual perception, measures of accessibility and movement are considered. Therefore, isovists and convex spaces (Benedikt, 1979; Hillier and Hanson, 1984; Hillier et al., 1987) are the key notions, where an isovist is a concept of spatial recognition that defines any particular viewpoint in a space by its visibility field; the visibility field of a single viewpoint can also be called the isovist field. Figure 3 shows the asymmetrical triangular relationship between attraction, configuration and movement...
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(Hillier et al., 1993). This theory suggests that, depending on the morphology of convex spaces as a whole, movement as visitor frequency and the attractors may be mutually influential, while the other two relationships are asymmetrical. The configuration may influence the location of attractors, but it is not certain that the location of attractors influence configuration. Likewise, the configuration may influence movement, but movement does not necessarily influence configuration. If strong correlations are found between movement and both configuration and attractors, the only logically possible means of influence are from the configuration to both movement and attractors, with the latter two factors influencing each other.

Figure 3 - Attraction, configuration and movement (Hillier, et. al., 1993)

The research explores if the integrated or segregated locations of the palace are related with the changing dynamics of physical and semantic configuration, within the hierarchy of the space. The comparative research examines and analyses the spatial layout of the Topkapı palace in relation to Mehmet II Era (1451-1481) with that of Süleyman I Era (1520-1566). As mentioned before, Mehmet II Era relates to the foundation of the palace as a synthesis of previous state traditions, while Süleyman I Era has the most significant developments and construction processes at the palace referencing and reflecting the configuration for the forthcoming centuries. Understanding the transformation of spatial order and configurative structure between the two periods is crucial in order to grasp the semantic shifts which present the significant data on the effects of changing power, public-private space relations within the palace and even on the changing positions in Ottoman Empire’s institutional and organizational structure through centuries. To understand the impact of the morphology of space on the former users of the palace during the Ottoman Era, consulting to the narrations of İlber Ortaylı (2017), who is a history professor and a former chief executive officer of Topkapı Palace Museum was also necessary. Crucial morphological understanding and syntactic values depended on the connecting spaces between the courtyards, formation of the hierarchy by the order between various courtyards and reference buildings. In this research, the relationship between syntactic values of configuration and the semantics of space is studied in detail with comparative analyses of 15th and 16th century Ottoman Palace. The attractors, namely, the ceremonial power, imperial functions dealing with the encounters of palace users and official gatherings such as senior administrators of the Ottoman Empire and non-palace users such as ambassadors, foreign representatives or administrators related within the homeland of the Empire are also considered in this relationship through certain syntactic analyses within the palace. Therefore, depending on the complex and developing physical structure of the palace a two-fold syntactic comparison is executed in this research; in order to define spatial hierarchy of spaces, public-private interfaces and the overall rationale behind the power concept. At the first stage, the configuration of the courtyards and thresholds of both periods are examined through defined reference nodes (Figure 4); whereas at the second stage Süleyman I era is scrutinized (Figure 5). The first stage gives an overall panorama on the motion flow, while the second stage focuses on the building scale. A total of 9 reference nodes are selected for the analysis; however for the second stage, the entrance to the first courtyard (no: 5) was left out.
in order for a detailed examination on the building scale. The selected nodes are as follows: 1st Tower of Justice – 2nd Courtyard Threshold; 2- 2nd Courtyard – 3rd Courtyard Connection Gate Threshold; 3- 3rd Courtyard - Throne Room (Chamber of Petitions) Threshold; 4- Courtyard of the Queen Mother in Harem – 3rd Courtyard Threshold; 5- 1st Courtyard Entrance Threshold (Bab-I Hümayun); 6- 4th Courtyard – East Gate Threshold; 7- 3rd Courtyard – 4th Courtyard Connection Gate (left) Threshold; 8- Enderun School East - 3rd Courtyard (Enderun Courtyard) Threshold; 9- 1st Courtyard – 2nd Courtyard Connection Gate Threshold.

Figure 4. Analysed nodes of Topkapı Palace during the 15th century (left) and 16th century (right)

Figure 5. Analysed nodes of Topkapı Palace during the 16th century
5. ANALYSES OF THE CASE STUDY

The Syntax 2D software developed by the University of Michigan used for this research, works by creating a grid fragmentation of cellular spaces and handles the analyses starting from a logical ground built over vision fields called isovists (Benedikt, 1979; Batty, 2001; Conroy, 2001; Edgü et al., 2012,Şalgamcıoğlu et al., 2015). As a methodology, all elements that are obstructing the sight or accessibility such as construction walls of the buildings within the system, and other structures like courtyard elements, extensions of city walls or the retaining walls in the garden are all handled as walls and affect the determination of the visual field (Turner and Penn, 1999; Turner et al., 2001; Ünlü et al., 2009; Şalgamcıoğlu and Ünlü, 2013).

Comparison of integration and depth values of different nodes and areas on the plans of two periods, helps us to figure out, how spatial layout is influenced through the change in centuries and how the integration value of a space is affected by the developments within the palace. Moreover, the spaces, which are more or less integrated, or morphologically reflecting the changing character of visual fields are important investigation orientations. Therefore, the data utilized for the nodes shown in Figure 4, interfacing areas or thresholds connecting the different zones in the system reflect the syntactic values of:

- Mean Depth
- Integration
- Occlusivity
- Circularity
- Isovist Perimeter

These five data sets used for examining the syntactical transformation, are also concepts addressed in space syntax theory, and were calculated separately for every referencing node or area (Figure 4). The values at the active grids of the palace site plans (Figure 6) were separated into these data groups and added on Table 1 and Table 2. On the other hand, Statistical Package for the Social Sciences (SPSS) correlates the statistical relationships between the changing syntactic data of two periods through Pearson's Regression analyses.

Figure 6 - Image of the Integration Analysis in 15th Century (Left) and 16th Century (Right)
The site plan analysis comparing the two periods shows the differences in the way that the palace users move within in the spatial hierarchy and the level of interaction related to spaces depending on their roles. Places that can be accessed by the public, by palace officers, by the Sultan and his family, and such are important in that sense. The level of accessibility shows the level of interaction between the “Public - Sultan”, “Sultan - Ambassadors/Homeland Administrators”, and “Sultan – Military” kind of relations. The information coming from the Mean Depth, Integration, Occlusivity, Circularity, and Isovist Perimeter is used to provide information about the level of interaction and movement in the palace between different users, and also the impact of administrative power on this spatial order.

Analyses depending on the points of reference and interfacing areas shown (Figure 6 and Table 1) are giving us the significant correlations about how semantic and syntactic order of space is coherent and strongly interrelated. Decreasing values of the Integration as shown in Table 1 from 15th century to 16th century significantly showing (Pearson’s R=0.956 and p=0.000<0.05) that the key points of interaction referring to referencing points (shown in Figure 4) and nodes are getting more deep in terms of spatial hierarchy and configuration as the Topkapı Palace is developing and annexes are built in courtyards and in garden within the palace walls. This development is also in accordance with the institutional development of the Ottoman Empire and the Topkapı Palace. It is quiet significant that as the institutional development and the power of the Empire increases, the syntactic values of Integration in determined reference points and key interfacing nodes within the Topkapı Palace are decreasing. For example it is clearly seen that the evolution of the palace building from a simple configuration of the 15th century to a more elaborated one of the 16th century, keeps the public from easily accessing the palace grounds, while distinctly separating the courtyards for different functions. On the other hand nodes related to private life of the sultan gets shallower within a closed system of controlled accessibility.

Although the circularity and the integration of the Throne Room (Chamber of Petitions), which is the meeting place of the Sultan or the senior head of state (vezir-i azam) with foreign ambassadors, other senior foreign state administrators and senior administrators from the Ottoman region, is decreasing from 77.17 to 40.43 between 15th century and 16th century, the detailed analysis of the Süleyman I Era showed that the central position and connection potential of this space is still very high between different zones and functions of the Topkapı Palace with the highest circularity value of 566.54 in Table 2. This result is significantly supporting the idea that The Throne Room is serving to the Palace as it is designed and built by being the meeting point of The Ottoman Palace with domestic and especially foreign senior visitors of the states. Semantics of the Throne room and the syntactic values overlaps and creates the harmony of the strong syntactic configuration value and the meaning.
The correlation between the changing values of isovist Perimeter shown in Table 1 from 15th century to 16th century significantly showing (Pearson’s R=0.969 and p<0.000<0.05) that the two dimensional isovist shape relating to the perimeter of the isovist area view is increasing in terms of 1st courtyard entrance threshold (point no:5 in Figure 6). The increase in this syntactic value is related with the developing construction process that is changing the geometry of the courtyard. Although the integration value is significantly decreasing, perimeter value is increasing. This increasing value shows that the number of edges creating a visual interface area between the observer and the buildings itself in the environment of the 1st courtyard in relation to the visual area is increasing. Longer dimensions in the geometry of visual field and various edges reflect this developing and more closed environment phenomenon in 1st courtyard.

For the second stage of the case study, a detailed analysis of the Topkapi Palace during the Süleyman I Era is made as shown in Figure 7. As this analysis started from the entrance of 2nd courtyard, and therefore omitted the main entrance to the 1st courtyard, and the surrounding palace gardens, we can see the evolved configuration more clearly. First of all, the 2nd courtyard maintains its semantic superiority, with Tower of Justice as the most integrated element of the system, while the 3rd courtyard, i.e. state affairs, army and privacy are mingled together as an indivisible whole. On the other hand, the expansion of harem operating almost like a connection space between the 2nd and 3rd courtyards also shows the increasing power of the royal women of the palace.

High circularity value of 566.54 of point no:3 in Table 2 shows that this interfacing point (Figure 5 and Figure 7) is strongly positioned at the central connection axis of the entire system in the spatial hierarchy of the palace. This area is an interface that is both connecting and distributing the movement semantically and syntactically. The morphological appearance, two dimensional shape of the isovist area perimeter, that is defined at that point is also getting transformed from a shape like square or circle to a long rectangle or a long, stretched ellipsoidal formation. This morphological change is signifying high axial connection potential of that point related with the Throne Room.
Although the configuration of the palace is getting deeper from 15th to 16th centuries in terms of mean depth and integration, the geometry of space in accordance with the circularity values of configuration within the referencing points such as 3rd – 4th courtyard connection gate, Enderun School (East) in the 3rd courtyard and the most significantly Chamber of Petitions (Arz Odası) in the 3rd courtyard are all strengthening their central position in the overall setting of the Palace syntactically and also semantically (see Table 2). This process develops as the institutional power of the Empire increases. In terms of the syntactic connectivity potential and again in the context of geometry that we see from circularity values, the central position of reference points such as 1st courtyard – 2nd courtyard connection gate, 3rd courtyard – 4th courtyard connection gate and interfacing thresholds, 1st courtyard entrance, Tower of Justice – 2nd courtyard threshold (see Table 1) in the spatial order of the palace, are all strengthening their positions from 15th to 16th century.

6. CONCLUSION

In this study, the most significant relations between the syntactic and semantic transformations related to the development of Topkapı Palace are examined. The effects of transformation through administrational and institutional structure from 15th century to 16th century in Ottoman Empire have also affected the spatial order and meaning in terms of deeper hierarchy, centralization of power, and introversion. As the linear configuration with clear hierarchy enables relatively easier access for both public and official users, the organic central configuration, creates barricades around the ruling power. This articulated system obstructs the access for both public and some level of official users, while creating an intricate inner circle of trusted members. However these newly formed circles, such as the deepening of structure, construction of additional walls or the expansion of harem, remains secondary to the initial code of laws. Therefore, it is seen that the foundations of state, based on traditions keep their significance within the spatial configuration, and the existence of power remains solid.

The main elements of the palace configuration such as courtyards or a strong reference point like Chamber of Petitions all have increasing syntactic values strengthening the meaning of space as well. However as the institutional configuration develops, it gets deeper, coherently. In other words, while the institutional structure of the empire advances and the palace expands, the spatial order gets deeper. In this context, accessibility of public and some minor administrators

<table>
<thead>
<tr>
<th>Syntactic Values</th>
<th>Name of the Interfacing Threshold</th>
<th>Mean Depth</th>
<th>Integration</th>
<th>Occlusivity</th>
<th>Circularity</th>
<th>Kievist Perimeter</th>
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<tr>
<td>1</td>
<td>Tower of Justice - 2.Courtyard Threshold</td>
<td>3.07</td>
<td>912.49</td>
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<td>8544</td>
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<td>3.Courtyard - Throne Room Interfacing Threshold</td>
<td>2.6</td>
<td>322.9</td>
<td>0.1267</td>
<td>566.54</td>
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<tr>
<td>4</td>
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<td>NA</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td>6</td>
<td>4.Courtyard - East Gate Interfacing Threshold</td>
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</table>

Table 2 - Syntactic Values of Topkapı Palace Plans in the 16th Century, Süleyman I Era
to the spaces like access to 1st courtyard, but mostly 2nd courtyard is decreasing significantly, in coherence with the decreasing number of ceremonial events.
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PERMANENT AND TEMPORARY MUSEUM SPACES: A Study on Human Behavior and Spatial Organization Relationship in Refunctioned Warehouse Spaces of Karaköy, Istanbul

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ABSTRACT
In Istanbul between Karaköy-Kabataş there is a region consists of warehouse spaces. Two of them are refunctioned as a museum building and a temporary space, which is used mostly for biennial exhibitions. Museum spaces are an important part of everyday life in the context of social life. Visitors’ behaviors in a museum space is affected by the spatial order that we may also name as configuration, the attraction potential of the items that are exhibited in spaces, and the movement of the visitors in these spaces. Visual perception within the space in terms of accessibility and visibility that are affecting the integration levels are also keys to this investigation.

In this study, temporary and permanent exhibition spaces will be scrutinized with a study based on the behavior of people in relation to configuration and exhibited materials. The main questioning is whether the type of the space (temporary/permanent) affecting the behavior of people in relation with the exhibited items and configuration or not. Two of the former warehouses are selected as case studies where Istanbul Modern Museum in Antrepo No.4 is a permanent museum space now; and Antrepo No.7 is recently used during Istanbul Design Biennial in 2014, which is a temporary exhibition space. Both of the warehouse structures that we call "Antrepo" are the parts of the main warehouses region between Karaköy and Kabataş in Istanbul; have similarities in the context of space configuration, size and environmental characteristics. In this study, both qualitative methods that are including the observation of behavioral modes and frequencies with on site analysis, and quantitative methods that are including the space syntax methodology are used. After these studies, results are overlapped to evaluate the relation between user behavior-space relationships and to compare permanent and temporary museum spaces.

In conclusion, the behavior of people seemed affected by the type of the artworks mostly on the basis of the time spent over them. In both cases, behaviors of people are verifying attractor-movement-configuration theory. In temporary case, artworks are the major parameter affecting the behavior whereas in the permanent exhibition case interfacing spaces between interior and exterior are affecting the behavior, as well. In the temporary one, artworks are affecting the usage more than the permanent one, with their physical being besides their context. The further discussion in that sense is how future curation of exhibitions and architectural design of spaces may be evaluated through these types of venues.
KEYWORDS
Building morphology, Exhibition architecture, Spatial layout, Temporary-Permanent Spaces, Visual perception

1. INTRODUCTION
Museum spaces are an important part of everyday life in the context of social life; not only a place that artworks and visitors meet but also a social space that people can interact with artworks, other people, the building itself in a time frame in their everyday life. There are many types of museums that varies upon the subject of the exhibitions, type of the artworks exhibited, concept, intentional/non-intentional design spaces, configurations and the periods of the exhibitions that they host.

This paper examines the visitor behavior in permanent and temporary museum spaces in refunctioned warehouse spaces (figure 1) in Karaköy region in Istanbul. Antrepo Zone is a complex made up of 4 buildings previously used as warehouses at the Salıpazarı Harbour in the district of Tophane, Istanbul. The history of the area, the transformation of the society and the permanent or temporary character of the museums itself are the key concepts that are primarily examined by the syntactic values and visitor behaviors in relation with their configurations. As many other spaces, museum spaces are also an important scene that space configuration-human behaviour relationship can be seen.

Figure 1 - 2016 map of Istanbul showing Antrepo Zone in Karaköy including Antrepo No.4 (Istanbul Modern Museum) permanent museum space; and Antrepo No.7 (one of the venues of Istanbul Design Biennial in 2014) temporary exhibition space.
Temporary or permanent character of the museums is taken as the main debate point in this research as “memory” is one of the most important factors that shape the behaviour of people. Experiencing the same venue for different exhibitions/events is different than going to a place for an exhibition/event for the first time. Despite the fact that each exhibition/event has its own dynamics, concept, scale, space configuration, suggested paths and visual fields, the building that is hosting the exhibition is another major input for the evaluation of the character relating to relationship between the exhibition and its visitors.

In this study, temporary and permanent exhibition spaces are scrutinized with a study based on the behavior of people in relation to configuration and exhibited materials. The main questioning is whether the type of the space (temporary/permanent) affecting the behavior of people in relation with the exhibited items and configuration or not. A comparative study of two former warehouses that are transformed to permanent and temporary exhibition venues are selected as case studies where Istanbul Modern Museum in Antrepo No.4 is a permanent museum space now; and Antrepo No.7 is recently used during Istanbul Design Biennial in 2014, which is a temporary exhibition space.

We researched the exploration in the museum spaces and how integrated or segregated locations in an exhibition space is influenced when it is permanent or temporary in terms of the installation of artwork, museum design and visitors’ use of space during their visits. These issues are also related with the short or long term memory of the visitors affecting their perception and cognitive maps. Here, how spatial layouts influence visitors’ explorations in a gallery space; how the integration value of a space affects the number of visitors to a specific gallery in the museum; the impact of visiting time (weekday or weekend) on the number of visitors to the museum during a specific period of time; which spaces are more or less visited and which artworks more or less viewed are all important investigations.

In a broader sense, we tried to explore some key factors and design strategies through the design of the museum spaces depending on the temporary or permanent character of the curated material. In addition to that the effect of the morphological state of the designed buildings investigated in relation to the character of the curated exhibitions in these buildings, which are warehouses.

Although a new harbour and a museum project is ongoing including the Antrepo No.7 and the rest of the harbour area excluding the Istanbul Modern Museum of Antrepo No.4, both of the settings selected in this study have importance semantically and syntactically as they contribute to the social interaction and intellectual awareness in Istanbul. Both of the warehouse structures that we call “Antrepo” are the parts of the main warehouses region between Karaköy and Kabataş in Istanbul; have similarities in the context of space configuration, size and environmental characteristics. Various temporary exhibitions including 2014 İstanbul Design Biennial took place in Antrepo No.7 and Antrepo No.4 is still hosting Istanbul Modern Museum (figure 1 and 2).

The question is how the temporary or permanent character of the museums affects the experience in museums/exhibition venues in terms of usage relating to functions, social interaction, and pedestrian flows. Spaces of the built environment such as museum spaces also structure social relationships such that society and culture become intelligible through their spatial form (Peponis and Wineman, 2003).

The aim was to overlap the semantics of space and the syntax of space in order to refine some significant key factors affecting the museum design. The semantics of space is coming from the behaviour of people and the curated artwork. The syntax of space is structured in relation to syntactic calculations starting from a logical ground built over vision fields that we term “isovists” (Benedikt, 1979; Batty, 2001; Conroy, 2001; Edgü et al., 2012). Within the definition of an isovist, the walls, furniture, exhibition systems, artwork and other systems obstructing our sight in the space are handled as walls and affect the determination of the visual field (Benedikt, 1979; Turner and Penn, 1999; Batty, 2001; Turner et al., 2001; Conroy, 2001; Unlü et al., 2009; Edgü et al., 2012; Salgamcioglu and Unlu, 2013). We used the University of Michigan’s Syntax 2D software for the analysis.
2. THE CONCEPTUAL FRAMEWORK OF THE STUDY IN RELATION WITH ANTREPO NO.4 & ANTREPO NO.7

2.1 SCOPE OF THE RESEARCH AND RELATIONSHIP TO EXISTING THEORY AND PREVIOUS STUDIES

Seamon (2011) mentions “people-in-place” that is understood as the space qualities and people using or experiencing the space are read as one. Place identity in relation to space is not something individual in that sense, it is rather a space with qualities that we call “permanent core” (Nascimento, 2014). The comparison between the permanent and the temporary exhibition space may also be discussed with their relations that are emerging the permanent core. Lefebvre defined the space, as it is becoming a “living organism” where, it is “designed and produced not only as an economic, programmatic and/or material container but also as a social morphology” (Nascimento, 2014). The social morphology that is shaping the museum/exhibition environment is also being shaped by the configuration of space. Experiencing the permanent or temporary environments in terms of exhibition spaces requires understanding this social morphology and its temporal qualities. The relations related to time is unique in these environments and the setting around this configurational, spatial order is emerging according to the qualities related to time as some visually connected interfaces with the outside environment, or some spaces related to functions other than exhibition such as restaurant or workshop spaces. Being permanent or temporary in an exhibition space determines the relations with different functional zones, which may be showing stronger connections visually and in terms of accessibility in permanent settings.

The relation with the more integrated spaces and the perception of space may also be discussed through the quotation of Reynolds (2016) for 2015 Venice Biennial, “We’ve been coming for many years now, and we still get lost,’ the Swedish woman said, with significant emphasis, over breakfast at the guesthouse. This was to become the theme of my visit to Venice, and applied not only to the perplexing nature of its labyrinthine passages and waterways, but to the 56th International Arts Biennale, curated by Okwui Enwezor under the theme of All the World’s Futures. It is important to stress here that getting lost, as writers as various as Thoreau and Rebecca Solnit, Walter Benjamin and the Surrealists have pointed out, is not necessarily a cause for anxiety, and might, on the contrary, be seen as a productive condition of disorientation that heightens one’s sense of receptivity.” where disorientation or getting lost may be valuable for a better experience inside the exhibition spaces. The discussion is also expanding to what the degree of correlation between the integration and the strong experience related position of space.
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Figure 2 - Views from temporary exhibition of Antrepo No.7 during 2014 Istanbul Design Biennial (left) and permanent exhibition of Antrepo No.4 hosting Istanbul Modern Museum (right) (photo, right middle – Murat Germen, 2015)
In this context, being permanent or temporary for an exhibition/museum in relation to the venues’ configuration may be reflecting various experiences and short or long-term memory evaluations are developing both depending on the artwork exhibited and the configuration itself.

In addition to this discussion, being “open” in terms of the behavioral impacts shaping the space configuration, and movement is also a key term for the used and the lived space (Tsoukala, 2015). Flexibility and openness in a space should be evaluated in comparison of the Antrepo Structures in Karaköy and syntactical considerations are required. In the adaptation of the topological logic to the space, the evaluation that is free of hierarchical order, but depending on the communication and movement as the primary aspect supporting the expandability and the open-ended point of view in spaces is also important (Tsoukala, 2015). Depending on the intentional and non-intentional characteristics of the configuration, the evaluation of the flexibility potential of the configuration and spatial order is considered as hard programmed (strong with permanently fixed elements and functions) or soft programmed (flexible with temporarily fixed elements and functions) spaces (Patel et al., 2012). This approach also has great impact on the experience of various spaces including the exhibition and museum oriented settings. Being hard or soft programmed or curated with some fixed elements in some cases in terms of museum/exhibition spaces is directly related with being permanent space or temporary space and their impacts on human behavior.

Besides the discussion of hard or soft programming, interfacing areas, facades with transparent or semi-transparent materials have an impact on the visitor behavior of the venues. Araguez and Psarra (2015) argued the inside-outside relationship through accessibility and visibility through SANAA’s building designs. In this research, when the accessibility and visibility relationship is weak in some points of the configuration, which may be as high visibility-low accessibility or low visibility-high accessibility, the space is being used more informal and tends to be programmed as more flexible (Araguez and Psarra, 2015). In the context of inside-outside relationship and interfacing areas within the cases Ünlü et al. (2009) compared two architectural schools in terms of their interfacing areas that may also have the potential of social interaction spaces. The results are significantly supporting the idea that independent from intentional or non-intentional design and use of the spaces; the existence of visually connected and also accessible outside area in connection with an inside area increases the frequency of people and activities. Interfacing areas are gaining importance in terms of social interaction, otherwise the lack of interfacing character results with the areas that are acting only as circulation and service spaces.

2.2 RELATIONSHIP TO SPACE SYNTAX THEORY

Built space is composed of patterns that are interrelated through different syntactic and semantic layers, and museum or exhibition spaces are a part of this significant composition. According to Peponis and Wineman (2003), built space is to be understood as a relational pattern supporting that situation: “A pattern of distinctions, separations, interfaces, and connections, a pattern that integrates, segregates, or differentiates its parts in relation to each other” (Peponis and Wineman, 2003).

Space syntax analysis is based on isovists (Benedikt, 1979; Hillier and Hanson, 1984); visual perception is primarily worked and accessibility and movement values are also discussed in results. Isovists and convex spaces that are key to space syntax research are still vivid in the analysis (Hillier et al., 1987). An isovist is a concept of spatial recognition that defines any particular viewpoint in a space by its visibility field, which is key to analysis in curated work of exhibitions and their spatial analysis.

As Hillier et al. (1993) note in Figure 3, beyond the relationship between visitor frequency and the configuration of the space in the exhibition area, depending on the morphology of convex spaces as a whole, while attractors and movement may be mutually influential, the other two relationships are asymmetrical. The configuration may influence the location of attractors, but the location of attractors cannot influence configuration. Likewise, the configuration may influence movement, but movement cannot influence configuration. If strong correlations are
found between movement and both configuration and attractors, the only logically possible lines of influence are from the configuration to both movement and attractors, with the latter two factors influencing each other. In this study, the relationship between visitor frequency and configuration is analyzed in detail; the attractors, namely, artworks by various artists, are also considered in this relationship through certain critical counts within the exhibition space.

Various techniques of spatial analysis have been used to discuss the functions of museums (Peponis & Hedin, 1982; Wineman & Choi, 1991). Choi (1999) has analyzed visitors’ paths and found that integration was significantly correlated with “tracking scores,” the number of people who reached each convex space, and the correlation of tracking scores with “tracking frequencies” was investigated. “Spatial variables play an important role in structuring exploration even where the purpose of exploration is not to comprehend the layout itself but to view the displays in it. Choi also studied the distribution of people present in the museum, using normal behavioral mapping techniques” (Peponis and Wineman, 2003).

Experiencing the temporary or permanent exhibition layout of these transformed former warehouse (Figure 2) is crucial to understanding the syntactic and semantic patterns that reflects the social and physical patterns studied here.

Grasping the idea of “the theory of natural movement” (Hillier et al, 1993) is important where the distribution of movement is a function of spatial configuration. The theory of “virtual community” (Hillier, 1989) is also a key to this understanding and “brings focus to a particular form of community that is based on the pattern of coawareness and copresence arising as a by-product of movement” (Peponis and Wineman, 2003).

Besides the movement, grasping the configuration and curation of the artwork in the exhibition space and the visitor frequency in relation to the isovist fields is crucial to understanding whether there is a correlation between the spatial order and geometry of the space and visitor frequencies depending on different convex spaces and gate connections in the museum space or the exhibition venue.

Settings of museums and exhibitions hosting permanent or temporary configurations have the opportunity to attract people from various communities and act as a gathering space and a space of information and developing intellectual values. Construction of spatial meaning through visitors’ movement is explained by Wineman and Peponis (2010), as “The ways in which visitors are encouraged to move through an exhibition, whether along a clearly defined path or more freely weaving a self-directed path, will structure the overall impression of the exhibition.” Wineman and Peponis (2010) discuss the contradiction in here and introduces the term, “spatially guided movement” and make a shift to “spatially dictated movement” and “spatially random movement” from a final point of view in between these two polarized views. “Spatially guided movement” kind of understanding makes the connection, interrelation of geometrical space with the perception and movement in space.
Perception and understanding of visitors in exhibition spaces are constructed through "patterns of accessibility through the space of the exhibition, connections or separations among spaces or exhibition elements, sequencing and grouping of elements" (Wineman and Peponis, 2010).

3. METHODOLOGY REGARDING THE CASE STUDY AND ANALYSIS

In this study, regarding the syntactic analysis and correlations with visitor frequency, we have made a comparative study at the selected two former warehouses of Karaköy, Istanbul. These warehouses are transformed to permanent and temporary exhibition venues. Istanbul Modern Museum in Antrepo No. 4 is the permanent one and Antrepo No. 7 is the temporary one.

In this investigation and comparison, quantitative methods that are including the space syntax methodology are used with the support of qualitative considerations that are observations depending on visitor behavior. After these studies, results are overlapped to evaluate the relation between user behavior-space relationships and to compare permanent and temporary museum spaces.

The space syntax method will provide significant data in terms of the method of analysis and is an important theory used to define the structural environment. Syntax 2D software that is developed by the University of Michigan is used in this study.

For this study, it is key to specify an analysis method in Syntax 2D that will allow us to examine the relationships among the two exhibition layouts of Antrepo No. 4 and No. 7 (figure 4), depending on their convex spaces (figure 5), depending on the exhibition venue and visitor frequencies counted separately for the specified convex spaces on weekdays and weekends. Comparison of two settings is the key goal of this study, which is also leading us to a key discussion and comparison of permanent and temporary settings of exhibition.

Figure 4 - Exhibition layout plans of Antrepo No. 4 above and No. 7 below
The data (Table 1) utilized for every convex space and gates are:

- Mean depth
- Mean integration (figure 6)
- Mean circularity

These three data points are three of the primary concepts addressed in space syntax theory. These data were calculated separately for every convex space and selected gate (figure 7). Subsequently, the values at the active grids of the exhibition plan were separated into these three data groups and added on three different charts, and a mean data value was obtained for the three concepts (Table 1). Contingently, calculations were made via the arithmetic averaging of the grid values for every convex space.
Figure 6 - Integration map of Antrepo No.4 above and No.7 below
To understand the impact of the morphology of space on visitors, gate counts and snapshot analyses were undertaken to understand visibility relations, the regions described and isovists. Gate counts for 10 gates of Antrepo No.7 and 17 gates of Antrepo No.4 (Figure 7) in the exhibition gallery, which provide access to the exhibition and circulation areas of the exhibition gallery, are taken into consideration on a designated route for several time periods. During these gate counts, snapshots are also used to analyze the visitor frequencies in each convex space shown in Figure 5. Snapshots are created using the observations for one day in Antrepo No.7 and No.4. For the day, observations for the snapshots and gate counts were repeated 8 times in the day, starting at 11:00 am and repeating hourly until 7:00 pm. At the beginning of every hour, the researcher walked the route and counted the number of visitors in each convex space (Figure 5). After completing the visitor count observations by walking the route, gate counts were taken for a period of 5 minutes at each gate, to find the number of visitors passing through the gates. These gate count values provide information about the movement of visitors in the exhibition venues and helped us understand the movement between different groups of convex spaces depending on the syntactic and curational issues. The visitor frequency is noted and the syntactic scores of the gates are also used to understand the relationship between the frequency of visitors and the syntactic measures such as integration, circularity and mean depth.
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Figure 8 - Justified graphs of Antrepo No.7 left and No.4 right
Table 1 - Mean syntactic data values and visitor frequency counts of Convex Spaces for Antrepo No.4 above and Antrepo No.7 below as a result of the space syntax analysis and observations respectively.
Visitors’ patterns of interaction within the exhibition are correlated with syntactic parameters and the results of Regression (Table 2) are discussed. During this investigation, visitors’ spatial experiences, their contact with exhibition content and the use of the overall layout is also considered to gain a better understanding of the relationship of syntactic measures and visitor frequency in the biennial venue.

Finally, the statistical relationships between the number of people present during a certain period of time in a specific convex space and the syntactic measures of these spaces such as mean integration, mean depth and circularity are scrutinized and the correlations assessed using the Statistical Package for the Social Sciences (SPSS) program.

Table 2 - Results of regression analysis between the values of mean depth, mean integration, mean circularity and the values of visitor frequencies depending on the gate counts and convex space visitor frequency counts

In Regression (Pearson’s R) analysis of Table 2, when p<0.05 or p=0.05 the result is significant as seen on “p” values of Table 2. “R” is a value changing between -1 and +1, where it’s close to -1 or +1, it is also getting more meaningful. The “R” values such as 0,537 - 0,728 - 0,629 - 0,518 are all significant results when they are supported by p<0.05 or p=0.05.

In this study gates are selected as the nodes connecting the convex spaces or the access points to the exhibition venues such as main entrance, level connections or restaurant-café entrance within the venue. The convex spaces are all counted, as they are the key elements of spatial order and configuration.

When we investigate the results that are seen at Table 2 of Regression correlations (Pearson’s R) between frequency of visitors-syntactic values of selected gates, and also frequency of visitors-syntactic values of convex spaces, we see significant results such as mean depth values of gates and frequency of visitors passing through the gates (R=-0,537 and p=0,026); mean depth, integration, circularity values of convex spaces respectively and frequency of visitors using the convex spaces in Istanbul Modern Museum of Antrepo No.4 (R=-0,652 and p=0,001; R=0,629 and p=0,002; R=0,666 and p=0,001 respectively).

We also get some significant results (Table 2) in Antrepo No.7 of 2014 Istanbul Biennial such as integration, circularity values of gates respectively and frequency of visitors passing through the selected gates (R=0,728 and p=0,026; R=0,737 and p=0,023 respectively); mean depth, integration, values of convex spaces respectively and frequency of visitors using the convex spaces (R=-0,504 and p=0,007; R=0,518 and p=0,006 respectively).

4. CONCLUSIONS

In this study the main question was whether the type of the space (temporary/permanent) affecting the behavior of people in relation with the exhibited items and configuration or not. The significant findings in relation to the regression analysis that was interpreted from various correlations between the frequency of visitors and the syntactic values of gates or convex spaces in Table 2 are found. The movements of visitors in the spaces of Antrepo No.7 of 2014...
Biennial Venue through the selected gates are significantly correlated with the syntactic values of integration and circularity in these gates. The meaning of this correlation is quiet related with the soft programming and short-term memory related experience of the temporary exhibition layout. Flexible and temporarily programmed spaces of Antrepo No.7 are getting experienced in relation with the increasing or decreasing values of integration, where higher integration means more visitor frequency in terms of movement in the venue in comparison to AntrepoNo.4’s more permanent and long-term memory related, learned configuration setting. In this context the circularity value is also having significant results with its correlation of visitor frequency, which is understood as the higher circularity value means the geometry of space is also significantly supporting the degree of movement in the venue. The gates that are connecting and supporting the movement by their central position in the configuration of the venue are attracting more visitors. This is also a result of flexible and permanent configuration of the venue (integration, circularity values of gates respectively and frequency of visitors passing through the selected gates: R=0,728 and p=0,026; R=0,737 and p=0,023 respectively).

In terms of gate-frequency correlations, Although Antrepo No.4’s mean integration-gate count correlation results are significant as the mean depth of the gates are increasing, the visitor frequency is decreasing, permanent and considerably hard programmed museum space of Antrepo No.4 tends to be giving weak correlation results in relation to its learned configuration and the cognition of space in connection with the long-term memory (mean depth values of gates and frequency of visitors passing through the gates: R=-0,537 and p=0,026).

The hierarchy of spaces in Antrepo No.7 of Istanbul 2014 Biennial is seen as they emerge a non-distributed and deep justified graph (figure 8) when we compare to Antrepo No.4 of Istanbul Modern Museum, that is showing a more distributed and a shallow character. Antrepo No.4’s more distributed and shallow character is a result of its configuration but the permanent museum function is also affecting this configuration as the curation of the exhibition is being considered in a more fixed character to the space rather than being flexible. On the contrary, Antrepo No.7’s non-distributed and more deep configuration may be seen as a disadvantage, but as we see from the correlations of visitor frequency with mean depth and integration values of convex space, the significant correlation results (mean depth, integration, values of convex spaces respectively and frequency of visitors using the convex spaces: R=-0,504 and p=0,007; R=0,518 and p=0,006 respectively) show that the flexible-soft programmed space and the exploratory character of the temporary exhibition increases or decreases the number of visitors in accordance with the increasing or decreasing integration and mean depth values of convex spaces.

In temporary case, artworks are the major parameter affecting the behavior whereas in the permanent exhibition case interfacing spaces between interior and exterior are affecting the behavior, as well. In the temporary one, artworks are affecting the usage more than the permanent one, with their physical being besides their context. The further discussion in that sense is how future curation of exhibitions and architectural design of spaces may be evaluated through these types of venues. The deep character of the permanent exhibition of Antrepo No.7 is taking the advantage of spatial hierarchy and the affect of artworks to the movement is increasing by orienting the people and circulating them through the exhibition. The only disadvantage of the configuration of Antrepo No.7 is the weak correlation of circularity and visitor frequency in convex spaces. This weak correlation means that as the number of visitor increases in the system, the centrally positioned connecting convex spaces do not work as they expected as a result of the deeper spatial order of Antrepo No.7 in comparison to Antrepo No.4.

As a concluding remark in relation to interfacing area results that Ünlü et al. (2009) mentioned in comparison of two architectural schools’ interfacing areas between inside and outside, the interfacing area of Istanbul Modern Museum (Antrepo No.4) between inside exhibition area and outside Bosphorus view terrace are also attracting more people in terms of frequency of the people spending time close to this interface. Although inside space is only visually connected with the outside and may only be accessible from the restaurant, the observed movement of people outside the façade from inside and the Bosphorus view is increasing the frequency of people using this space inside the building. The social interaction potential of these spaces are
significant in results that is in coherence with the findings of the previous work. Interfacing areas are significantly gaining importance in terms of experience and the use of space in the permanent exhibition setting of Istanbul Modern Museum of Antrepo No.4.

Independent from the configuration of space, the less integrated, segregated spaces may be attracting more people with the attraction potential of artworks and the feeling of strong experience in a disoriented setting. We may see this strong character from the correlation results (Table 2) of Antrepo No.7 despite the fact that the configuration is deeper that the Antrepo No.4 as seen in Figure 8.

The spatial order and form of space is always a parameter affecting the perception and movement issues as Wineman and Peponis (2010) discussed, here "spatially random movement" is acting a role when we think of the artwork in both of these settings as syntactic and semantic values are not overlapping and giving significant correlation results all the time, but "Spatially guided movement" kind of understanding is strongly making the connection between the syntactic and semantic understanding as we find the significant correlations between the syntactic measures such as integration or circularity and visitor frequency.

As Araguez and Psarra (2015) mentioned, when the accessibility and visibility relationship is weak in some points of the configuration, which may be as high visibility-low accessibility or low visibility-high accessibility, the space is being used more informal and tends to be programmed as more flexible. Convex space No 18 of Antrepo No.7 and Convex space No 9a & 9b of Antrepo No.4 are such spaces acting as low visibility but high accessibility that are serving as a transition but also a gathering area within the exhibition venue. These spaces tend to be programmed as more flexible, and also has the potential of non-intentional use of the space.

As a final discussion that is summing up the conclusion and serving to a broader reflection on the significance of this study, we see permanent and long-term memory related, learned configuration is having significant various dynamics. In that sense, we have seen a significant issue in relation to the interfacing areas of the museum spaces. The learned and permanent design of the Istanbul Modern Museum (Antrepo No.4) especially relating to its interfacing areas between inside exhibition area and outside Bosphorus view terrace are attracting more people that is not correlating significantly with the syntactic measures of the interfacing areas. Visitors are spending more time close to these interfacing areas whether or not related to its shallow or deep syntactic value. These spaces are seen as the attractors in the museum. The observed movement of people outside the façade is also another attractor in this sense.

The findings are supporting the idea that the lack of interfacing areas are tending to be less social interaction oriented that we see in the temporary character of Antrepo No.7, but as Reynolds (2015) mentioned disorientation or getting lost may also be valuable for a better experience inside the exhibition spaces is valid this case. We see that situation significantly in Antrepo No.7.

The museum spaces may be evaluated and designed in the sense of the contribution of interfacing areas to the experience in museum spaces.

In terms of gates’ visitor frequency, when the number of visitors are decreasing, permanent and considerably hard programmed museum space tends to be giving weaker correlation results. This result may also be linked with the long-term memory that is not overlapping with the syntactic values. In contrary, the flexible-soft programmed space and the exploratory character of the temporary exhibition increases or decreases the number of visitors in accordance with the increasing or decreasing integration and mean depth values of convex spaces. Being temporary acts in full accordance with the syntactic values in terms of visitor frequency. This result is a significant input for museum design for the future.

It’s a fact that the circularity value helps us in exploring the geometry of space in temporary settings that is also significantly supporting the degree of movement in the venues. The gates that are connecting and supporting the movement by their central position in the configuration of the venues are attracting more visitors. This is a result of flexible and also permanent configurations.
In terms of being temporary, we may also be facing with flexibly programmed spaces as we have seen at Antrepo No.7. The experience in relation with the increasing or decreasing values of integration, where higher integration means more visitor frequency in terms of movement in the venue in comparison to a permanent and long-term memory related, learned configuration settings. In addition to temporary case, in the cases of high visibility-low accessibility or low visibility-high accessibility, the space is being used more informal and tends to be programmed as more flexible. When we design the programme more flexible, spaces also have the potential of non-intentional use. The behavior of people seemed affected by the type of the artworks mostly on the basis of the time spent over them. In both cases of temporary or permanent design, behaviors of people are verifying attractor-movement-configuration theory.
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#23

LIVING IN FORTALEZA CITY CENTRE:
A study about multifamily residential buildings and urban vitality

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ABSTRACT

Scenarios of development and degradation have marked the urban space of Fortaleza city centre. The intensification of the commercial and services occupation through the years promoted, paradoxically, the valorisation of the land price and the devalorization of the residential use. The residential occupation was consolidated in a discontinuous way, concentrated mainly in the external limits of the historical core of the city centre. The present paper has the objective of analysing how the multifamily residential buildings located in Fortaleza city centre relate to the public space, aiming to identify what aspects could promote or inhibit urban vitality. The research is structured over the delimitation of an area in this region and the selection of multifamily residential buildings, built since the 1960s, close to the central core of the neighbourhood. The first step involved the study of the selected residential buildings and the development of land use maps of their surrounding blocks. Subsequently, with the use of the software DepthmapX, axial and segment maps of Fortaleza urban grid were generated, with their respective data. This data was composed by values of integration (HH) and connectivity, considering global and local scales, which were compared with the land use maps and the points of access from the residential to the public space. The ways the private residential space interacts with the public urban surroundings and the access to diverse land uses reveal different aspects of the urban vitality. The collected data allowed to verify that the buildings are located in areas that present heterogeneous land uses, with a great number of residents and users. However, these aspects are not sufficient to promote the vitality of the public spaces in the neighbourhood, since the people movement in the streets is controlled by the opening hours of the predominant commercial use in the area. In addition, the residential space is marked by introspective space organization, with hierarchical and self-sufficient programmes. The conservation conditions of the public spaces and the insecurity influence the inhabitant’s everyday relations with the neighbourhood, affecting fundamental aspects for the urban vitality in the central area of Fortaleza.

KEYWORDS
Fortaleza city centre, urban vitality, multifamily residential buildings

1. INTRODUCTION

The city of Fortaleza, located at northeast region of Brazil, is the fifth city of the country in population, with 2,609,716 inhabitants (IBGE, 2016). Fortaleza historical city centre is in a neighbourhood named Centro. Scenarios of development and degradation have marked Centro’s urban space. The intensification of the commercial and services occupation through the years promoted, paradoxically, the valorisation of the land price and the devalorization of the residential use. Over the past years, the residential occupation was consolidated in a
discontinuous way, concentrated mainly in the external limits of the historical core. Nowadays, Centro has approximately 28,538 inhabitants (IBGE, 2010). The present paper has the objective of analysing how the multifamily residential buildings located in Centro relate to the public space, aiming to identify what aspects could promote or inhibit urban vitality.

In this paper urban vitality refers to urban ‘liveliness’, argued by Jacobs (2009) to explain that live urban spaces are marked by functional and physical diversity among adjacent uses, and by diversity of users. Urban vitality also refers to ‘urbanity’ (Hillier, 2007), which implies co-presence of visitors and inhabitants in public space, with diverse land uses, density and movement.

The analysis of the relations between the residential buildings’ configuration and urban vitality at Centro involved the concepts of ‘urbanity’ and ‘formality’, argued by Holanda (2010). ‘Urbanity’ involves the intense participation on urban life, where the social space is not only private and the limits that connects private and public areas are soft. ‘Formality’ is marked by hierarchical social systems that blocks the connection between private and public space (Holanda, 2010).

Centro daily attracts people from all parts of the city and the metropolitan region of Fortaleza. The public spaces of the neighborhood are marked by intense movement of vehicles and pedestrians (inhabitants and visitors). The co-presence of different groups of people with different activities affects the relations of space and time, especially in a local scale (Hillier, 2007). The streets are full of life during the business hours. However, during the night or weekends, with most of the uses closed, the movement through the public spaces declines, affecting negatively its urban safety.

Centro’s urban space is dominated by private activities and by real estate dynamics, with a concentration of commercial use in the central core of the neighbourhood. In this context, the public spaces assume a utilitarian and functional identity, used mostly as a transitional space, affecting the sense of permanence and appropriation by inhabitants and visitors (Villaça, 2001).

The research is structured over the delimitation of an area at Centro and the selection of 8 multifamily residential buildings (Image 1), close to the central core of the neighbourhood, where the commercial use is predominant: Fortaleza (1956), Jalec Avenida (1959), Palácio Coronado (1965), Paraguaçu (1979), Sky Tower (2010); Cidade (2014); Naica Praça de Cristais (2016) and Regency Park (under construction).
Figure 1 – Studied buildings
2. DATASETS AND METHODS

The first step was the study of the selected residential buildings to identify how each one relates to the urban space from their private space. The study also required to collect, map and analyse the land use present in a 300m ratio around each selected residential building (Image 1).

Subsequently, with the use of the software DepthmapX, axial and segment maps of Fortaleza urban grid were generated, with their respective data, composed by values of integration (HH) and connectivity, considering global and local scales. The values were compared with the land use maps and the points of access from the residence to the public space.

The axial map was generated based on a linear representation of Fortaleza urban grid elaborated by Ugo Santana (2017). The segment map was generated considering the ratios: R400, R800, R1200, R1600, R2400, R3200, R5000, R7500. A second axial map was created based only on the streets contained within the neighbourhood boundaries to analyse Centro's streets relations to each other.

Based on the study of the integration and connectivity values it was possible to analyse the relations between the studied buildings and the spatial structure of Fortaleza's urban grid. Once the grid structure is responsible for the majority of the variations in the movement density, the location of the residential buildings represents a fundamental aspect of the urban space analysis (Hillier, 2007).

3. RESULTS

The land use maps analysis reinforced that location is an aspect that affects the dwelling dynamics. It is possible to see that three of the studied buildings are mostly surrounded by commercial use. The others, closer to the limits of Centro, are surrounded by a more diverse land use. The commercial core of the neighbourhood has its limit approximately in Av. Duque de Caxias at south, R. Padre Mororó at west and Av. Dom Manuel at east. Av. Duque de Caxias and Av. Heráclito Graça are the same avenue, that changes the name after the intersection with Av. Dom Manuel, to the west direction. The importance of Av. Duque de Caxias as an avenue that passes through the whole Centro is reinforced by the location of five selected buildings and a sixth that is less than 300m away. The connection of this street with Av. Dom Manuel shows that five buildings’ location intersects at a 300m radius (Image 2).

Although the variety of uses on the surroundings of the residential buildings is a positive aspect, the effects of commercial use, regulating movement, keep the inhabitants and visitors away from the neighbourhood streets at night or Sundays, when there aren't commercial activities at Centro. It is relevant to note that schools/universities and temples activities, present at Centro, has an important role on the use of public space, once attracts pedestrians at periods out of business hours.

Fortaleza axial map (Image 3) reveals the integration role of the main streets of the city, that converges to Centro and connects the neighbourhood to other regions. Centro is one of the most integrated and connected areas in the city. The correlation between integration and connectivity, which Hillier (1987) named ‘intelligibility’, reinforce Centro’s importance. The more the user gets away from Centro, the more segregated the streets become. When only Centro is observed, the axial map identifies that the straighter and continuous streets present higher values of global and local integration.

The study involved the identification and analysis of integration and connectivity values of the streets that surrounds the selected buildings and its relations with their types of accesses, such as pedestrians, vehicles and commercial areas (Table 1). The buildings Fortaleza, Jalcy Avenida, Palácio Coronado, Paraguacu and Cidade have a commercial area at the street level, and their residential area has an independent access. Fortaleza, Jalcy Avenida and Palácio Coronado are located at Av. Duque de Caxias, with axial connectivity value of 46, much higher value than the city average of 4.48. Sky Tower and Cidade are located in less integrated and connected areas, different from new residential investments, such as Naica Praça de Cristais and Regency Park.
When considered only Centro's urban grid, Av. Duque de Caxias is the only one that presents the maximum value of 34, and Av. Dom Manuel presents a value of 16, still much higher than the average value of 5.39. The study shows that these streets have easy access to other parts of the city and concentrate a large number of public transportation, making movement easier.

All the selected buildings are located in streets with very similar values of axial integration in city axial map. All of them have integration values that varies from 1.11606 to 1.26817 of a 1.2868 maximum, higher than the city average of 0.8116. In this analysis, Av. Duque de Caxias is the most integrated, followed by R General Sampaio with 1.24388. When only Centro streets are considered, it is possible to observe a higher variation of the values. In this new situation, Av. Duque de Caxias becomes the higher value of the system with 3.00949, followed by R Floriano Peixoto with 2.68644. The other streets vary from 1.93686, closer to the average 1.7627, to 2.67135.
The axial map reveals, at global scale, that in four of the five analysed buildings that have commercial units, those units are located at the most integrated streets of the neighbourhood. It is also important to observe that six buildings are located at block corners, and five of them has pedestrians and vehicles’ accesses located at different streets. Considering the newest residential buildings, only Sky Tower presents accesses to both pedestrian and vehicles, side by side, at both streets. All of the six buildings located at corners have the pedestrian access placed at the most integrated street while the vehicles access is at the less integrated one.

Considering the segment map, at global scale, the integration varies from 9628 (R. Pereira Filgueiras) to 11729 (R. General Sampaio). All the segments present higher integration values than the city average (7916) and some very close to the maximum value (12236). The values increase towards the commercial central core and decreases towards the limits of the neighbourhood. Cidade and Sky Tower are located at a less integrated area, when compared to the other studied buildings.
Considering Centro axial map, it is observed that 14 streets, where the residential buildings are located, are represented by 12 axial lines. It is important to explain that, although named as different streets, Av. Duque de Caxias and Av. Heráclito Graça are the same axial line. This situation also happens to R. Pero Coelho and R. Pedro I.

During the analysis, it was observed that when Fortaleza and Centro axial maps are compared at global scale, there is a reduction of connectivity value at several axial lines of the system. Centro axial map indicates that five of those axial lines – that represents R. Floriano Peixoto, R. Solon Pinheiro, R. Pereira Filgueiras, R. Guilherme Rocha and Av. Dom Manuel – present less than 60% of the value presented at Fortaleza’s axial map. This fact demonstrates that some streets
have a reduced importance at the neighbourhood scale, but still are relevant to link Centro to the rest of the city. These streets also have a considerable reduction on integration value although remaining higher than the average. Five axial lines – that represents R. Rodrigues Júnior, R. Pedro I / R. Pero Coelho, R. 25 de Março, R. Padre Mororó, R. Agapito dos Santos – doesn’t present any connectivity reduction, implying that their whole length are inside the neighbourhood limits.

### Table 1 – Connectivity and Integration values.

<table>
<thead>
<tr>
<th>BUILDING</th>
<th>STREET</th>
<th>AXIAL</th>
<th>SEGMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CITY</td>
<td>CENTER</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CON</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>INT</td>
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<td></td>
<td></td>
<td>INT R3</td>
<td></td>
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<tr>
<td>Fortaleza</td>
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<td>46</td>
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<td></td>
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<td>Av Duque de Caxias</td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>R General Sampaio</td>
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</tr>
<tr>
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<td>Av Heráclito Graça</td>
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<td></td>
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<td></td>
<td>R Rodrigues Júnior</td>
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</tr>
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<td></td>
<td>R Pedro I</td>
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<tr>
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<td></td>
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<td>Naica</td>
<td>R Pero Coelho</td>
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<td>Praça de Cristais</td>
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<tr>
<td>Regency Park</td>
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<td>MAXIMUM</td>
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</tr>
</tbody>
</table>

**INT** – Integration HH  **P** Pedestrian access  **C** Commercial area

**CON** – Connectivity  **V** Vehicles access

**CITY** – Axial or segment map created considering all streets inside the city boundary

**CENTER** – Axial map created disregarding all streets outside the neighborhood

23.8
Comparing the whole city system with the streets of the neighbourhood, the relations of the different accesses (residential, commercial, pedestrian and vehicles) and the public space remains mostly similar as argued before. There is an exception in the case of Edifício Cidade, because R. Guilherme Rocha is the least integrated street, when only Centro’s system is considered.

Figure 4 – Spatial configuration of the studied buildings
The residential occupation has an important role in this area of the city because the inhabitants’ daily routine can affect movement and urban vitality. In this context, the spatial configuration of the residential buildings and their connections to the public space influences how the inhabitants relate to the residence surroundings. At Image 4, the volumetric schemes of each residential building demonstrate the spatial distribution of the uses, the scale and the location of the different entrances.

Fortaleza, Jalcy Avenida, Palácio Coronado and Paraguaçu present spatial configuration that connects their private space with the public space at the street level. At the same time, the location of these buildings, in more connected and integrated streets, stimulates the use of public spaces nearby. However, it was observed that the conservation conditions of the urban spaces also influence how the inhabitants use them, distinguishing spaces of movement and permanence.

The spatial configuration of the new residential buildings, recently constructed at Centro - such as Sky Tower, Cidade and Naica Praça de Cristais - presents introspective private space organization, with hierarchical and self-sufficient programmes, that regulates visual and physical connections with the public space (Holanda, 2013). In these cases, it is possible to observe that aspects like the building scale, the quantity of garage floors and the location of the entertainment areas, further disconnect the residential units from the public space (Image 4). These high density buildings reproduce the urban soil at maximum legal limits and are located in less integrated areas, where generally there are not other uses to support residential use, affecting the pedestrian daily movement at the local scale and the urban vitality.

4. CONCLUSIONS

During the study, when the city urban grid was analysed in both axial and segment maps, and compared to the information collected in the field, it was observed at first that the segment map better reflected the neighbourhood urban life. However, when it is analysed at DepthmapX only the streets inside Centro’s limits, it can be concluded that the values of integration and connectivity really reflect the relations of the residents within each building location, considering movement, use and activities at the urban space.

The axial and segment maps indicate that higher integration and connectivity values are concentrated at Centro. The neighbourhood is also highly accessible, concentrating movement, especially public transportation. The high integration at global scale affects resident’s and visitor’s movement at local scale (Hillier, 2007).

Considering the relations between the spatial structure and movement (Hillier, 2007), the central core of the neighbourhood tends to remain attractive for commercial activities. It is also observed that there is a reduction of concentration of commercial uses and also the values of integration and connectivity towards the neighbourhood’s limits. The land use map shows that this area presents other kinds of uses, especially residential. The commercial activities predominance in some areas stimulates the real estate speculation, affecting the land value and occupation. This context demonstrates that the land occupation remains unbalanced, influencing negatively the urban vitality, once the movement is affected by the opening/closing time of commercial activities.

The study reveals that vitality is not only related to the diversity of land uses. The land uses mapping shows that there is diversity of uses at the studied buildings’ surroundings. However, these uses are not always complementary to the dwellings’ dynamics. In some cases, the irregular urban occupation also affects the physical quality of the public space, and inhibits the pedestrian movement in sidewalks, parks and squares in the neighbourhood. These aspects affect the appropriation of the public space by residents and visitors.

All studied buildings are a reflection of the real estate market dynamics, optimizing the income of investments by the production of high density buildings. However, the dwellings built from 1960s to 1980s present configurational characteristics and location that indicates more connections with the public space at the street level, stimulating the resident’s movement.
The insertion of the contemporary residential buildings in the urban space, such as Sky Tower and Cidade, represents the logic of 'formality' (Holanda, 2010), marked by the valorisation of the private spaces. And it is also a reflection of 'desurbanism' (Hillier, 2007), once the spatial configuration at the street level breaks the relation between the buildings and the public space.

The urban vitality complexities involve the spatial structure of the urban grid, the diversity of land uses and users’ activities, the connections between private and public space. Centro is marked by heterogeneous land uses with a large number of inhabitants and users that go everyday to work, shop, visit or simply pass through the neighbourhood. However, these aspects are not enough to generate vitality and diversity at the public space in a constant way, in different times of the day and the week. In spite of the positive aspects observed in the neighbourhood, the high concentration of commercial use in its central area, the conservation conditions of the sidewalks, parks and squares, and the physical disconnection from private and the public spaces promote the dilution of pedestrian movement and security problems.
REFERENCES


#24

SPACIAL CONFIGURATION IN SINGLE FAMILY HOUSES
Study about the work of Marcos Acayaba

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ABSTRACT
The present paper is based on the analysis of the spatial configuration of single-family houses designed by Marcos Acayaba, between 1970 and 1996. Acayaba’s work represents a moment of maturity of the Brazilian Modern Architecture, specifically the one produced in São Paulo. Starting his career during the 1970s, when the Paulista Brutalism movement was at its apex, his projects show the interest in the construction details, incorporating different technologies and using the materials characteristics to generate the desired geometry associated with an identifiable structural system. The buildings’ plans allowed the development of justified graphs, considering the depth from the exterior space by two different paths: one representing the users from the main access, and another representing the users from all existing accesses. All the spaces with some kind of roof, inside or outside the houses, were considered. The spaces were categorized as sectors, as function and as spaceness. The development of digital plans of the dwellings, allowed the study of Space Syntax using the software DepthmapX for the calculation of the Integration HH values of each system, based on the convex representation of the selected spaces. The calculations were done in two steps: first, considering the exterior as another space; and second, disregarding the exterior space. Isovists were developed, staring on the living room, to complete the analysis and observe privacy concerns. The Space Syntax Theory was used to comprehend in which aspects the houses are similar or different, and how the design decisions influence the user’s movement, the permeability, the privacy and the space appropriation. The topological proximity, the different possibilities of accesses and connections of the studied spaces, directly affects the use of these buildings. The analysis of these dwellings shows that during a period of more than twenty years, the architectural programmes changed very little, being composed of almost the same main spaces, and the separation of functional sectors has been done in a very defined way. Despite of that, it is possible to observe distinct organizational characteristics influenced by the period the house was designed, the built area, and most importantly, the selected structural technology.

KEYWORDS
Single-family Houses, Brazilian Modern Architecture, Spatial Configuration

1. INTRODUCTION
The present paper is based on the analysis of the spatial configuration of single-family houses designed by Marcos Acayaba, during the decades of 70s through 90s. Acayaba’s work represents a moment of maturity of the Brazilian Modern Architecture, specifically the one produced in São Paulo. He graduated at the end of the 60s and starts designing houses in the 70s, strongly influenced by the acting architects of the moment and the main characters of the Brazilian brutalism. His projects show the interest in the construction details and in incorporating different technologies to generate a geometry associated with the structural system.
Considered one of the variations of a late modernism, the movement called Paulista Brutalism started in São Paulo and was disseminated in the following years throughout the country. This movement, empowered by Brazil’s economic and industrial development, was associated with an excessive formalism and usage of apparent concrete structures. It is important to notice that the diffusion of this architectural ideas in the Brazilian territory allowed a great variety of experimentations, and subsequently influenced back the acting architects in São Paulo (Bastos; Zein, 2010).

This paper started by the selection of a group of 7 houses (Image 1): MILAN (1972), PINDORAMA (1974), KÔU (1981), KOVADLOFF (1985), OLGA (1987), BAETA (1991) and ACAYABA (1996). It is important to note that both MILAN and ACAYABA are houses owned by the architect and represent distinct moments in his career. The first one incorporating characteristics of the Brazilian Architecture done in São Paulo and the last one representing his research in wood structures.

2. DATASETS AND METHODS

The buildings’ plans allowed the development of justified graphs, considering the depth from the exterior space by two different paths: one representing the users from the main access,
and another representing the users from all existing accesses. All the spaces with some kind of roof, inside or outside the houses, were considered. The spaces were categorized as sectors, as function and as spaceness (Hillier, 2007). The development of digital plans of the dwellings, allowed the study of Space Syntax using the software DepthmapX for the calculation of the Integration HH values of each system, based on the convex representation of the selected spaces. The calculations were done in two steps: first, considering the exterior as another space; and second, disregarding the exterior space. Isovists, staring on the living room, were developed to complete the analysis and observe privacy concerns.

3. RESULTS

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* Number of convex spaces disregarding the external space
** Space-link ratio: number of links plus 1 divided by the number of convex spaces plus the exterior
*** The number of spaces disregarding the exterior

Table 1 - Spatial characteristics of the houses

The main access of the buildings has a very important role in the paths done by the users. In six of the seven studied houses, the user’s access to the indoor space can be done by social and service sectors. Hidden from the main entrance, the private sector is also connected to exterior in all of the houses. OLGA and ACAYABA houses, built in a very steep terrain, have connections to the exterior through two spaces: one at the main access level and the other at an inferior level, preventing an exterior path between the two accesses. Considering the main access, in every house the social sector acts as access control for the other two sectors in all of the houses.

It’s possible to observe in Table 1 that these houses present depths that varies from 7 to 12 steps considering the main access path. When considered all accesses possible in each house, all houses have their depth reduced. Five of the seven houses, reduce to about 50% to 60% of the original depth. KOU and ACAYABA houses reduce their depth only from 7 to 5 steps. It is important to note that the first one has 9 points of access.
Permeability was analysed from the arrangement of the justified graphs and using the space-link ratio concept (Hillier et al., 1986) to determine the relation between spaces and connections on the system. Table 1 shows that considering the main access path, 6 houses present values between 1.00 and 1.11, and only KÖU present 1.28. This confirms that the great majority of the houses have more tree-like configuration. When considered all the accesses, all space-link ratio values increase, confirming that the exterior acts as space of connection, increasing the ring-like characteristics in all the houses. However, the values stay between 1.09 and 1.26, and only KÖU presents 1.47.

Another important point to analyse is the number of a, b, c, d-type spaces (Hillier, 2007). In two houses it is possible to identify the decreasing order of a>c>b>d, and in a third, a>c>d=b. In four of the houses, a-type are the highest number of spaces; and in the other three, a-type are the second highest. At the same time, in six houses, d-type are the lowest number of spaces; and three of these presenting 0 and another presenting 1. These characteristics implies that the houses present a great number of dead-end spaces, generally bedrooms and bathrooms, and that the other spaces serve as circulation, associated to rings, that generates possibilities of movement. When considered all accesses, a-type spaces are still the highest in four of the houses. Now, d-type spaces are the lowest in only three houses, and b-type are the lowest in four houses. Although the exterior creates new possibilities of movement, there are still a great number of dead-end spaces, but the rings become more complex.

All of the houses present the relation between functional spaces and the total number of convex spaces varying from 75% to 91%, and four of these houses present a relation above 81%. The
houses present very few spaces exclusively for transition and the circulation is mainly done through functional spaces. The most common transition space exists to connect the private to the social spaces.

Regarding the sectors, when considered the main access, six houses present all spaces from the same sector grouped together, as displayed in Table 1. In all of the houses, social sector is the first step. In five of them private and services are not connected to each other, and are placed as a second step, both directly linked to social sector. KOU house have two groups of private sectors connected to social, and one of them connected to service. ACAYABA house present the service sector split in two groups, with one of them as a third step connected only to private. The separation of sectors in more than one nucleus can be seen in Image 3.

The study demonstrates that a characteristic that changed through the years is the decreasing number of service spaces, and the increasing number of private, shown in Table 1. MILAN (1972) presents a proportion for social, service and private spaces of 25%, 43%, 32%. BAETA (1991) presents 28%, 7%, 65%. ACAYABA (1996), the last house in the sample, is a bit different in the trend, with the number of spaces more balanced, presenting 32%, 23% and 45%.
Figure 4 - Isovists from living room for MILAN (1972) and ACAYABA (1996) houses

As seen in Image 4, when it’s analysed the isovists from the centre of the living room, the houses present a great possibility of visualisation of the exterior, allowing different views of the garden in almost all façades. But when the isovists are used to understand privacy, another characteristic stands out: MILAN is the only house that allows the visualisation of the interior of the bedrooms and of a major part of the circulation that connects to the bedrooms. Four of the houses, including ACAYABA, separate the private sector from the rest of the house by floors differentiation. MILAN is the only house that separates the private sector in another floor, but still allows the visualisation of the bedrooms.

As seen in Table 2, in six of the houses, the most integrated space is a transition space, when considering the main access. MILAN is the only house in which an indoor functional space (dinning) is the most integrated one. However, in this house, dinning acts as a space that controls the horizontal and vertical circulation. When the exterior space and all the accesses are considered, now four houses present a transition space as the most integrated. In one of houses the exterior is the most integrated space.

The Table 2 also displays the Integration HH values of the main spaces of the houses for comparison: exterior, living, dining, kitchen, laundry, main bedroom and maid’s bedroom. Considering the main access, living or dining are the most integrated spaces in five of the houses; and the exterior is the most segregated in four of the houses. It is important to notice that even when these social spaces are not the most integrated ones, they present a very high value in the system. Laundry and maid’s bedroom are, in general, very segregated spaces. The main bedroom is very segregated in the first three houses, and in the other four this value increases.
When it is considered the main spaces and all accesses, in five of the houses the exterior becomes the most integrated, and in the other two houses this value increases. Social spaces are still very much integrated. In the four houses that exists maid’s bedroom, this space is the most segregated. The main bedroom is very segregated in the first four houses, even when it’s considered all the connections to the exterior and all the new possibilities of movement. However, the last three houses present an increase in the main bedroom integration, even existing only 2 points of access to the exterior. Considering all spaces, four of the houses still present a transition space as the most integrated.

4. CONCLUSIONS

Modern buildings were designed based on the idea of the ‘machine for living’, producing and organising spaces for each own functionality and removing everything that were deemed unnecessary for the living. It was imperative the organisation of groups with similar function together, described as the ‘sector’s paradigm’ (Amorim, 1999). And the circulation space was incorporated to connect several different functions together.

The society of Brazil, created over slave work and social segregation, absorbed the Modernism as an idea of development but kept, comfortably, traditional ideas of social and work relations (Marques; Trigueiro, 2000). Differently from studies that show similarity between functionalist architecture around the world, Brazilian Modern Architecture clearly displays social codes imprinted in the domestic space organization. Hanson (2003) affirms that it is possible that the modernist houses in some parts of the world present the invariance of the vernacular residences.
In Brazilian houses, from colonial to modern, circulation is done in most cases through functional spaces, presenting very few spaces used exclusively for transition. In these houses, service quarters are very segregated to hide the workers, as it happened in slavery time. This remains true even in contemporary architecture, generally associated to middle and upper classes. The main bedroom changed from a more centralised space, with the possibility of controlling the life of the inhabitants, to a more secluded location to achieve more privacy, specially when it's considered the main bedroom. All the bedrooms stopped being interconnected and started being dead-end cells. The Modern Architecture brought a valorisation of the social spaces with less compartmentalisation, supported by advances in building technology. With time, the lack of physical divisions reduced the possibilities of formal and informal differentiation (Trigueiro, 2015).

The residential architecture in Brazil changed during the 20th century, with the valorisation of the family life towards a spatial organisation of interconnected social rooms as opposed to the physical separation found before. The spaces were designed to guarantee spatial continuity as a substitution to the excess of walls or doors. In some cases, this continuity extended beyond the social sectors, valorising and connecting the kitchen (Reis Filho, 2013).

The buildings that represent the Paulista Brutalism movement were organized on a single block under one massive concrete roof, but were characterised by spatial richness on the interior with physically and visually connected spaces separated by level differences (Bastos; Zein, 2010). MILAN, the first house of the studied sample is a very clear example of the Brazilian Brutalist movement, presenting all characteristics and mainly organised under a single concrete arc. Privacy is achieved by closed doors only, and it’s much weaker than the other houses. From the living, the users can visualise all the external entertainment area, but also, most of the private circulation, bedrooms, dinning and services spaces doors. The envelope transparency guarantees almost the same visualisation quality of the living room from the main terrace. The physical separation is done by doors on each bedroom and the service spaces. Even the lavatories of the private spaces are placed on the circulation and outside of the bathroom, and can be partially seen from the living.

The visualisation of the private circulation and bedrooms continues in the next two houses but with a dramatic reduction, disappearing completely on the last four houses, where the private space is in another floor, separated by the staircase. In six houses, the bedrooms are accessed through a single continuous private circulation. Furthermore, the relation between bedrooms and bathrooms in the private sectors modifies during the years, representing the valorisation and individualization of the private spaces. In the houses built before the 80s all the private bathrooms are directly connected to the private circulation and they are not accessed through the bedrooms. This reaffirms a trend for individualisation and segregation of the private spaces.

Only one of the houses presents a traditional service sector, grouping kitchen, laundry and maids’ bedrooms. Three houses don’t present maids bedrooms and two houses present the kitchen disconnected from the rest of the service. Differently from what is expected in modern dwellings (Trigueiro; Marques; Cunha, 2001), the service is not always connected to the rest of the house through the kitchen. However, the laundry and service bedroom are generally very segregated. The kitchen has a much more important role, always directly connected to the continuous social space. It’s important to notice also the reduction of service spaces, and the simplification of this sector, representing the changes in work relations in Brazil.

It is clear that Marcos Acayaba has been influenced by an architectural movement, developing his own design process, and always heavily based on the chosen technology. The spatial organization are very related to the structural solution implying a certain variety in the configuration. However, it is also possible to observe certain characteristics presented in Brazilian Modern Architecture as a whole, that reflects the society codes and traditions of the period that these houses were designed. The houses’ configurations confirm the continuity of social spaces and the addition of transition spaces that leads to private or segregated rooms. The exterior is an important area for the resident, once allows other paths through the domestic space, connecting different sectors and reducing depth.
REFERENCES


ABSTRACT
Societies change and with it the buildings that host them. Space is therefore, a carrier of culture and meaning, and thus, fundamental for our understanding of architecture. Vernacular architecture is said to be a direct reflection of the society who build it and its surrounding natural context. However, the Industrial and Technological Revolutions have changed this premise. Man is no longer dependent on its natural context, and the particularities of each society have been softened by the era of continuous exchange of information.

Still every society holds norms and values that should influence the way space is built, but those are more difficult to identify specially in societies that suffered an accelerated socio-economic growth.

The paper is part of an ongoing research which aims to understand the social suitability of contemporary subsidized housing in the Kingdom of Bahrain by analysing space as a carrier of social meaning. The paper makes a comparative analysis between the object of study and the traditional Bahraini house.

It is argued that the contemporary houses have lost its fundamental characteristics of the traditional Bahraini house which served the norms and values of Bahraini society which persist to this day.

KEYWORDS
Housing, dwelling, domestic space organisation, traditional housing, subsidized housing, Bahrain, space syntax.

1. INTRODUCTION
The countries that constitute the Arabian Peninsula, especially the ones who are part of the GCC (Cooperation Council for the Arab States of the Gulf), have been suffering the consequences of the rapid urban growth verified after the discovery of oil (first discovered in Bahrain in the 1932).
In Bahrain, since mid 1950's, the growing residential pressure led the governmental authorities to develop various programs to house the growing population and plan its geographical distribution to several new towns. A new urban landscape slowly emerged composed by a variety of housing typologies experimentations that searches for the most suitable house for the modern Bahraini family.

The spatial configuration of the Bahraini house was determined by the culture, needs and values of the society, economic resources, physical and technological constraints (Rapoport, 1969, p.13), but after 41 years of designing and building houses for the Bahraini citizen it is necessary to question to what extent their design acknowledges and integrates the configurational pattern of the traditional house, which has been determined by deep-rooted social norms and by the inner meaning of space and form in this specific culture.

Hillier (2008, p.223) considers that most studies on domestic space suffer from a denial of real space as of theoretical interest. Space acquires significance only while a reflection of the society who inhabits it, but not in terms of the patterns of shaped and interlinked spaces of the everyday life. According to Hillier and Hanson (1982, p.9) it is not possible to conduct a research in architecture without embracing the idea of the fundamental relationship between man, culture and buildings.

This paper makes a comparative analysis of the spatial domestic configuration of the traditional Bahraini house and of the subsidized houses developed by the Bahrain Ministry of Housing (MOH). Analysis of the spatial characteristics of both traditional and subsidized houses, is expected to shed light on their spatial and structural differences and/or similarities.

2. DATASETS AND METHODS

The methodology uses configurational analysis of the traditional Bahraini house and MOH subsidised houses along with a review of the social, economic and political historical background.

The sample is composed by traditional Bahraini houses - aristocracy houses (8) and commoner's houses (6); and MOH subsidized houses built between 2000-2015 - most repeated typologies (7), and less repeated typologies (3).

The comparison was based on the analysis of the justified access graphs, levels of depth/integration; visibility/permeability; transition-space ratio, rings-sequence ratio, and symmetry.

Configurational descriptions help to determine how a system of spaces is related to form a pattern, which is independent from the intrinsic properties of the individual spaces themselves. Justified access graphs are a simple way to visualize configurational differences in buildings. The graph is aligned bottom-up from a starting node, called root (the outside or any other space), the nodes directly connected to the root (i.e. with depth 1) are aligned horizontally immediately above it, then the nodes directly connected to the former set (i.e. with depth 2) are aligned in the same way, and so on, until all levels of depth from the root are accounted for. This allows us to understand how distant, in topological terms, each space is from the root (depth), as well as how spaces relate to each other which, according to Hanson (1998, p.27) are fundamental properties of architectural space configuration.

3. PRIVACY AND FLEXIBILITY IN THE TRADITIONAL BAHRAINI HOUSE

The introverted house, as the basic constituent element of the Arab City, stands before the public space accumulating most social and cultural aspects of daily life (events such as weddings and other festivities, receiving visitors, etc.), hosting, under one roof, all types of family reunions protected from the intervention of strangers (Hall, 1969, p.158).

The house also reflects the fundamental aspects of the social interaction between genders within the family daily social practices, manifested spatially in the hierarchical division of the dwelling in two zones: the male (diwan-khana) and feminine (haram) (Al Thahab et al., 2014, p.239).
The entrance space never allows a direct view into the ‘heart’ of the house and the spaces that relate directly with the entrance have a semi-private nature, since they serve the ‘life of men’: their visitors, public events or others. If the house has several courtyards, there will be a clear hierarchy of each divided between men and visitors (semi-private); women and family (private). If the house only has one courtyard this will always be a semi-private space. (Serageldin, 1995, p.198)

Privacy also defines the location and arrangement of openings to the outside world. The upper floors, normally have a few wood decorated extended windows (mashrabyia) where women can sit and observe the outside world without being seen, specially by men which are not related in 1st degree. If they wish to speak to women from neighbouring houses, it is possible to open this lattice wood window, and engage in a lively conversation. (Al-Thahab et al., 2014, p.242).

The courtyard, surrounded by the functional spaces is the ‘heart’ of the domestic realm, but visibility towards other spaces is limited due to the small and narrow entrance door and/or openings. The spaces distributed around the courtyard(s) usually have the same size, shape and function, (except the kitchen, storage and the area for animals) and its use or function varies throughout the day and throughout the seasons. The roof terrace is a space of great importance serving multiple functions such as storage, production (such a drying fish), sleeping (on hot summer nights) and circulation. The upper rooms located in this area may be used by women when external visitors are in the house. This vertical movement is, therefore, both daily as seasonal. According to Yarwood, El-Mansari (2005, p.18) most spaces are extremely flexible and can be used to sleep, eat or socialise.

Serageldin (1995, p.198) names it flexible formalism which can be experienced both in the use of the courtyards and of the several divisions in the home, and implies a complete symbiosis between all inhabitants regarding the overall norms of conduct.

4. THE TRADITIONAL BAHRAINI HOUSE: CONFIGURATIONAL ANALYSIS

4.1 THE INTEGRATING PROPERTIES OF THE COURTYARD

Noor (1979, 1986) describes the “Arab House” as determined by three factors: environmental conditions; religion and social life; design structure and space articulation. The courtyard house, even if not exclusive, is a constant typology in the GCC region, the reflection of a direct response to a combination of climatic and human factors, and how local societies understand concepts as a family, religion and culture.

In the traditional Bahraini house, both aristocratic and commoner’s houses show a tree-like configuration, meaning a minimum number of connections amongst spaces which reflects a segregated spatial configuration, oriented towards inhabitant-inhabitant relationship, in this case centred in the courtyard(s).

This tree-like configuration growth is based on the multiplication of the same basic structure with few exceptions. The spatial configuration observed in the justified access graphs is confirmed by the high integration values: apart from Al Shirawi (0.41), all houses (aristocratic and commoners) vary between 0.61 and 1.14. The courtyard is always the most integrating space of the house, the central space through where all residents pass and perform all sorts of daily activities. It’s integrating power seems to be mainly affected by the number of courtyards within the house and the relationship with each other.

Sh. Isa and Sh. Salman houses have both 4 courtyards but the integrating values of Sh. Salman courtyards (1.44, 1.24, 1.43, 1.23) are always higher than Sh. Isa’s (0.82, 1.07, 1.16, 0.74). This is related to the distributedness characteristics of each house, as described by Hanson (1998, p.28). It is interesting to observe that in the case of Sh. Isa house the most integrated courtyard is not the main or visitor’s courtyard but the female/family one, with its secondary entrance and centralized location connected to all areas of the house – higher degree of choice.
The analysis of the traditional houses sample shows that the division of functional areas around distinct courtyards is more common in the earlier and bigger houses, beginning to shift to only one or two courtyards already around 1880. Therefore, it is reasonable to assume that size alters the spatial configuration but rather the appearance of wealth to the eye of the viewer and/or the optimum functionality within the household.

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The reception quarters (majlis) is normally described as the reflection of the almost total segregation between male and female members: a space, representative of the status symbol of the household owner, directly related to the entrance, or with a completely independent access from the domestic/family domain (Yarwood, El-Mansari, 2005, P.19).

Waly (1992, p.30) believes the traditional house can be categorised according to the nature of the reception quarters (majlis) as a spatial and functional element:

1. private majlis visually separated from the dwelling but spatially connected to the mass of the building;
2. majlis with its own individual entity within the mass and its own entrance and courtyard;

3. a simpler form of majlis in the shape of a main qa’aa adjacent to a central courtyard for daily living;

4. no private majlis within the mass of the house but connected to public majlises existent in the residential neighbourhood (fareej). These were more common in commoner’s houses.

The analysis of the traditional houses shows that the reception quarters acquire different positions within the house. The less integrated examples normally occur in the bigger houses, located in the open roof, accessed from a private vertical access. This is a deep space apparently designed to promote the social status of the household owner, allowing its visitors to make acquaintance with a part of the house (used by male members), as they move towards the reception quarters (majlis). This is revealed in a tree-like branch configuration with a sequence of transition spaces leading to the majlis: Sh.Salman, Al Shirawi, Seyadi, Sh. Isa houses. Sh. Abdullah reception quarters (majlis) with an independent access from the exterior is shallow but highly segregated, as the previous examples. These examples seem to correspond to Waly description n.2.

The reception quarters (majlis) of the remaining houses are more integrated. In commoner’s houses this space is normally shallow but equally segregated (houses 1, 3 and 6) reflecting a strictly rational approach to the norms of privacy and segregation prevalent in the traditional house: by placing it directly accessible from the main entrance vestibule, the visitor’s visibility is immediately "blocked" from the remaining interior spaces, including the central courtyard, allowing residents to move freely while insuring the proper reception of visitors. In the humbler houses, it would also be a way of concentrating care and decoration in the entrance area insuring the pride of the household owner. These seem to correspond to Waly description 3.

The reception quarters (majlis) in Ahmed Mattar, Sh. Abdullah Bin Mohamed and commoner’s houses 5 and 2 are highly integrated, located in the central courtyard. This is the only configuration where the integration level of this space is equal, or similar, to the remaining spaces (rooms) located around the central courtyard. In these cases, privacy could be achieved through a vertical movement between the ground floor and the open roof.

In summary, it is possible to conclude that the reception quarters (majlis) have a significant importance in the overall configuration of the traditional house. However, the varied positioning within the overall spatial configuration doesn't allow us to describe it as a highly structured and segregated space since, even if this occurs frequently it is not a norm.
4.2 THE IMPORTANCE OF TRANSITION SPACES

Spatial configurations can be made up of four topological space-types normally represented with letters - 'a', 'b', 'c', 'd' – where, 'a' are terminal spaces, static in nature; 'b' spaces are thoroughfares on the way to a terminal space, where movement is still highly directed; 'c' spaces have more than one link and can be crossed, part of a single ring; and 'd' spaces have more than 2 links part of more than one ring which generate choice.

Space-types represent structural dimension of spaces. Dominant space-types within the system support the measurement of key spatial characteristics of buildings layouts such as transition-space ratio, ring-sequence ratio, symmetry and asymmetry (Hanson, 1998, p.173).

The transition:space ratio measures the economy or insulation of the layout independent of size, allowing the interpretation of spatial patterns as a product of social practices, unaffected by economic constraints. Transition spaces may be used to a greater or lesser extent to separate and insulate activities and people from one another or draw them together respectively.

A predominance of ‘a’ and ‘b’ space-types emphasize tree-like configurational properties, because such spaces offer no route options, strongly framing the activity of its occupants and, therefore more segregated and non-distributed, whilst the predominance of ‘c’ and ‘d’ space-types are conductive to ringiness, which give people choice and is therefore, more permissive and distributed.

According to Hanson (1998, p.188) transition:space ratio allows the understanding of the distributedness of plans: \((a+b)/(c+d)\)=distributedness, where a low value is distributed and a high value is non-distributed; whilst the ring:sequence ratio measures asymmetry which expresses the houses potential to differentiate and express distinctions of personalities and social situations: \((a+d)/(c+b)\) = asymmetry, where a low value is asymmetric and a high value symmetric.

The transition:space ratio in the analysed houses is overall high varying between 1.55 and 3.00, which confirms that this is a non-distributed scheme. It is noted that transition spaces seem to be mainly concentrated in two areas of the house: the main entrances and the roof terraces. Commoners house 5 has the lowest transition:space ratio of the entire group (1.55). The exterior space and first courtyard is, on average, separated by 2.5 transition spaces. All houses, aristocratic and commoner’s, share this characteristic, designed to ensure the privacy of the domestic realm, and constituent part of the configurational pattern of the traditional house.
According to Waly (1992, p.35) the urban house was characterised by the extension of open spaces on two levels: the residential courtyard on the ground floor and the open roof on the upper floor. The open roof, due to its high parapet walls ensured enough privacy for the family to circulate between several (or single) courts of the house, as well as to perform several daily and seasonal activities. This means that the open roof integration is in direct opposition to the ground floor segregation.

The analysis of the traditional houses transition-space ratio with and without considering the roof level reveals striking differences. When the measure considers the roof level, the values are overall lower (between 1.55 and 3.00) and the aristocratic houses show the lower transition-space ratio, meaning that the plans use a higher number of transitions in relation to the overall number of spaces, the only exception being commoners house 5.

However, the same measurement, not considering the roof level, shows that the overall transition-space ration increases (between 1.86 and 4.50) and the former distinction between aristocratic (higher use of transition spaces) and commoner’s houses (lower use of transition spaces) disappears.

This means that the traditional Bahraini house optimises the use of transitions with respect to the function spaces drawing people together, and focusing the use of transition spaces in specific areas such as the entrance area for insulation and thus configuring space efficiently to achieve the described social purposes. However, the roof is an open space that performs the link between all areas of the house, which means that in houses with higher number of courtyards, the number of transitions will tend to increase, whilst, in houses with only one courtyard, the opposite will happen, and the circulation will occur through the strategic location of staircases in different areas of the house.

Therefore, we can conclude that the traditional house both insulates and brings people together: each courtyard acts as a social integrating element while transition spaces are employed in strategic spaces to separate or allow communication between the different integrating elements.

The analysis of the ring:sequence ratio shows that all houses is above 0.5 except for Salman Mattar, Ahmed Mattar and Sh. Isa houses (however, when measured without the roof only Salman Mattar house reveals a value of 0.14). This is mainly due to the unusual combination of the 3 usual rings that can be found in these houses.

The ringiness dimension appears in very specific conditions:

1. from the situation described previously — the open roof connects all areas of the house and occupants use it both for daily activities and to compensate, when necessary, the segregated ground floor;
2. rings relating specific functions such as courtyard-room-hamman (bath); and more rarely courtyard-liwan (portico hall)-room, which are quite irrelevant in the overall configuration;
3. rings passing through the exterior that connect different entrances of the house to the main courtyard(s).

As the houses grow the tendency is to create more “trees“ not rings. This is a transition-integrated complex.

Most topological spaces are ‘a’ and ‘c’, followed by ‘b’ and ‘d’ and most ‘c’ spaces are mainly located in the open roof area, therefore we conclude that the traditional Bahraini house is, non-distributed and asymmetric, meaning the spatial configuration reflects strongly framed spaces, governed by strong rules of behaviour, where routes are constrained functionally to separate the circulation patterns of different categories, so that subtle spatial segregations are maintained (Hanson, 1998, p.188).
5. HISTORIC BACKGROUND: THE SUBSIDISED CONTEMPORARY BAHRAINI HOUSE

It is necessary to begin by contextualising the subsidised housing program developed by the Ministry of Housing in Bahrain (MOH) since its foundation, within the social, economic and political frame of Bahrain in the second half of the twentieth century.

Bahrain, according to Bahrain Central Informatics Organisation, between 1941 and 2014, saw its population increase 1461% (between 1941 and 1981, this growth rate was 350% and between 1981 and 2014 the growth rate was 375%). If we consider solely the growth of Bahraini citizens, between 1941 and 2014, the population increased 852% and between 1981 and 2014 264%.

By mid 1950’s the residential pressure in the main cities of Manama and Muharraq led the Bahraini government to develop several housing projects firstly oriented to house the workers of these two cities and to build the first new town – Isa Town, 1963. The Ministry of Housing (MOH), established in 1975, bolstered and continued the previous efforts by developing subsidized affordable housing programs for citizens with low disposable income.

Several new towns were founded according to rules and legislation specifically developed for that purpose, with the main goal of ensuring the minimal standards of quality, suitability and comfort to Bahraini families, giving shape to a new urban landscape. Between 1976 and 1993, the MOH developed and built 58 different housing typologies, experimenting with various spatial configurations and relationship of building with the plot and street. In 2010, the number of different housing typologies used by the MOH didn’t surpass 10 variations giving origin to a very homogenised built environment.

In 2010, the MOH, before the need to build 50.000 new housing units, established public-private partnerships programs to meet the demand and supply 24,000 to 25,000 houses by 2016.

6. THE SUBSIDISED BAHRAINI HOUSE: CONFIGURATIONAL ANALYSIS

6.1 THE URBAN DIMENSION

Since 1975, the houses developed by the MOH, with very few exceptions, have ignored the traditional relationship between house and street creating setbacks (at least one front and back yard) that have been reduced to a minimum of 3 m front and 2 m side and back, contained by high boundary walls. These dimensions leave little space for any type of outdoor function to occur besides circulation and visual privacy from the surrounding neighbourhood.

The introverted characteristic of the traditional house, fundamental generator of the highly dense city, with almost blank boundary walls on the ground level, has been reversed but
not completely: the almost blank boundary wall defining the street space remains, but the introverted characteristics has become extroverted. Openings now face the boundary walls on the ground floor level, or the immediate neighbours in the upper levels. Family members no longer overlook each other but rather unknown neighbours.

Figure 6 - Aerial photo of Old Muharraq, Bahrain, 1950 and Government housing in Hamad Town. Source: Tarek Wall via studio Anne Holtrop | Armand Hough.

6.1.1 THE EXTROVERTED HOUSE

The analysis of the MOH houses show very low flexibility. The domestic space has acquired extreme functional specialisation — formal reception room (*majlis*), living room, family room, kitchen, outdoor kitchen. Even if this specialization process is verified throughout the nineteen and twentieth centuries in many developing countries, in the case of Bahrain, leads to an interesting paradox — as social norms become more flexible, the house becomes more rigid. The only flexible place of the house seems to be a room sometimes located on the ground floor, adjacent and accessible from the living room, acquiring all sort of varied functions — sleeping, dining, living, office, playroom.
Figure 7 - Plans and J-Graphs of MOH subsidised houses — prototypes. Source: http://www.housing.gov.bh/en
1. entrance hall; 2. majlis; 3. living room; 4. family room; 5. kitchen; 6. toilet; 7. bedroom; 8. master bedroom; 9. storage; 10. garage; 11. outdoor kitchen; 12. laundry; 13. maid room; 14. veranda/terrace
The MOH houses have a strictly tree-like, non-integrated configuration. The bigger houses are more segregated than the most commonly used prototypes, but the variation is very low, unlike the range of variation verified among the group of traditional houses – integration values between 0.58-0.69 in MOH and 0.41-1.14 in traditional houses.

The formal reception room (majlis) has a constant position within the overall spatial configuration of the house: it is shallow, positioned in the frontal part of the house, adjacent to the main entrance hall. The integration of the reception room varies according to the level of segregation in relation to the overall complex (integration values vary between 0.55 and 0.82). The less integrated examples may have a direct access from the outside; be isolated by the entrance hall with its own guest toilet; or be the most segregated space within a ring that connects the majlis and living room to a guest toilet. The reception room is more integrated in the cases where the main entrance hall serves as the main distributor to all areas of the house, or within a ring highly integrated with the living room.
Unlike the variety in the traditional houses, the contemporary house seems to have drawn inspiration from the most common disposition of majlis in the last period aristocratic houses and commoner’s houses — direct access from a main entrance vestibule — to optimise the need for transition spaces but still ensure an acceptable degree of privacy for the family members.

The living room is, in most cases, a highly-integrated space (T3M, T8A, T8C, D5, D9, V2), the role performed previously by the courtyard, serving both as a transition space connecting entrance, kitchen, toilet, staircase and a functional space. The integration values range between 0.80 and 1.10 very like the integration values of the courtyards in the traditional aristocratic houses with several courtyards (0.82 - 1.24).

6.2 FROM A SPACE-INTEGRATED COMPLEX TO A TRANSITION-INTEGRATED COMPLEX

The transition:space ratio of the MOH houses (2.00-3.00) is similar to the traditional commoner’s houses (1.55-3.00) and quite higher when not considering the connection with the exterior (2.86-3.83), which means that the space is not highly insulating.

However, if we also analyse the ringiness dimension, the contemporary MOH houses are extremely non-distributed with values ranging between 1.22 and 22 while the traditional house ranged between 0.14 and 13 with a clear prevalence of ‘a’ and ‘b’ spaces.

The traditional house, even in its most basic configuration, appears to be more distributed than the contemporary houses. Previously the roof terrace hosted daily activities but also had a unifying function contributing to a higher connectivity amongst all function spaces while, in the contemporary houses the division of the domestic space in 2 functional levels increased the overall level of insulation within the house while the previous vertical separation —the 1st floor is simply the functional host of the most segregated spaces in the house — the bedrooms (integration levels between 0.42 and 0.53), contributing to a higher insulation of its residents.

The positioning of the formal reception room (majlis) within a ring, is a configurational solution that appears in 1976. According to Waly (1992, p.35) in the traditional house, the reception room (majlis) could have a coffee burner placed specifically at a side, away from the door, or it was prepared in a room annexed to it. Servants quarters were quite often located in mediating position between visitor’s court and private court.

In the new houses however, the kitchen is normally located in the back of the house, connecting to the living room or distribution hall. The need to ensure privacy while allowing an easy access to a guest toilet and service to guests from the kitchen, led to the integration of this space in a ring, that makes the mediation between the public and private spheres. In this case, the ring is of extreme functional importance: some reception rooms such as T8A are more integrated than others within a ring - D11, D5, D9, D10 - however, it fails to fulfil its social purpose - to ensure the necessary levels of privacy between guests and family (secluded access to guest toilet).
The other common ring is exterior, connecting the yard (front and side) to the kitchen, living room and/or main distribution hall, successfully separating daily activities and offering occupants alternative routes and possibilities of behaviour – such as the possibility of accessing the house without having to cross visitors. It is the contemporary interpretation of the exterior rings in the traditional house, but more limited, in the plans where the guest reception area is not isolated from the rest of the house, especially the vertical circulation.

The levels of integration of the kitchen will vary deeply not from its location in the house, but from the connections with the exterior and, consequently, the integration within a ring.

The house went from a space (courtyard)-integrated complex to a transition-integrated complex where a sequence of distribution halls performs the task previously achieved by the courtyard. The living room is, in most cases, the only integrated space that contradicts the overall tendency for insulation.

7. CONCLUSIONS

Hanson (1998, p.3) refers that houses everywhere serve the same basic needs but a closer observation reveals an astonishing variety in the ways these activities are accommodated in the houses of different historical periods and cultures. “The important thing about a house is not that it is a list of activities or rooms but that it is a pattern of space, governed by intricate conventions.”

The analysis of the traditional Bahraini house and the subsidised houses promoted by the Ministry of Housing in Bahrain (MOH) reveals both continuities and ruptures which might indicate a potential social inadequacy of the new houses to the social norms and values of the society it hosts.

It would be expected that the strict social conventions which governed the traditional house would have become more flexible as we move towards a globalised society, while keeping its fundamental essence. However, it seems like the new houses have lost the former unique ability to segregate genders while integrating family members through the high flexibility of its spaces and the strategic use of transition spaces in key areas such as the main entrance and the open roof to connect all segregated areas.

The new houses use transition spaces to isolate different functions of the house — reception, living and dining, family gathering and sleeping — in such a strict structure that has become overall, less integrated, non-distributed, insulating people instead of drawing them together. This happens both in terms of permeability and visibility: family members cannot visualise one another through a central integrating space (courtyard), as they are confined to functional key areas, overlooking the outdoor. This constitutes a major change in the former visual order.
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RELATIONSHIP BETWEEN VISITORS’ MOVEMENT PATH, STAYING ACTIVITY AND SPATIAL STRUCTURE IN THE LIBRARY AS A “THIRD PLACE”:
Focusing on Yamanashi prefectural library

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ABSTRACT
Public library have been changing with the change of lending system. In recent years, many documents have been put into digital form, and then the argument that library is unnecessary arose. In response to this controversy, another argument about the meaning of library arose too. Nowadays, the movement that reconsider library as a “Third place.” is also seen. “Third place” means public space coming after home and workplace. In this way, architectural planning of public library, particularly in browsing space, have been changing to be designed as a place of relief gradually, and new libraries called “stay-type library” have been built recently. Therefore, this study aims to reveal the relations between visitors’ behavior and spatial structure of public library in order to design better library for staying.

This study examines Yamanashi prefectural library. We recorded visitors’ movement paths on maps by tracking visitors and recorded visitors’ distribution by taking movies. We investigates the correlation between visitors’ movement, staying activity and spatial characteristics analysed by space syntax theory. Space syntax values were calculated by convex analysis, Isovist, and Visibility Graph Analysis (VGA). Through these analyses, four points are revealed:

1. Correlation between visitors’ movement path and spatial indices calculated by space syntax analysis,
2. Seat selection preference between the types of activity,
3. Correlation between the seat occupancy rates divided by the type of activity and values calculated by space syntax analysis,
4. Differences of spatial configuration indices between the types of activity.
1. INTRODUCTION

Matsufuji et al. (2011) and Kitaoka et al. (2011) mentioned that the public library in Japan has been changing with the change of lending system. In Meiji era, Yukichi Fukuzawa wrote “Seiyo jijo” (affair in the Western Countries) and introduced the public library to Japan because there were few places to read books for citizens at that time. Under the influence of this introduction, the first public library was established in Japan. Before the end of WWII, library had closed stack system, so the plan of library is divided by the function, separated to browsing space and closed-stack bookshelves. But after the WWII, transition of the library planning is continuous process of trial and error. Uemura et al. (1999) explained that library system had changed from closed-shelf system to open-shelf system, therefore bookshelf had been closed to browsing space. After the change of system, the distance between people and books was becoming short and they could browse books easily. However, many people — most of them were the students — used the browsing space as a room only for study. So the browsing space was designed small by the people thinking that the situation at that time was not good. Nowadays, information put into digital form and many books are sold as an electric books. Uemura (2013) mentioned that the argument that library is unnecessary arose because of “Libraries and Librarians in an age of electronics”, written by F.W. Lancaster. In response to this controversy, another argument about the meaning of library arose too. Nowadays, the movement that reconsider library as a “Third place” is also seen. “Third place” means public space coming after home and workplace. In this way, architectural planning of public library, particularly in browsing space, have been changing to be designed as a place of relief gradually, and new libraries called “stay-type library” have been built recently. Therefore, this study aims to reveal the relations between visitors’ behavior and spatial structure of public library in order to design better library for staying. It seems that the library planning should be designed as a place to take place many kind of activity spontaneously, not only the usage as a library, — reading books or studying for example — but also as a “Third place” — getting together with friends or taking a rest, talking with the neighborhood — . We expect that a library has a potential to become a facility for making community and making better life.

We review some studies targeted the public library. Capillé et al (2015) study three libraries in Medellin, Colombia. They investigated ‘snapshot’ and ‘trace’ observation and mapped in one figure. They connected the relation among the visitors, staffs and convex spaces considering the visual association and access association. They explained the formation of informal interaction using network analysis. Zook et al (2012) focused on two type of architectural tasks, and investigated Seattle central public library from two direction, social staging and phenomenal staging. In social staging, they collected visitors’ walking routes, those that is different from some types of usage, then they analysis where the visitors walk through using space syntax analysis. In phenomenal staging, they examined what the visitors feel while walking through the library by describing the sequence of phenomena encountered by the visitors. Both of two study tried to propose the new analytic method and it serves as a reference on how we should research public facility.

2. INVESTIGATION AND SPACE SYNTAX ANALYSIS

2.1. YAMANASHI PREFECTURAL LIBRARY

This study targeted the Yamanashi Prefectural Library situated near Kofu station in Yamanashi. This library was built in 2012, designed by Kume Sekkei and Miyake Architects and Associates as a joint venture. This library is a complex facility with hall, exhibition space and many small discussion rooms. Figure 1 shows the plans of Yamanashi prefectural library. On the first floor, there are two entrances, café, exhibition room, and discussion rooms, library section (magazine, children, PC area, and counters). A lot of tables are arranged along the path connecting the two entrances like a sidewalk café. Main bookshelves section is on the second floor, and many type of browsing spaces are in various places in the plan. On the third floor, there is a room for study placed like a bridge. Library office put onto the east side of the building so as to plan a large
library section in the center of the building. Moreover, this facility has a big open ceiling space and it is connecting the different rooms visually. Moreover, this library has no border between the other sections so that visitors can walk through the building with no barrier and visitors can read books anywhere and study anywhere. Designer who planned this library describes it as “Food court of knowledge.” In this library, we can see many kinds of activity. After the complete in 2012, the number of visitors increase obviously, this library is in second place in the number of visitors ranking in Japan two years in a row. This showed that many people living around recognized this library as a “Third place.”

Figure 1 - the plan of Yamanashi prefectural library
RELATIONSHIP BETWEEN VISITORS’ MOVEMENT PATH, STAYING ACTIVITY AND SPATIAL STRUCTURE IN THE LIBRARY AS A “THIRD PLACE”: Focusing on Yamanashi prefectural library

Figure 2 - The pictures in the Yamanashi prefectural library


2.2. INVESTIGATION

We investigated the visitors’ activity in order to figure out the feature of it in Yamanashi prefectural library. We investigated the visitors’ movement path and the distribution of activity. The investigation was conducted by 6 surveyors from 11:00 to 15:00 on weekday in July of 2015. 5 surveyors investigated the visitors’ movement path, and 1 surveyor investigated the distribution of activity.

Visitors’ movement path

3 surveyors were located south entrance, 2 surveyors were located north entrance. They tracked visitors until visitor sat on a chair or stopped to read a book. Then they recorded the movement path to the map. We collected 195 movement paths in this library. Figure 3 shows the results of all paths on the plan. The atrium connected two entrances is well used by the visitors therefore this atrium is relatively restless. Moreover, we observed a lot of flows of people that pass through the magazine space, go up using the central staircase and spread in all direction of second floor. Then on the edge of second floor and third floor, we were able to observe few Movement path.

Distribution of activity

At the same time, we shot the video all over the building every 30 minutes and recorded the distribution of visitors’ activity on the map. Of course some people walked around so pedestrian distribution in the library were counted by snapshot method. Distribution was counted five times in this investigation. We collected 1301 visitors’ activity in this library. Figure 4 shows the result of distribution of activity on the plan. The visitors studying with friends or reading books casually were observed along the circulation space, particularly in the first floor atrium. The visitors studying alone or concentrating on reading were observed on the area that is far from the entrance, especially on the second floor.

Figure 3 - Visitors’ movement paths.
2.3. SPATIAL CONFIGURATION ANALYSIS BASED ON SPACE SYNTAX THEORY

We analysed the special configuration of Yamanashi prefectural library using Space Syntax Theory. In this study, we used convex analysis and calculated Isovist using depthmap (Turner, 2004), which is a software for special analysis based on space syntax. Firstly we made the plan of each floor about Yamanashi Prefectural Library using CAD software. And we use it on each analysis.

Convex analysis

We divided the space of this library into 168 polygons on the basis of psychological cost. Figure 5 shows the plan divided by convex space. Considering how they feel when they walk in the library and what they feel as a boundary of space, we divided the space by the pillar, corner, direction of bookshelf etc. Then we connected these convex space if we can access. In this analysis, we used a new program “New Convex” considering the area. So we put the convex map to this “New Convex”, and analysed it.

In this study, we calculated three indices: Depth, Connectivity, global Integration value. Depth means how far the space is from the entrance, how deep the space is for the people entering from the entrance. Connectivity means the accessibility of space. The larger this value is, the more spaces the space is connected. In this study, to consider the difference of convex space area, we calculated the weighting connectivity based on the smallest convex space as minimum size. Then we calculated global integration value using connectivity considering the area. Global integration value means the centrality of space. When this value is large, it means that we can reach at all of spaces more efficiently. Figure 6, 7 and 8 are the result of Depth, Connectivity and Global integration value respectively. The larger each index is, the redder colour is and the smaller each index is, the bluer colour is.
RELATIONSHIP BETWEEN VISITORS’ MOVEMENT PATH, STAYING ACTIVITY AND SPATIAL STRUCTURE IN THE LIBRARY AS A “THIRD PLACE”: Focusing on Yamanashi prefectural library
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Figure 7 - A result of Connectivity.

Figure 8 - A result of global integration value
Isovist calculated by depthmap

Firstly, we put the plan of each floor into depthmap, then calculated the Isovist of each seat in the library. We calculated four kinds of Isovist. Figure 9 expresses the method of calculation about Isovist.

360° Isovist was set 360° and calculated as “Viewed Range.” “Viewed Range” means how large they are seen from around the seat they sit on. When we calculated, we used the plan whose furniture that obstructed the view when we sit on the seat are drown as walls not to calculate the area over them. In addition, we did not calculate the void area as "Viewed Range" because we cannot view the seat from the void.

The other three Isovist were set 180°, 120° and 90° on each Isovist based on the seat direction, and calculated as “View Range.” “View Range” means how large they saw from the seat they sit on. In the same way as 360° Isovist, we used the plan whose furniture were drown as walls. And we interpreted the void area as "View Range” because we can see the void from the seat. These isovist indices were used later analysis.

![Figure 9 - Calculation method of Isovist.](image)

3. RELATIONSHIP BETWEEN VISITORS’ ACTIVITY AND SPATIAL CONFIGURATION

3.1. RELATION BETWEEN VISITORS’ MOVEMENT PATHS AND SPACE SYNTAX INDICES

To reveal the relationship between the flow of people and space syntax indices, we analysed the correlation between visitors’ movement path and special configuration. First, we calculated the number of Movement path that passed through each convex space. Then we divided the number of Movement path by the area of each convex space. This index is named Movement path per unit area and means how many people pass through this convex space. By using this index, we can grasp the flow of people and how restless space that is. Figure 10 shows that the result of calculation of Movement path per unit area. The redder colour is, the larger the index is. The place whose index value is high concentrates on the first floor, especially the spaces around the entrance and near the central staircase have high value. Moreover, the values of vertical path are high. Table 1 shows the correlation coefficient. Movement path per unit area is associated with Depth and Global integration value. We use this index in later analysis.
## Table 1 - Correlation analysis between visitors’ movement path and special configuration

<table>
<thead>
<tr>
<th>Route</th>
<th>Movement path per unit area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>-.491**</td>
</tr>
<tr>
<td>Connectivity</td>
<td>-0.01</td>
</tr>
<tr>
<td>Global integration value</td>
<td>.358**</td>
</tr>
</tbody>
</table>

****: statistically significant at the 0.01 probability level (p<0.01)

### 3.2. SEAT SELECTION PREFERENCE

In the investigation, we found out that there are some deviation of visitors’ distribution. In this section, we examined the seat selection preference to reveal where was used for the visitors who read a book alone, study with groups etc. First, we classified the visitors’ activity by result of observation as Table 2.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Temporary Activities</th>
<th>Quiet Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporary</td>
<td>Reading a book casually, Talking, Studying with friends,</td>
<td>Studying alone, Reading a book alone,</td>
</tr>
<tr>
<td>Quiet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vacancy</td>
<td>No one sitting on</td>
<td></td>
</tr>
</tbody>
</table>

Table 2 - Classification of visitors’ activity

After that, we made a cross tabulation and performed Chi-square test and Residual analysis to reveal what the place was used for. Figure 9 shows the result of seat selection analysis. Red space means that we observed temporary activities significantly more than the other spaces. Blue space means that we observed Quiet activities significantly more than the others.

Red spaces concentrates on the first floor, especially along the atrium. Furthermore, there are red spaces around Magazine area. On the second floor, we can observed red spaces near...
the atrium, and around the vertical path. There are blue spaces in the place surrounded by the bookshelf. In these space, a lot of tables with partition or carrel are located. Therefore, it seems that visitors who perform the Quiet activity selected the seat where they do not feel someone looking at them. The third floor have studying room only thus there are only blue spaces.

![Figure 11 - A result of seat selection preference.](image)

### 3.3. RELATIONS BETWEEN SEAT OCCUPANCY AND SPACE SYNTAX INDICES

The previous section we focused on the seat selection preference to grasp the deviation of visitors’ distribution. In this section, to reveal the relationship between spatial configuration indices and seat occupancies of visitors in each browsing space, we performed the correlative analysis. However, there was no correlation between any space syntax indices and seat occupancy. Therefore, we used the previous classification, “Temporary”, “Quiet” and “Vacancy”, and then we calculated the seat occupancy on each activity. We calculated the seat occupancy of each category and make a correlative analysis between the occupancy and spatial configurations. Table 3 shows the result of analysis. It should be noted that we investigated visitors’ distribution five times so we calculated the average of seat occupancy.

In Temporary activity, it indicates a significant negative correlation between seat occupancy and Depth. It shows that Temporary activity occupancy is high in the place where it is near the entrance. In Quiet activity, it indicates significant negative correlations between seat occupancy and Global integration value or Movement path per unit area. It shows that the place where it has high Quiet activity occupancy have low centrality of space and few people walking though. Therefore visitors reading books calmly or concentrating on studying are observed in the place that it is far from the central space or the place that is tranquil. In addition, Quiet seat occupancy is strongly associated with Depth. In Vacancy, there is no significant correlation.
The average of seat occupancy

<table>
<thead>
<tr>
<th></th>
<th>Temporary</th>
<th>Quiet</th>
<th>Vacancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>-.420**</td>
<td>.566**</td>
<td>-.051</td>
</tr>
<tr>
<td>Connectivity</td>
<td>.002</td>
<td>-.164</td>
<td>.196</td>
</tr>
<tr>
<td>Global integration value</td>
<td>.223</td>
<td>-.452**</td>
<td>.123</td>
</tr>
<tr>
<td>Movement path per unit area</td>
<td>211</td>
<td>-.421**</td>
<td>.067</td>
</tr>
</tbody>
</table>

**: statistically significant at the 0.01 probability level (p<0.01)
*: statistically significant at the 0.05 probability level (p<0.05)

Table 3 - Correlation analysis between seat occupancy rate and special configuration.

Figure 12 - scatter plot of Seat occupancy vs Depth

Figure 13 - scatter plot of Seat occupancy vs Connectivity
3.4. SPATIAL CONFIGURATION DIFFERENCES AMONG ACTIVITIES

In this section, to reveal the influence of spatial configuration against the seat selection, we examined whether or not they have significant differences among activities. At first, we organized the spatial configuration as Table 5.

<table>
<thead>
<tr>
<th>index</th>
<th>Spatial characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>360°Isovist</td>
<td>“Viewed Range”, how much the seat is viewed</td>
</tr>
<tr>
<td>180°Isovist</td>
<td></td>
</tr>
<tr>
<td>120°Isovist</td>
<td>“View Range”, how large they view from the seat</td>
</tr>
<tr>
<td>90°Isovist</td>
<td></td>
</tr>
<tr>
<td>Depth</td>
<td>Depth from outside</td>
</tr>
<tr>
<td>Connectivity</td>
<td>The accessibility of space</td>
</tr>
<tr>
<td>Global integration value</td>
<td>The centrality of space</td>
</tr>
<tr>
<td>Movement path per unit area</td>
<td>How many people pass through the convex spaces</td>
</tr>
</tbody>
</table>

Table 5 - spatial configuration indices.
Then we used Kruskal-Wallis H test to compare three categories, Temporary, Quiet and Vacancy. Figure 8 expresses the differences of spatial configuration as box-and-whisker plot.

Figure 8 shows the significant differences between three categories in ‘Viewed Range’ and ‘View Range’. The largest is Temporary, followed in order by Vacancy and Quiet. It indicates that visitors doing Temporary activity tend to sit on the seat from which they can see the wide view. Depth in Figure 8 shows that it has differences among categories, it followed by Quiet, Vacancy and Temporary in descending order. It seems that visitors doing Quiet activity have a tendency to choose the seat which is in the place far from the entrance. On the other hand, Connectivity shows the significant difference between Temporary and Quiet or Vacancy. However, it does not have a significant difference between Quiet and Vacancy. Global integration value and Movement path per unit area in Figure 8 show the significant differences among three categories, the largest is Temporary, followed by Vacancy and Quiet in descending order. It indicates that the visitors doing Temporary activity tend to select the seat in the place where is accessed efficiently and used as circulation space.
4. CONCLUSIONS

This study analysed the relationship between the visitors’ activity and special configuration in public library. Consequently, we obtained some tendencies about the visitors’ activity. First, we revealed that there are deviations of visitors’ distribution in each activity. Moreover, we found out some correlations between visitors’ distribution and spatial configuration. This result shows that “Quiet” activity occupancy is high in the place that it is far from the entrance. Second, we focused on each seat to reveal the tendency of seat selection. We examined whether or not they have significant differences among the type of activity using Kruskal-Wallis test. As a result, we obtained that they have differences among three categories in “Viewed Range” and “View Range”, the largest is “Temporary”, followed by “Vacancy” and “Quiet” in descending order. Moreover, visitors doing “Temporary” activity tend to select the seat whose global integration value and Movement path per unit area are high. On the other hand, visitors doing “Quiet” activity tend to sit on the seat which is the high value of Depth. They show that visitors select the seat considering the spatial configuration — “Viewed Range”, “View Range” and Global integration value etc.— by the type of activity. They indicate that library has to be design the facility including various characteristic space in order to accept various activity. Future study is to make the equation to estimate the selection probability to reveal how and what purpose the seat is used. For the future study, we have to collect the other indices such as attribution of visitors or indoor condition. This analysis is able to be utilized for future facilities planning such as the library that people visit as “Third place”. 
REFERENCES


#27

**A CONFIGURATION GENERATOR**

Housing as a toolkit for spatial exploration by users

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**ABSTRACT**

Social Logic of Space (1984) showed conceptual house plans of 3x3 room layout that can generate completely different permeability graphs. Hillier and Hanson’s point was that a genotype of a building can only be retrieved by looking at its spatial connectedness, not its geometric form. Since then, researchers have successfully verified there are culture-specific housing genotypes in each society. We try to re-think about this archaeological process of genotype retrieval by designing a new housing scheme that will be used as an open genotype test-bed. Based on a concept of ‘incremental self-build housing’, an apartment unit plan of 2x3 interpretable layout was developed for Malaysian low-income city dwellers. Generating a large number of spatial variations out of a single geometry, it can accommodate a wider range of domestic life styles. 24 examples of different configurations were suggested and tested by space syntax analyses to show how a small number of rooms can generate a huge variety of spatial possibilities. At some point in post-occupancy, it is expected that we will get the idea on what ‘actuals’ occur amongst all ‘possibles’ and what dominates while others vanish. By identifying the most socio-culturally adapted plans and decoding the embedded spatial connectedness, it is hoped that we can filter out the modern Malaysian genotype. It is a new way of thinking of a house not as an end product but as a process. Here, finding a genotype does not come from measuring a frozen building form from the past but from continuously looking at its transformation in time - how residents experiment their own way of living to arrive at an optimum solution. In this experiment, the role of architects will be to offer a dwelling toolkit for users to explore configurations that will eventually reveal statistically meaningful genotypes within a given context.

**KEYWORDS**

Genotype, Incremental housing, Configuration generator, Toolkit.
1. BUILDING GENOTYPE REVISITED

In Social Logic of Space (1984), Hillier and Hanson showed four house plans with identical room layout yet with different access patterns (figure 1). By representing them with justified graphs, they clarified that a same geometric form can accommodate completely different patterns of domestic living. Building on this idea, they made an assumption that if there appears dominantly recurring patterns within a wide variety of possible syntactic configurations, they are culturally embedded patterns of spatial invariants which are shared and transmitted through generations in that society, i.e. genotypes.

![Figure 1 - Four theoretical house plans in Social Logic of Space (Hillier and Hanson, 1984)](image)

These statistically meaningful patterns or deep structures of spatial commonalities can be retrieved by investigating any built systems through syntactic analysis as explained by Hillier:

"As we will see, what we discover through applying these techniques to the analysis of spatial and formal patterns in architecture, wherever they are found and whatever their embodiment in either buildings or urban systems, are invariants in patterns which lie not on the surface of things but which are buried in the nature of configurations themselves. These invariants we can think of as deep structures or genotypes." (Hillier, 2004: 60)

For decades, researchers around the world has adopted this concept of genotypes and analysed vernacular and modern houses to prove there are certain types of permeability patterns that suit to particular way of indigenous behaviour. When a society is settled and maintains its socio-cultural coherency for generations, it is highly probable that there emerge underlying configurations of behavioural patterns materialised and embodied by the spatial structure of its cities and buildings. However, when it is undergoing radical changes, the existing genotypical patterns would be influenced by socio-cultural or political changes as represented by the configurational transformation of yeoman farmhouses in Oxfordshire in English through 17th century (see Hanson, 1998: 56). Henry Glassie (1975) discussed about formal change of folk housing in Middle Virginia and suggested three phases of cultural change. The first phase is
‘balance’ where the society maintains the established pattern of culture without no serious challenge; the second phase is ‘change’ by the internal and external impact and it is subdivided into ‘disequilibrium – expansion – synthesis’; and the third ‘new balance’ where things are getting into the new status of equilibrium after the change. When we are lucky to investigate the built forms belonging to the first and third phases, it might be relatively easy to pin down culture-specific patterns of genotypes; but if they belong to the second phase of change, it will not be a simple task to reveal what could be a meaningful spatial manifestation of the social norm of that time. Hillier perfectly pointed out this circumstance and suggested ‘generative mode’ of spatial configuration:

Where we find strong genotypes, we find them associated with strong rules of behaviour, because the form of the building is already a mapping of that behaviour. But when the social rules decay, or are no longer enforced, then the spatial configuration reverts to the generative mode. (Hillier, 2004: 304)

In Malaysia, through centuries, typical forms of vernacular houses have been evolved to adapt to the regional climate with their own unique spatial layout. This ‘balance’ has been challenged when the country began to be urbanised in an unprecedented speed after 1970s. As the cities become more populated without enough land to build houses, multi-level collective housing became the most appealing solution for the government and developers. From luxurious condominiums to cheap low-cost housing, empty plots in major cities in Malaysia are now filled with highrise apartment blocks. Without enough time to test its adaptability in the market, this new housing typology was randomly designed and quickly constructed, and as a result, a huge amount of reports have been made by private and public sector that indicate how ill-planned and unsuitable they were to meet the demand of the people. This dissatisfaction is much bigger for the dwellers in the low-income housing which typically has limited floor areas with lower quality of construction standard. To cope with this issue, we have developed an apartment house prototype that will make a completely different approach to the problem. It is an incremental self-build house, of which the basic structural frame is provided first and further fit-outs are implemented later by residents. It is based on ‘open building’ concept where structural frame and internal infills are intentionally separated to facilitate layout changes by users. With no fixed configuration, this housing scheme encourages dwellers to decide where to allocate doors, partitions and windows within the floor area of 65 square metres. Our intention is to allow people to choose their domestic behavioural patterns and through the process of post-occupancy evaluation, we can indentify statistically meaningful spatial configuration which might be labelled as emerging genotypes in the modern apartment housing that has potential to be regenerated for better satisfaction of living conditions for the low-income population in Malaysia.

If Hillier and Hanson’s original approach was ‘archaeological’ in the sense it emphasises the possibility of genotype retrieval from artefacts of the past, our approach is ‘procedural’ to acknowledge the fast-changing trend in the market and to embrace the temporality of users’ changing preferences in our search for the candidates for modern genotypes.

2. MALAYSIAN CONTEXT

The tropical climate in Malaysia influenced the indigenous house form. Due to the humid monsoon season, the traditional house has developed the timber-frame structure elevated on piles. Malaysian housing culture has gone through a radical change during the last half of the twentieth century. With fast-rising numbers in the indexes of population, industrialisation, urbanisation, and gross domestic product (GDP) per capita, the mainstream housing culture has moved from the traditional floor-sitting culture in a detached house towards modern furniture-based living in a collective housing. As the proportion of urban population has increased from 26.8% in 1970 to 61.8% in 2000, it became a major goal for the Malaysian government and local authorities to build as many affordable houses to cope with a housing shortage problem in cities. The Public Low-Cost Housing Programme (PLCH) from the First Malaysia Plan (1970-75) clearly notes that the programme is ‘to improve the quality of life, eradicate poverty
among the low-income group and to resettle the urban squatters’ (Mohit, 2010). In urban areas, due to the high land price, both the public and private sectors opted for a higher density type: apartment housing. In particular, for the low-cost housing developments, which should comply with the regulation of ‘less than RM 25,000 of unit price’, the high-rise would be the only feasible option. The 2010 population and housing census shows that apartment housing occupies 19.9% in the whole country, but when Kuala Lumpur is taken alone, its proportion goes up to 66.6% (Department of Statistics Malaysia, 2010). Those who were accommodated in the apartments were not only from rural areas outside the city but from squatter settlements within the metropolitan area. In any case, adapting their family life to the new multi-storey dwelling was a significant challenge for them, disrupting their existing routines. It has been reported that the main issues of dissatisfaction in low-cost highrise apartments are cleanliness, community breakdown by racial conflict, small unit size, inadequate facilities, crime and social ills, and inability to allow home-based business (Aziz, 2012). Amongst these, from the designers’ perspective, we are more interested in two particular issues: small unit size and inability to allow home-based business. The new housing is smaller than their former squatter homes and thus typically called ‘pigeon holes’ and ‘chicken coops’ by dwellers (Ali, 1998; Yeoh, 2001; Bunnell, 2002; Suffian, 2009). For low income families, home is not only for living but needs to be used to generate income by allowing proper spaces for home-based enterprises for those who want to work but cannot leave their homes (Aziz, 2012).

In developing the low-income housing, we examined the way Malay people live in their traditional setting. Although life styles have changed, there are things that still have significance in the modern life style. First, there is a unique way of treating the level of the floor in Malay houses. Traditionally, the front living area was elevated by taller stilts while the cooking and dining area was positioned lower, and this practice continues even in modern vernacular houses (Figure 2).

It is based on the distinction between the served space which is formal and clean and the serving space which is dirty and informal (Seo, 2015). In principle, any space that belongs to the former is elevated while those to the latter are lowered. Thus even in modern apartment houses, we can find that bedrooms, living rooms and formal dining rooms are typically positioned higher while toilets, bathrooms, kitchens and balconies are lowered at least a few centimeters in their level of the floor. Second, along with the distinction between the formal front and the informal back, traditional houses had two entrance doors as in figure 2. In their hierarchical spatial setting, it could have been more effective to have two separate entrances rather than one. Although this has almost disappeared in modern apartments, many high-end flats still provide two entrance doors; one for residents and the other for servants. Third, Traditional Malay houses were not
constructed all at the same time. Once you build the main structure of living house, it was gradually growing by adding additional spaces. So basically the housing has the characteristics of incremental growth following people's demand and family sizes. In developing our design scheme, these three indigenous traits were examined and applied. As the main complaints of apartment residents are attributed to the sudden and radical change in domestic environment, it was considered to implant these elements to the new home design.

3. OPEN BUILDING AND INCREMENTAL CONSTRUCTION

The issue of providing spatial flexibility has at least a half-century long history. It has been constantly discussed throughout the second half of the twentieth century. On a small scale, it could be applied to a single house level by providing movable partitions as in Schröder house and on a bigger scale to a mass construction level by utilizing the frame/infill concept as represented by SAR method. When we use the term ‘open building’ however, it includes more comprehensive meanings that surround the issue of flexibility. It means that the process of construction permits at many different levels a possibility of architectural intervention or participation of users or experts. Standardized multi-unit housing typically has a limit in allowing a wide spectrum of lives due to its small number of unit types, but open building can offer more configurational freedom to residents. Our strategy aims to increase the resilience to cope with future transformation of domestic layout but without sacrificing too much of efficiency by modularising the demountable components.

The most critical problem of low-income housing in Malaysia is its affordability for poorer people. Although the ceiling price has been set by the government, many low income families cannot secure the amount of money to buy it. For the government and local authority, it is also difficult to fund the low income housing more than they do now. We aim to solve this social problem by adding the time dimension to open building construction with the name ‘Incremental SI (structure-infill) housing. It is the housing supply system where structure is built first with reduced amount of budget, and infill is added later in an increment manner. Unlike normal open building construction, this allows the bare structure of the first phase construction to be utilised as a basic shelter, and in the following phases, those who moved in can participate in the incremental construction of their homes. By splitting the total construction into smaller manageable volumes, it is expected that the local authority can initiate the development with less risk and financial burden within a limited timeframe. As the nature of house is ‘incremental’, those who moved in can also have flexibility of handling and managing their construction plan, based on their own financial status.

The concept of incremental construction is not new. In many developing and developed countries, this kind of participatory housing development has been experimented. There are expected gains by implementing incremental housing. First, by adopting support approach rather than supply approach, the quantity of low-income dwellings can be increased. Second, government can share the cost of development with households. Third, the managemental communication between authorities, communities and participants can be made more efficient. Fourth, it can reduce uncontrolled, low density urban sprawl and encourage high density, compact development. Fifth, through the engagement of households and community leaders, a good governance can be established. Sixth, local communities are strengthened, job opportunities are created, and household incomes are increased; curing social conflict and anti-social behavior (Turner and Wakely, 2015). In spite of these potential benefits, many attempts have been failed due to the malfunction or dissatisfaction in delivery, finance, location, and maintenance.

In our research, we decided to put the issues of the delivery and finances aside because our goal was to suggest a new design solution. We targeted the area of urban squatters as potential sites and investigated a possible solution that is more livable and affordable and also adaptable to poorer people’s needs. In the viewpoint of building as an asset, it has been observed that the typical reason of failure in the development of incremental housing is the deterioration of built environment by using varying non-standard materials by non-professional workers (Hassan
et al, 2015). Thus we attempted to provide certain level of building quality by obligating the use of standard component, i.e. windows, partitions and doors. In the following section, it is suggested how we conceptualized the design approach and how we solved the problem of incremental construction, flexibility, sustainability, and quality control.

4. DESIGN CONCEPT AND BASIC PLANS

Looking at the old precedents of housing around the world, one can find that the rooms are generally multi-functional, and activities in a room can be transferred to others without much conflict. This can be best exemplified by Palladian villas where each room has plural number of access openings leading to other rooms, not to a mediating space for movement, i.e. corridor or a central hall. When a row of rooms are directly connected sequentially like this, it makes a spatial configuration known as a ‘room-to-room enfilade’. It is suggested here that this enfilade is an effective spatial device that can generate an enhanced degree of flexibility in space use as in Palladian villas. When two rooms of similar sizes are placed next to each other and directly accessed, they could support each other by accommodating similar activities when needed. When three rooms of comparable sizes are directly attached and accessed in a row, the room in the middle can support the two in each end. In this case, due to its innate ambiguity, the middle room can provide a higher degree of adaptability. The central room can either support or interchange activities with other rooms, or act merely as a buffering zone in-between. This is how an enfilade of rooms operates for functional flexibility. If the room-to-room enfilade makes a ring-shaped spatial structure that can allow an unending circular movement, then the freedom of movement and activity allocation are maximized as in Palladian villas. In the modern house, however, the ring structure is hard to be realised. This is because the modern house, especially the apartment houses are becoming a compact unit of functional container where the movement optimisation and space efficiency are encouraged by making the whole configuration linked by central halls or corridors. Another reason is the ever growing number of furniture that requires more wall surfaces rather than openings. In the typical configuration of the modern apartment unit, each functional space becomes a dead end, accessed from the central corridor or hall, allowing no interchangeability of functions. By actively providing access links to neighbouring rooms, the ring structure can be regained to induce polyvalency of function.

With the spatial strategy described above, a multi-storey walk-up apartment housing was planned (figure 3). The Incremental Housing adopted a slab block shape for its building form where units are linearly added side by side. For vertical access, communal staircases are inserted between two flat units at each floor. Reinforced concrete structure makes the basic skeleton of the whole building and each unit has six rooms that are spatially open to each other. The unit is entered by two entrances that are positioned on different levels of landing, where the second entrance is 900mm higher than the first. The unit floor plan has three horizontal zones and three vertical zones. Vertically, those rooms in the deepest side is named ‘shelter zone’ because it will be the initial living area when residents first move in. At the first phase of construction, the very basic fit-out will be provided in this zone and other zones will be left as bare skeleton for future growth. The second vertical zone is ‘incremental zone’ which is gradually filled in or fit-out in the later stages. Horizontally, the top row is ‘wet zone’ which has -200mm level of floor from the main living space. This is the zone to accommodate bathrooms, toilets, and other service spaces such as balconies for wet or dirty activities. The middle row is the ‘lower zone’(±0). It is named so in relation to the ‘upper zone’ which is +900mm higher. This upper zone and lower zone split the living area into two just as in the traditional Malay house where formal living zone is typically elevated higher than the informal dining and cooking area. It is this reason that two entrances are positioned on different levels to provide direct access to the lower and upper zone.
When the first phase construction is completed, the shelter zone will be fit-out by using the standardised components in figure 4. These components are basically variations from the same sized module of 1,000 x 2,700mm and functions for windows, doors and partitions. Having the same size and joint details, these three components can be attached and detached from their positions and interchangeable. This will allow the change of links to other rooms and therefore convert the overall configuration easily even after the occupation. Starting from the basic house, the unit can grow to occupy the whole floor to become a fully grown house, or depending on residents needs, some rooms can be left as exterior space for other functions such as home-based enterprises or a large balcony space. During the process of this expansion, more components would be required to fill in additional openings. The additional cost for more components and other finishing materials can be earned while users are living in the basic house and spent when additions are needed. Moreover, there is a potential of the local community’s involvement in manufacturing the whole or parts of the component, if we consider the low-tech design of the component, to generate their own income to meet the incremental construction cost. Figure 5 shows the basic house on the left side and the fully-grown house on the right. By changing the opening and closing of the access pattern, a large number of unit variations can be made. Since the house has two entrance doors, it is even possible to split the house into two smaller houses of which are inter-connected or completely separated.
5. VARIATIONS AND SYNTACTIC ANALYSIS

The base frame of the incremental housing is made of reinforced concrete which is a most common practice in Malaysia. Before it gets filled in by brick masonry and components to set up internal room divisions, the arrangement of six rooms are open to all adjacent rooms like Palladian villas. With this initial condition of open structural frame, the plan enables maximum permeability. The justified format of graph representation will make it easier to identify its embedded spatial connectedness (left in figure 6). The alphabet label in each node came from figure 3. The graph has three small rings but counting all nested ones in it, there are a total of six small and large rings in the configuration. Having multiple rings, it has a potential to allow a variety of possible layout by closing and opening the accessibility. Theoretically, the lowest depth will be 3 when all openings are maintained open while the deepest depth is 6 when all rooms are linearly connected as in figure 6.
This base frame is an initial condition of the skeleton of the house. Having maximum configurational freedom, users will experiment and choose their own solution that fits to their life style. With enough sample size of housing units, this can be a real-time process of finding new spatial patterns embedded in their invention of layout of which the most frequently-used ones can be candidates for ‘modern genotypes’. To find out how variously the basic frame can be developed into different solutions, we simulated some representative types of layouts (figure 7).

Figure 7 - Examples of possible variations from the base frame (copyright: Kyung W Seo, 2016)
The variations are not exhaustive but show a small number of possible solutions. The first several variations have smaller houses yet with open yard spaces to satisfy low-income people’s needs to raise household stocks or to run home-based businesses. Moving towards later versions of variations, the base frame is gradually filled in to become fully grown houses packed with functional rooms. It is recognisable that variant 01 and 24 are actually the two representative plans in figure 5, the former as a basic house and the latter a fully-grown house. They are perhaps positioned in two extreme ends in the whole spectrum of possible variations. Now some notable plans are converted to j-graph format to further investigate spatial properties (figure 8).

It is found that graph patterns do not exhibit similar distribution at all. Variant 01, 02, 04 and 06 have un-enclosed yard spaces with multiple rings but this does not seem to influence the overall depth of the system. Most of the graphs have depths of 4 which is between the theoretical minimum and maximum of 3 and 6. With many graphs sharing a branching-out pattern, variant 14 has the deepest structure with the terrace at depth 5 while variant 24 has shallower structure. This is a small amount of sample plans but still shows the power of an open plan, enabling a wide variety of configurational possibilities. When similar functions are colour coded, there emerges a strong tendency of clustering. The yellow indicates living and circulation spaces that are unexceptionally located adjacent to the exterior or entrances and make strong connection with other yellow spaces; thus always exist in a single cluster. The blue indicates wet spaces, i.e. bathroom, toilet, kitchen and drying yard which is the typical semi-open utility room in Malaysia for washing machine and drying laundry. Due to the zoning concept of the base frame, these wet spaces are naturally clustered in the wet zone on one end of the floor plan, and as a result, they tend to make a cluster or at least locate themselves at the end of branches of the graph. Finally, the red indicates bedrooms. As expected, they are all positioned at the end of branches as separate islands. Overall, it can be said that the configuration of this open plan is decided by
locating living and circulation spaces together as a single cluster at the lowest part of the graph; followed by wet spaces at deeper levels; and finally distributing individual cells of bedrooms at the end of appropriate branches. It is visually clear that the living and circulation spaces are in the most integrated positions in the house while wet spaces the most segregated positions; and bedrooms in varying positions yet as separate cells. Obviously, the base frame of the house seems to have some internal configurational restrictions, generating repeating patterns of clustering and distribution of functional rooms. However, it is striking at the same time that this simple geometry of 2x3 room layout has such a potential to generate uncountable number of different types of floor plans. Undoubtedly, this unit variations out of a single base frame is possible due to the open plan with room-to-room enfilade and rings that are two essential spatial devices for the configurational freedom as discussed in section 4.

6. CONCLUSION: HOUSING AS A TOOLKIT FOR MASS CUSTOMISATION

We have targeted urban squatter area to apply our design solution. It is the area stigmatised as an urban ill and the government and local authorities want to remove and build new high-rise apartments. It has been pointed out by many researches that apartments are not conforming to the needs of low-income people and creating other problems for the city. We saw the most critical problem of the mass housing from the design aspects that do not fit to the local domestic behaviors and suggested a new solution to it. The design intention of the incremental housing is to provide a base frame of dwelling that reflects Malaysian context, yet allow users’ individual preferences. Inherited with the vernacular wisdom of level-distinction, two entrances and yards, and adapting them to the modern concept of open building for the interchangeability of activities and configurational freedom, the incremental housing can be an appropriate solution for those who need affordable yet livable homes. Moreover, the incremental housing actively utilises the sustainable tradition of vernacular Malay housing which transforms and grows in time in relation to the family size and needs. This is a time-based thinking that regards the house not as a frozen mould to regulate domestic behavior but as an open field for endless spatial exploration. Eventually, this will lead us to question what genotypes really mean in the future of architecture. Architects’ role then will be to provide a toolkit by which users can continue to exercise new way of living and unconsciously engender statistically meaningful spatial structures in their collective efforts. A house in this way will become a configuration generator.

ACKNOWLEDGEMENTS

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ABSTRACT

Architectural design is a sophisticated process that advances from abstract thought to concrete design. In this process, the designed product is shaped and impacted by the unique experiences, observations, perceptions and characteristics of the designer, while the design work of the architects develops through the utilization of various design tools and the designer’s own architectural knowledge, one that is fed from a variety of disciplines and fields. It is this scientific knowledge that directs the innate intuitions of the designer. This ‘evidence-based design” approach is thus an attempt to bring science based knowledge into design.

This study focuses on the contribution of scientific knowledge in the architectural design process and explores the potentials and advantages provided by using space syntax as a tool in this complex design process. The aim of this work is intended to serve as a decoding of the invisible characteristics of space by focusing on the configurational theory of space.

To undertake this work, we established a three-staged design workshop as a means to evaluate the potentials of space syntax in the design process. Workshop participants (five architects and one interior designer) were given a design problem and this problem was examined during one-to-one meetings with the participants. Workshop participants were asked to design a living space for a specific site and with predetermined proportions. The workshop was divided into three stages. In the first stage the designer was asked to consider some issues related to life in a residence and the design of living spaces. In the second stage, the designer was asked to specify a set of home design relationships within a concept/action set, which includes residence-based activities (living, cooking, etc.), spaces (garden, balcony, etc.), measurable parameters (sound, light, etc.), and concepts (visibility, privacy, etc.). The third stage of the workshop focused on the space-making process. During this stage, the designers were expected to create a living space that reflected his/her design concepts. At the completion of these three stages, syntactic analyses were carried out on the designed spaces. In these analyses, the spatiality of the designer’s preferences was explored and the potentials of designed spaces were discussed.

The findings of the study showed that space syntax succeeds in creating a link between science and design by transferring science-based knowledge into design process and produces graphical and mathematical data that the designer can use in testing his/her design proposals.

KEYWORDS

Architectural design process, design tools, design and science, space syntax
1. INTRODUCTION

Architectural design is the process of transforming abstract design ideas into physical spatial installations. Lawson tells us that the meanings inherent in the word “design” vary according to different career groups and its only common point is that it is a distinctive and complex activity (Lawson, 1997). For example, while scientists adopt a problem-oriented strategy during their development of a design process, architects adopt a strategy that is solution-oriented. Architects reflect the experience they gained in the construction of their design solutions. In architectural design, art, science and technical practice are intrinsically intertwined and serve as elements that are indispensable to architectural design. Utilizing such elements that differentiate architecture from other design domains and make it even more complex as a springboard for thinking and acting actually constitutes architecture that materializes while it is being fed from its scientific streams.

Vries and Wagger (1989) identified three problematic points in the architectural design process. The first issue is the fact that the number, order or timing of processes or tools used in every stage of design are open to change. The second is the fact that architectural design is open-rather than close-ended. The third is that architectural designs do not have a specific starting point. In this context, design is devoid of a clear sequence of phases that needs to be followed. The process thus becomes quite unique and exclusive to the designer. The originality of the architect and the world of suggested alternatives enable the architectural product to also be original.

The design process is a matter of synthesis of physical and mental behaviour. This process is also marked by the fact that it includes the kinds of physical and mental tools that mutually trigger and shape behaviour.

When we speak of an architectural design tool we are actually talking about a set of methods, tools, mechanisms, and apparatuses that assist in transforming the design idea from one mental state into another. The designer uses these tools in the thinking process and so such tools are not limited to the kinds of physical objects we used only while designing the ideas that were first conceived in our minds (Şişman, 2015). Another critical point is the fact that utilization of the defined tools or vessels is not hierarchical. And, as it is not hierarchical, any given tool can also be involved in a process more than once. The utilization of a tool depends on the uniqueness of the subject and how it is especially reflected onto the design product. Any tool may come into play based on the designer’s wishes or the prerequisites inherent in the specific design, while it is also possible that while the tool is included in the design, its use is based on almost intuitive forces.

According to Hiller and Hanson, design is a process that moves from an unknown state into one that is known (Hiller and Hanson, 1997). Design tools mentioned here allow the production of information to be included in the design, along with thought processes during both the design process and the testing of the design solution. The tools used by the architect help the architect to gain access to information, transform it, and guide the design. This interaction between the tool and the designer is not unilateral, but is rather mutual and circular. This interaction is also mutually interacting and transforming.

In this sense, the architect becomes an actor who uses different goals and methods in the design process, integrating different sources of information, and thus enriching the design idea by transforming it. Not only does the personal view, character, intuitions, experience, and authenticity of the architect ensure that the architectural product will be original and free, the design process is also fed by theory, science, and research-oriented universal information.

In other words, architecture is a practice of “thinking by doing” led by data from different sources and different types of information in which intuition and science is brought together (Dursun, 2007). Information is required during each phase if this architectural product is to succeed in moving through design, production, and utilization phases, for it is information that leads the design, shapes the product, and is reproduced and reshaped for each design problem that rises during the process.
In the design process the architect is accompanied by his or her own architectural knowledge, and it is precisely this base of information that serves as the synthesis of practice and scientific theories. The intuition and reason that shape this body of knowledge and guide the architectural design process are locked into a dialectic relationship. According to Hiller and Hanson, design is the process of integrating intuition and reasoning (Hiller and Hanson, 1997). Scientific information that comes into play in the design process enlightens the designer and guides the designer’s intuition. “Evidence-based design” is thus an example of utilizing scientific data in design (Şişman, 2015).

The architectural design process is a conscious activity, one that combines the mind, which is reason, and intuition, and does so in conjunction with each other. Aydınli (2001) describes the relationship between intuition and reason as:

“Architectural training may impart two different categories of information packages, each in two different categories. While their desired relationships may be understood, the implementation of these two disparate sets may reflect certain challenges, challenges that lie in the kind of overlapping information acquired via reason or in information acquired via intuition. The designer has to decide how to maintain these two sets as they are intertwined, rather than allowing them to coexist simultaneously. In fact, immutable and rational information supports and enlivens the kind of information that flows from intuition and which is itself variable depending on the context.” (Aydınli, 2001).

A design that accords with scientific knowledge is stronger as it is supported by reliable sources. Evidence-based design is the term used for the common methodology that best enables scientific information to be transferred into design process. Hanson emphasizes that any socially responsible architectural design effort must be supported by evidence-based research (Hanson, 2001).

Post-occupancy evaluation represents an effort to analyse the true performance of a building after it has been put into use; such an evaluation, if it is conducted according to scientific principles, is a significant step as it provides valuable feedback to professionals about the design and also adds to a body of data that will aid the architect in the making of future design decisions. While this is true, we also have to point out that post-use evaluation efforts focus on the post design process, not the design process itself. Such an analysis does not evaluate the design per se, but rather the end-product utilization of the design itself.

Although the architect envisions the space as a living organism during the design process and uses his or her personal experiences to conceive of it in terms of human utilization, the designer has no real way of testing its human dimensions before the design is produced and utilized. In other words, even though physical representative tests may be conducted, and mental configurations construed during the design process, the end result is a construct that is built without human trial. It is at this confluence that the designer feels the need for methods and tools that will allow him or her to test the design suggestions (Şişman, 2015).

Because space syntax is a theory developed to reveal the kinds of spatial features hidden in spatial patterns, it has the aims of deciphering both the relational structure of the space and performing as an approach that includes scientific, digital and graphic-based methods (Hillier and Hanson, 1984; Hillier, 1996). It is precisely for these reasons that it has been chosen as the focus of our discussion. Hiller (2005) further expounded on space syntax by saying that models formed by this methodology reveal phenomenological dimensions about the space that can be scientifically tested and such models function as a bridge between humans and science based viewpoints. Space syntax with the theory and spatial measurement tools it presents allows us to delve not only into the visible but also allows us to uncover the kinds of hidden meanings that decipher the social meanings coded in that space. Another important aspect of space syntax is that it focuses both on human behaviour and the relational network of a meronymy (Kozikoğlu and Dursun, 2015).

Analyses of space syntax demonstrate that it can be used to analyse current spatial constructs in building and urban scale, and to test design suggestions (Dursun, 2007). Space syntax is
very frequently used in building renewal processes during developing the design decision or restructuring public spaces in urban interventions (Şişman, 2015). In this study, the potential for using space syntax in the design process is discussed. This work also asks whether the above-mentioned approach can be used as a scientific design tool that feeds the design process by helping the designer to test the design suggestion.

2. DATASETS AND METHODS

This study evaluates workshop sessions held to shed light on the potentials of space syntax as a design tool that can be used from the first stages of design process onwards (Şişman, 2015). Analyses of this workshop set, which includes architect participants, focuses on questions as to whether space syntax has, or does not have, the potential to be used in architectural design through a design process based on a designated design problem. Thus, the study aims to investigate whether this approach can test the architect’s own design through the numerical, comparable, tangible data this approach has produced and can help, or not help, the transfer of scientific information into the design.

In the conducting of the study, a designated workshop design problem is discussed with the participants through one-on-one interviews held with each designer. This design problem is specified as a living space design with both specific design concepts and located in a determined area. Instead of building a design for an imaginary parcel of land where the designer can determine all relationships, priorities and requests, the designer is asked to shape a living space in a specific area to test to what degree priorities can be reflected within the design. This area is specified as a 16 x 5 m parcel of land with two blind sides, one facade overlooking the sea, and the other facade onto the street.

The interviews with designers were held in three steps. The first step looked for answers to questions about the house itself, such as, “Which main concepts / components do you think life in this house is built on? What can you say about the concepts required in the design of this living space?” The answers were recorded for a limited time frame (5 minutes). The goal here is to obtain a description of the preferences and approaches established by the designer based on the individual characteristics and priorities of the designers prior to having received any guidance. This stage was transcribed so as to later reveal the designer’s own words and emphasized concepts.

In the second step the designer was asked to determine the network structures he/she wanted to create within a set of concepts / actions (Figure 1). Current concepts / actions were listed as follows; (relationship with outdoor space; publicity; privacy; light; safety; compactness; depth; sound; hierarchy; visibility; accessibility; work; entertainment; balcony/terrace; eating; living; cleaning, garden; entrance; sleeping; circulation; cooking). The designer was allowed to intervene with the mentioned concept / action set; the designer could also inject new additions and suggestions into the given set. During this workshop step, the preferred “direct relationships” were determined by connecting the dots representing concepts / actions set placed on a sheet with the help of a rope. This investigation primarily revealed the structures similar to shaped networks, structures that had certain potentials in terms of specified concept, actions and relationships. Syntactic analysis was used to analyse these network-like structures created in accordance with concepts/actions during the entire workshop. How these deciphered potentials are transferred into the design and the designer’s awareness of this process was discussed during the design stage.

The third step focused on the design practice. The network structures established in the previous step is expected to be reflected upon the design in this step. How the design of the house accords with the specified features of the building lot becomes significant at this step. The analysis also looked at the degree to which the designers’ preferences were spatialized. During this step, a syntactic analysis was conducted on the designed spatial constructs so that the potentials of designed spaces could be established for discussion.
As previously mentioned, a one-on-one interview was conducted as a chain of three steps. Six designers were interviewed during this workshop. The participants consisted of architects with academic and professional backgrounds and with an undergraduate or post graduate degree in architectural design / architecture, and post graduate students majoring in architectural design. Five of the designers have a background in architecture, and one in interior design.

At each step of the workshop, the focus of the data gathered and the analysis conducted were specific to the interviews. At the completion of all steps, the body of data from all interviews was evaluated and subjected to comparative and contrasting interpretations. The concepts and words emphasized by the designer that were revealed in the transcription of the interview held in the first step were identified as keywords, and in the second step network-like models defined through concept / action sets were analysed. Jass and Syntax 2D software were used for the syntactic analysis applied in the transcription of designed house. The spatial analysis applied on justified graphs was complemented by visibility graph analysis on isovist graphs. Figure 2 provides the plans for the living spaces designed in the workshop.

![Figure 1 - Relationship Network Creations (red words are new additions)](#)

![Figure 2 - Designed House Plans](#)
The street was taken as the point of origin in the drawing of the justified graphs for the syntactic analysis to be applied to such spaces. Outdoor spaces such as entrance, front yard, back yard, terrace, and balcony are shown as convex spaces in the spatial construct to appear in the justified graph. Staircases are represented as convex space allowing transition between floors. Justified graphs show the in-depth values of the space (Figure 3).

Figure 3 - Justified graphs of designed houses

Isovist graphs with inherited isovist integration values were established for each floor. The darkest red in the graphs represents the most visually integrated, in other words most visible spaces in the area, while the visual integration value decreases in the colour code moving from red to blue, which represents the least integrated spaces (Figure 4).

Figure 4 - Isovist visibility graphs of designed houses

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The evaluation of the interviews procedures included superimposed interpretations of all stages:

1. Transcription of the designers’ own verbal expression in the first step;
2. Establishment of network-like models defined through concept / action sets and their analyses in the second step;
3. Design of the houses and syntactic analyses run on the space in the third step.

3. RESULTS

This section includes a comparative evaluation of the data collected in three steps through the workshop.

Parameters emphasized throughout the verbal expression transcriptions in the first step are user-oriented; concepts such as an individual’s needs, habits, activities and feelings, comfort / functionality etc. are emphasized to be significant in the interviews. While two designers emphasized occupancy rate (2nd and 6th designer) and privacy (5th and 6th designer), the designers independently also emphasized concepts such as aesthetics (1st designer) / space scenario (2nd designer) / ergonomics (3rd designer) / heating and insulation (4th designer) / harmony (5th designer) / flexibility (6th designer) / communication (6th designer) (Figure 5).

Figure 5 - Analysis of Total Data
In addition to the available components in the network structures determined in the second step, five designers added nine concepts (aesthetics / comfort-individuality / heating-ventilation / harmony-context-feeling / flexibility), while one designer built relationships between the given components without adding any other. As any one component has a higher number of connections in the network structures than the other components, it also gains prominence in the relational structure. These integrated (3-4-5 times connected) components / concepts (most integrated spatial concepts) in the network similar to spatial analysis lined up as follows;

1. Network table: living (4), accessibility (4);
2. Network table: relationship with outdoor space (4), privacy (4), living (3);
3. Network table: relationship with outdoor space (3);
4. Network table: (all connections have 2 and 1 connected concept/component);
5. Network table: privacy (4), living (4), eating (3);

‘Living’ can be interpreted as a significant common component as it has 4 connections in three network tables, 2 in two network tables, and 3 in one network table. This allows us to conclude that this concept is situated at the centre of the housing space. ‘Privacy,’ ‘relationship with outdoor space,’ and ‘eating’ are integrated components in two different network tables, while ‘accessibility’ in the 1st network table and ‘compactness’ in the 6th network table are particularly integrated components.

Examination of the plans of the designed houses in third step demonstrate that houses numbered 1, 2, 3 and 6 are designed to be two story, and houses numbered 4 and 5 are three-storied (Figure 5). As a larger percentage of the lot in houses numbered 1, 2, 3 and 5 are used as indoor space, the percentage of indoor and outdoor spaces in the whole lot in houses numbered 4 and 6 are quite similar. Outdoor space used in houses numbered 1, 2, 3 and 6 are shaped to be ground and balcony/terrace in the upper floor; only house number 4 has a ground level garden, while house 5 has a terrace and winter garden on the second floor.

An analysis of the syntactic data of the designed houses reveals that the maximum number of spaces in the house is 18 (house 5) while the minimum space number is 12 (house 3) (Table 1). The average number of spaces in these houses designed to be on the same lot is 14.16. The average ratio value of number of spaces to the number of spatial relationship as stated in the justified graphs is 0.95. If this value calculated by the ratio of the number of spaces over number of connections of the space is different than 1 it means that the particular house has a circular structure (Hiller and others 1987a). House 1 (0.86), house 5 (0.94) and house 6 (0.92) are the ones with circular structures creating alternative routes in the space.

As seen in Table 1, the depth values in the designed houses vary between 5 and 7. Justified graphs are created by including outdoor spaces into the system as a convex space and enabling the connection between floors through stairs. As the street is taken to be the origin, accessibility is analysed when outdoor space is included in the house, depth and integration values are also analysed.
Table 1 - Syntactic data of the designed houses

The average integration values of the houses (RA) vary between 0.35 and 0.55. House 1 with the nearest average integration value to ‘0’ is seen to be the most integrated house and house 2 with the nearest integration value to ‘1’ is seen to be the most dissociated house.

Table 2 - Integration ranking order of the spaces in designed houses

The visibility graph analysis of the designed houses shows the following results for integration values: As House 1 has the highest, ground-level entrance hall, its lowest is in the WCs on the upper floor. In House 2 passage axes have the highest values bathroom and WC on the upper floor have the lowest. In house 3, as the connection between ground level entrance hall and living space has the highest value, it is reduced to the lowest in the kitchen and the WC on ground level. In house 4 the value is the highest in the ground level eating section, while it is the lowest in the kitchen and WCs. In house 5 the value is the highest in the ground level living space, the office and the WC, the bedroom workshop and WC on the upper floor and the WC on the second floor have the lowest values. In house 6 the value is the highest at the connection point of hall-living space-garden on ground level while the master WC and dressing room are the spaces with the lowest values.
Integration value ranking for the accessibility of designed houses can be seen in Table 2. Generally, halls and staircases appear to be the integrated spaces with low values as the spaces that have access to such spaces seem to have integration values lower than the average. Spaces with higher depths that are accessed directly rather than through passage points such as the garden, balcony, terrace and WCs are located in the bedrooms appear to be most dissociated spaces having values.

The intent of the first design is to achieve a design that is user-centred and focuses on such concepts of aesthetics and comfort that emphasize life and accessibility. The syntactic analysis of this design reveals that life and visible accessibility are achieved in the ground and upper floors. The designer, whose intent is to locate such activities as sleeping and personal hygiene in private and secure spaces has located these spaces in the deepest areas, thus achieving the goals set. The intent of the second design is to achieve a user-centred design focusing on space scenario, individuality and comfort so as to emphasize privacy and user relationship with outdoor space and living. The syntactic analysis reveals that the attempt was to achieve privacy via passage between spaces. The intent of the third design is to create a design that focuses on ergonomics, living space, user and user's needs so as to emphasize the relationship with outdoor space. The most integrated space in the isovist visibility graphs visually is the living space. The designer, who associates outdoor space with privacy, fulfilled this intention by choosing the deepest areas for the outdoor space. The intent of the fourth design is to create a design focusing on comfort, spaciousness and functionality so as to emphasize heating and ventilation. While the first and second steps demonstrated an emphasis on the relationship between eating and cooking, the visual integration values of locations chosen by the designer for these actions differ from each other and these spaces are located far from each other. This contradiction leads us to acknowledge that the designer could not achieve his/her goal. The intent of the fifth design is to create a design focusing on such concepts as humans, privacy, habits, feeling, harmony and context so as to emphasize privacy, living and eating. Stairs used at the entrance increased depth providing privacy between the street and the house. The positioning of the outdoor spaces on the top floor of the three-story building, in other words in the deepest locations dissociated from the system, can also mean that privacy is achieved in the indoor space construct. The relationships between eating, living, and cooking are observed to be integrated visually with outdoor space construct. The intent of the sixth design is to create a design focusing on humans, flexibility, communication and privacy so as to emphasize such components as compactness, eating and living. The concept of privacy is reflected on the design in the indoor space through the front yard design being between the street and the house and outdoor spaces positioned in higher depth locations. On the other hand, the food preparation, eating and living areas are designed as an open space, making this area one of the most integrated spaces in the whole, as the visibility graphs reveal. This shows that the intended communication is reflected onto the design.

4. CONCLUSIONS

This study has been conducted to investigate the usability of space syntax as a design tool methodology when included in the design process. Beyond deciphering the potential of construct designed in late stages of the design process, the potential of space syntax to be used as a tool in the first stages of the design is studied experimentally.

During interviews held during the workshop, architects were asked how they tested their designs. Designers’ methods to test their products include testing them through experience and knowledge, imagining, modelling and consulting others’ views as critiques. According to the given answers it is possible to say that design is tested primarily through intuition. Time constraints meant both that the designers could not be introduced to space syntax theory and its concepts, nor could they be allowed them to use such tools during the workshop. Syntactic reading/analysis on designed products by the authors reveal that space syntax methods offer significant potentials for the designers enabling them to comprehend the relationships between their goals and their designs, test their designs, predict the possible results of their design suggestions and comment on the spatial construct through numerical, scientific data
on designed spaces. Undoubtedly, conveying the mentioned data to the designer during early stages of the design will contribute to the development of the architectural product. In this sense, it seems valuable and possible from the early stages of the design onwards to include evidence-based, concrete, scientific, universal information into the design process by valorising it as an intellectual tool that can guide architects’ intuitions.

The analyses and space syntax evaluations allow us to unequivocally state that space syntax:

- Functions as a connection between science and design allowing scientific information to be transferred into the design process.
- Produces numerical, scientific data that allows the architect to test spatial constructs shaped showing the architect possible results of the design decisions made.
- Has potential to be a design tool that can be used in earlier stages of design.
REFERENCES


ABSTRACT

Floor plan retrieval for supporting design by suppliance of reference objects requires comparable information in understandable categories. Spatial properties of floor plans are objectively comparable, but hard to relate to subjectively perceived verbal demands toward a searched-for spatial configuration in a digital reference repository. In this paper, we will sketch a comprehensive methodological approach on filling this gap by presenting a prototype framework, which combines databases, responsive web interfaces, analysis measures and aggregation methods of all kinds, in order to conduct online surveys about icon allocations in floor plans. Participants allocate these icons, which are adjustable to any examined verbally stated meaning in floor plans. We aim at supporting previous studies like, e.g., Güney (2007), Hanson (1999), Seo (2004) and Monteiro (1997), by using a floor plan database that contains information about multiple local (e.g., ‘daylight factor’, ‘isovist properties’, ‘visibility graph’, ‘exterior view’) and relational (‘euclidian distance’, ‘walking distance’, ‘visual step depth’) spatial properties grid cell-wise for the usable interior area of floor plans. We developed this prototype framework in order to gain knowledge about (1) the behaviour, while participants operate on allocating icons in floor plans using the framework, (2) approaches towards the exploration of relationships between the assumed allocations and their spatial properties and (3) the method itself regarding its applicability and enhancements for future studies. As a use case, we exemplarily study how people allocate activities (‘Cooking’, ‘Eating’, ‘Hygiene’, ‘Leisure’, ‘Sleeping’, ‘Working’) in single-floored apartment units and whether certain patterns can be
detected, in order to show potential for the database application framework that we seek to develop. We asked 154 participants online to allocate expected user activities (represented by icons) in floor plan drawings of apartments (without furniture) via drag and drop, in order to determine afterwards, by which degree which kinds of spatial configurations meet the participants’ expectations towards the cultural code transported by the icon. Participants were advised to mark exactly the location where in their opinion the user would be situated ‘best’ while acting on an activity. Each participant saw three floor plans that were a priori categorized as (1) closed structured, (2) open structured, and (3) not supplying a separated space for each activity. In addition to the final allocations of the activity placements, the drag events done on the icons were stored and analysed. We concluded that the framework meets the expectations well, yet enhancements can be identified. The gathered data reflects on the expectations towards its characteristics well; and thus there is strong potential in implementing ‘fuzzy’ matching algorithms based on comparable studies in anticipation of the future environment of a case-based reasoning approach. Our long term objective is to fill a floor plan database containing geometries and analysis measures of floor plans, in order to supply a reference repository with ‘fuzzy’ retrieval approaches based on participants’ input data regarding allocations. Additional use cases can be found for design automatisation, support and decision making.

KEYWORDS
Activity Patterns, Space Usage, Spatial Properties, Online Research Tool, Floor Plan Retrieval

1. INTRODUCTION
The steadily increasing availability of web-technologies (such as databases and responsive interfaces in browser clients) provides numerous possibilities for the automatisation and support of research and spatial planning tasks (such as online surveys, design tools and floor plan repositories) and reaches many people worldwide. This article describes a prototypic framework that brings together database technology, web applications and spatial analysis methods in order to conduct web surveys on user allocations in floor plans.

The context of our former work on web technologies and their potential in the field of architecture (Triemer, 2014; Schneider, 2014) was the motivation for the work at hand. We previously aimed on the retrieval of reference objects from digital floor plan repositories, considering precalculated spatial properties of a floor plan’s geometry as ‘performance-based search criteria’. An often occurring demand towards a searched-for floor plan is to supply a specific room schedule like ‘small flat having two individual rooms, kitchen, two bathrooms ...’ or similar. However, not even an experienced user of such a design tool could manage to state such demands towards a searched-for reference object’s floor plan using spatial property measures as criterion intuitively. Thus we needed to offer additional criteria, which could help to translate these verbal demands to spatial property specifications. These specifications could be compared to the ones of spaces in the repository’s database and give back a fitness value for a ‘fuzzy’ search/matching or ranking algorithm. For this heuristic approach on floor plan retrieval we first need to understand, how a human confronted with a floor plan solves the same problem to think about where in a spatial configuration certain human activities are how likely to be carried out. Thereby, local (properties of the location where an activity is assumed) as well as relational spatial properties (physical and visual distance between the activity’s allocations) have to be taken into account.

Previous comparable studies that investigated relationships between spatial properties and user activities were often based on manually compiled large data collections about apartment units including time-consuming semi-automatic and thus non comprehensive spatial analysis (e.g. Monteiro, 1997; Hanson, 1998; Seo, 2004; Güney, 2007).

Monteiro (1997) gained data from 101 apartments that represented three types of homes (favela, public housing estate and middle class neighbourhood). The authors identified activities that
happen in these flats and compared the former by examining the mean integration and depth measures of activity allocations in the floor plans. A justified graph for every apartment had to be elaborated as the basis for further calculations. Justified graphs arrange functional spaces along a tree-like structure with the exterior as the root and thus visualize the permeability of floor plans (page 4). These functional spaces do not necessarily need to be equal to the physical closed spaces (rooms): Monteiro used convex space break-ups, which are defined in an ambiguous way, because their layout might vary by researchers’ judgement. Thus, a possible way to extend this study is to use a grid-based approach, calculate spatial and relational properties for each of these grid cells and relate them to as many different coexistent break-up layouts as are available.

Hanson (1998) aimed to “illustrate the complexity of human habitation and to suggest ways in which houses can carry cultural information in their material form and space configuration” (page 1). Consequences for the historic and contemporary lifestyle, popular taste and thus the relevance of spatial properties are worked out by discussing three different examples of ancient habitations as an introduction and afterwards showing recent work done on spatial analysis methods (page 49). Most approaches were dedicated to the justified graph method spectrum and visibility analysis, by means of the isovist (see figure 2) - here only for selected locations. Floor plan collections were managed partly by database technology.

Seo (2004) studied the evolution of habitation in Seoul by describing its emergence from the traditional Korean courtyard houses to contemporary serialized detached apartments. 75 examples from different periods were analyzed by utilizing the justified graph to compare integration. A special feature of Korean building culture is to differentiate between two ground levels: Seo (2004) identified clusters and the permanence of this separation principle dividing in “elevated clean space” and “earthen-floored dirty space” (80.1). This separation principle could also be handled as an allocation in a floor plan as supported by our framework.

Güney (2007) enhanced the concept of integration with measures for each grid cell and visibility analysis. By investigating 108 houses in Turkey, correlations between visual depth and integration were shown. Conclusively visual measurements were found to be more sensitive than permeability (page 1). She describes how depth and integration measures characterize the evolution of the apartments in subgroups per decade.

These four exemplary research projects have in common that they required sophisticated data collections about the spatial characteristics of apartments. Their analysis was time-consuming. User allocations in floor plans like the room usage were gathered by surveys. In some cases they were conducted in field, visiting investigated apartments and their users. This approach could have profited from using a mobile device for ascertainment. Furthermore, subgroupings in statistical operations on the compiled data were necessary in order to discover influences by comparing data sets. In other words: much effort was invested to obtain a limited spectrum of methods at once and data acquisition required complex management. We argue that we can use similar study concepts like the previous as basis for the implementation of an algorithm that is able to predict how likely a particular user activity will happen at a specific place in a floor plan. A derived algorithm from the gained knowledge could not only be applied for a matching factor for the retrieval of floor plans from reference repositories, but also for design validation and automatisation, decision-making and other improvements of the computer-aided design process, where heuristics are needed. The prototypic framework will be applicable to various comparable research tasks - not just on activities, but on anything, that could be marked by allocating an icon (from furniture, building technology and day time to proceedings or scents).

Hence, the main objectives of this article are to gather knowledge about

1. the way participants operate on allocating icons at a certain location (2d-space),
2. the possible approaches towards heuristics regarding the assumed allocations and spatial properties of the floor plans’ geometry,
3. the study concept itself regarding its practicability and flexibility for future studies and the extension of our framework found.
For these objectives, we developed a prototype framework that supports publishing similar surveys as in the outlined previous research, but makes the technical requirements more accessible for researchers by combining database technology, responsive web interfaces and spatial analysis. On this basis we will conduct an economical exemplary survey on activity allocations in single-floored dwelling units with the icons ‘Cooking’, ‘Eating’, ‘Hygiene’, ‘Leisure’, ‘Sleeping’ and ‘Working’.

Our paper focuses on the methodological approach rather than the results (which still were not gathered in in the intended environment and do not have ecological validity). We will describe strategies to increase meaningfulness and quality of derived knowledge and thus algorithms.

2. METHODS

2.1 MATERIALS

To explore our proposed framework and to predict where in spatial configurations specific allocations are how likely to be assumed, the use case considers precalculated spatial properties of the floor plan’s geometry as ‘performance-based search criteria’ for a reference repository. Furthermore, the prototype framework should meet the aspirations to

1. be able to flexibly manage bulk floor plan collections including their analysis measurements,
2. collect various user input from a huge number of user devices (icon allocations, drag events and form input) online and
3. provide efficient interfaces for advanced analysis that facilitate sub grouping, derivating data and generating automated visualisations.

The software is based on a server-sided script, concatenating HTML and JavaScript documents to render a graphic user interface in the participant’s browser/client (figure 1). The underlying database application is derived from the software ‘floorplandb’ (Triemer 2014) where floor plan’s analysis data – the so called ‘performance values of reference objects’ – and their geometry are stored together into a relational database.

![Figure 1 - screenshot of the online survey interface including the frameworks technical infrastructure](image-url)
2.2 FLOOR PLAN ANALYSIS

In preparation of a study by means of our framework, floor plans need to be drawn in a CAD system and be comprehensively analysed by the toolbox presented by Schneider (2014). This analysis algorithm subdivides the interior area of a single-floored apartment unit in quadratic grid cells of an edge length of 20cm and calculates several measures for each of them. Afterwards, the calculation results are stored into the database and can get visualised (figure 2). Among other data, the measures of spatial properties were precalculated and stored. The grid cells can correspond to various layouts of spatial break-up and could be aggregated for each space unit of it. For the purposes of the prototype we implemented the in figure 2 explained analysis methods on local spatial properties for each grid cell and relational properties for each pair of them. Additionally general measures like sizes of the physical closed space (room) the grid cell is situated in are available.

![Daylight Factor](image)
![Exterior View Length](image)

![Isovist shape on red and blue marked grid cell](image)

![Isovist Occlusivity](image)

![Isovist Compactness](image)

![Isovist Perimeter](image)

![Isovist Area](image)

![Isovist Minimum Radial](image)

\[\text{ISOVIST ANALYSIS}\]

(A isovist is the shape of an area that is visible from a certain point. (Benedikt, 1979))

![Relational spatial properties](image)

![Step Depth From Entrance](image)

![Visual Mean Depth](image)

Figure 2 - spatial properties - explanation and heat map display
2.3 USER INTERFACE

Three types of user interface templates are available in the framework: (1) info pages, (2) forms and (3) floor plan stages. On the latter, participants see a floor plan of an apartment and are asked to allocate icons by drag and drop (figure 1). The icons represent a configurable meaning by a pictogram (figure 3 left). By default, the placement sequence is up to the participants. An icon cannot be dropped upon another one. The icons snap to the grid when they are dragged/dropped by the intention that the mapping between grid cells and icon allocations is always unambiguous. The participants can manipulate the icons’ position as often as they want. Every drag and drop event gets listed including its start time, drop time and drop target. All icons have to be placed inside the floor plan before the final placements and task duration get ascertained and participants can continue. This set of rules is easy to adapt in the framework.

The icon allocations and drag event targets correspond to grid cell ‘22’ in the centre of an icon, having three times the edge length of a grid cell (figure 3 right). In case they exist, the eight neighbours surrounding the grid cell ‘22’ get stored for the final allocations in order to affine results by compensating analysis outliers.

2.4 USE CASE

To test on a use case, we asked participants to allocate ‘common’ user activities in the floor plans and supposed to create an algorithm miming this ability. We assigned six categories of activity as meanings to icons (see figure 3 left): ‘Cooking’, ‘Eating’, personal ‘Hygiene’, spending ‘Leisure’ time, ‘Sleeping’ and ‘Working’. These cultural codes/meanings were chosen to be applicable for as many people as possible and leave space for interpretation or a translation to the own culture, because we suspect these to be intuitive labels on searched-for spaces that shall be found in performance-based reference repositories (see introduction) matching the code’s underlying spatial definition to a certain degree. For every icon/label a strong iconic pictogram was chosen and a brief description and examples were supplied.

For our exploratory study we used nine different floor plans (see figure 4). These correspond to three variations of three different floor plan categories. The floor plan categories were chosen to depict different structural typologies. They were designed to check, if the cultural code of the spatial configurations can be read by the participants and thus manifests in easy to expect allocating behaviour. Their variations should provoke participants to behave differently by only small modifications of the spatial configurations. We worked with three categories/scenarios (details: appendix):
1. ‘enforced overlap of activities’ (four spaces; 1-3)
2. ‘closed structured’ (five spaces, 4-6)
3. ‘open structured’ (one space, 7-9)

These nine floor plans can be understood as a minimum test database, being open to further millions of examples, which are not available yet and would result in few answers per single floor plan, because of the limited media penetration of the exemplary survey website. For our test survey we aimed at an economic placeholder with simple and small floor plans to validate the reasonableness of larger effort by stating expectations that can have reflections in the aggregations of the derived data.

For gaining the test data, a survey website generated by means of the framework was put online and promoted via different channels: design and architecture related and not related fora.

Here, as first step, participants filled-in their year of birth, gender, country they grew up in, highest educational degree, profession, and the experience level in designing apartment units (scale 1: lowest to 5: highest). On the subsequent info page, the operation of the interface of the floor plan stage (figure 1) was described in a tutorial. Participants were told to exactly mark the location where the activity (figure 2 left) would be located best in an apartment floor plan. It was stated that they should not think about their own circumstances, but rather of a scenario of a single person between 20-40 years (because we suspected different forms of residential community). Furthermore, technical issues, such as pipes and wires, should also not be considered to be of priority. Afterwards the icon allocation procedure started. Every participant had to solve three floor plan stages with one out of the three variations randomly chosen for each of the three floor plan typologies (figure 4). Additionally, the floor plans were randomly either displayed in their original layout, or rotated north to south, in order to find whether there was an impact of cardinal direction on the placement behaviour. After finishing these three tasks, participants were asked to comment on their strategy.
3. RESULTS OF USE CASE DATA

Among the 154 participants were 67 men and 83 women; age ranged between 17 to 77 (M= 31.2 years; SD=10.1) and their field of study was mainly related to architectural design (50%).

In the following, we will provide an analysis on the gathered data in order to better understand the placing behaviour. Additionally, considering participants who stated they studied more than four years, worked in architectural, interior or urban design, were older than 21 years and had an experience level of three of five or more, we differentiated in a group of 62 experts and another of 92 laymen.

3.1 PLACEMENT DECISION-MAKING

Individuals intuitively have an idea where to conduct certain activities best and, how these relate to each other. These opinions might be diverse due to personal preferences. Thus the validity of such studies is limited, if we try to only elaborate results testing our own way of thinking. Consequently, the participants’ comments on their strategy are an immediate source for further hypotheses. We were interested in understanding, how participants would describe the researched cultural patterns (see appendix for a summary and interpretation of the participants statements).

3.2 SEQUENCE OF PLACEMENT DECISIONS

Box plots were used to examine the drag and drop handling during the task (to examine whether we could identify clues to the solving strategy). The plot (figure 5 A) about the number of drag events done with the icons of each activity suggests that the participants did not iterate the icons’ positions a lot. Interestingly the sum of seconds every activity icon was dragged (figure 5 B) is lowest, where also the fewest drag events occurred: for ‘Hygiene’ and ‘Sleeping’, which thus are considered to be least demanding. After the implementation of the survey interface, we watched beta testers: some held the mouse button down and dragged icons around and others were repeatedly dragging and dropping when concentrating on finding a solution.

On the interface the icons were displayed in alphabetical order (see figure 1). Assuming the placement decision was done when the participant dropped an icon to the position where it was confirmed later (final position), it appears that the ranking of decisions equals the enumerated sequence of the latest available drag events for every activity ordered by their timestamps increasingly.

The aggregation of these rank numbers shows that there is a tendency to place the icons in the order they were displayed for all participants (figure 5 C). In a few cases more than other activities, ‘Hygiene’ was preferred to be in a fixed position first. Thus it is very unlikely to find clues on priorities or operational strategies when allocating icons.
Proceedings of the 11th Space Syntax Symposium

A WEB-BASED PROTOTYPE SURVEY METHOD EXEMPLARILY APPLIED ON ACTIVITY ALLOCATIONS IN APARTMENT FLOOR PLANS AND THEIR SPATIAL PROPERTIES

3.3 FREQUENCY OF PLACEMENT DECISIONS

Heat map analysis of the frequency of participants choosing the grid cells for the six activities in the nine floor plans will be taken into account to evaluate how these grid cells are distributed and whether there are patterns to find (figure 6).

Obviously, the least varying activity was ‘Hygiene’ - it was in almost every test allocated in the same room, while other activities almost never occurred here.

‘Cooking’ seemed to occur pretty close to the entrance and participants tended to place this activity in alcoves. ‘Leisure’ was more likely placed in one of the largest rooms available. The heat maps also suggested that ‘Sleeping’ was influenced by the entrance location.

The floor plans ‘4’, ‘5’, and ‘6’ represent the ‘closed space’ typology (figure 4). In floor plan ‘4’ we expected the smallest room without windows to be in use for ‘Hygiene’, which turned out to be always the case. Floor plans ‘5’ and ‘6’ were geometrically identical. Only the position of the flat entrance varied to be aligned to either one of the small rooms’ doors. One was neighbouring the larger room and one the smaller room among the bigger rooms available. Surprisingly, no differences could be observed in the allocating behaviour when the entrance’s position was altered: ‘Hygiene’ was placed more often neighbouring the smaller room and ‘Cooking’ equally more often neighbouring the larger in both variations. Participants also tended to allocate ‘Leisure’ in the larger room, neighbouring the small room, which was often used for ‘Cooking’. The latter condition’s impact seems predominant.
3.4 CHARACTERISTIC LOCAL SPATIAL PROPERTIES

The next question was how spatial properties were distributed for the places of activity allocations (figure 6). To plot figures 7 and 9, these spatial properties $p_{loc}$ of all grid cells including their neighbours (according to figure 2 right) were normed to the percentage of range $p’$ between flat’s/floor plan’s minimum $\min(p_{flat})$=0% and maximum $\max(p_{flat})$=100%.

$$p \in R, \ min(p_{flat}) < max(p_{flat}), \ p’ = f(p_{loc}) = \frac{p_{loc} - \min(p_{flat})}{\max(p_{flat}) - \min(p_{flat})} \cdot 100\%$$

The results $p’$ were aggregated in a box plot, showing one box with given mean and standard deviation for each spatial property and activity. Thus, we deal with a proportion among all possible choices inside a specific flat. Otherwise, a high maximum of only one apartment would turn placements at the maximum in other ones into medium values for the aggregation, despite they are preferably extreme.
To keep it short, we will only comment on the most striking findings. We state for the ‘area of room’, that ‘Hygiene’ is likely to be allocated in the smallest available room, while ‘Sleeping’, ‘Eating’, and especially ‘Leisure’ cumulate in the hugest rooms.

‘Visual Mean Depth’ is significantly high for ‘Hygiene’, and shows a strong tendency to be lowest for ‘Leisure’ and secondly for ‘Eating’. Thus ‘Hygiene’ appears to be most integrated and ‘Leisure’ to have the best accessibility from the entrance.

Even no outlier of ‘daylight factor’ occurred for $p \geq 69\%$. Participants seem to avoid placing any activity but seldomly ‘Working’ and ‘Leisure’ at the grid cells with maximum ‘daylight factor’.

‘Visual step depth from entrance’ has the lowest median for ‘Leisure’ and the highest for ‘Sleeping’ and activities never occur right at the flat’s entrance.

Participants appear to avoid allocating ‘Sleeping’ in extremely large and also small isovists and have a remarkably unambiguous optimum around medium values here.

75% of all placements for all activities had ‘isovist occlusivity’ $p < 56\%$, which suggests that highly occlusive places correlate with left free circulation space.

All in all, this data shows the expected heuristics (which in this case is desired); and gives strong input for informing an algorithm.
3.5 SUBGROUPING

We plotted groups of boxes combining the aggregations of $p'$ for all participants with the influence of displaying floor plans in altering cardinal direction (figure 9; appendix). One could argue that the cardinal presentation of the floor plans had an impact. This is only partially the case. Analysis via median subtraction shows that there were slight differences for 'area of room', 'daylight' etc.. Furthermore, individuals with more experience react stronger. Additional groups could be defined based on these kinds of data sets and could be compared in the same way.

3.6 RELATIONAL SPATIAL PROPERTIES OF ALLOCATIONS

In order to summarize about patterns to find in the spatial relations between all activities (and additionally between the entrance and these activities), we analysed the heat maps (figure 8) displaying measures for each pair of allocations. Three heat maps display the percentage of participants' placing activities together in the same closed space (room); considering different subgroups of floor plans. Another three heat maps display $p'$ for the distance measures/relational properties (figure 2).

Considering; if activities are in the same room and if it is getting more or less likely if one space more is supplied to combine them, the most striking finding was that 'Hygiene' has been placed solitarily. A majority of participants grouped 'Eating' with 'Cooking', which indeed gets less likely when an additional space is supplied. Only 37% thought 'Leisure' would fit 'Cooking' and still less (26%) in case a fifth space is available. We found that 'Sleeping' is combined with 'Working' or 'Leisure' much more unlikely when there is an extra space (65% to 33%). In general 'Sleeping' seems to be favoured to be in a room separated from other activities. Regarding distance measures in all three plots it is interesting that there are high minima to find, thus there seems to be a strategy to keep a moderate distance between all allocations. We could identify the group of 'Eating' and 'Cooking' to be close to 'Leisure', but as far away as possible from 'Sleeping'. The 'euclidian distance' between 'Sleeping' and 'Hygiene' is surprisingly low, while 'shortest walk' tends to be comparably long.

The following sequence of activities from entrance is apparent according to:

-euclidian distance:
'Cooking' < 'Hygiene' < 'Eating' < 'Working' < 'Sleeping' < 'Leisure'

-shortest walk:
'Cooking' < 'Eating' < 'Working' < 'Hygiene' < 'Leisure' < 'Sleeping'

-visual step depth:
'Cooking' < 'Eating' < 'Working' < 'Leisure' < 'Sleeping' < 'Hygiene'
Figure 8 - distance analysis between activities and relation to entrance
4. DISCUSSION AND OUTLOOK

The result of our work is a prototype framework smoothing the path to a future method for bringing together verbally stated cultural codes and measurable properties of spatial configurations by online surveys. We tested the method by conducting a test survey on activity allocations in apartment floor plans. We found potentials and concrete indications on strengthening synergies by achievable enhancements. The framework improves the analysis depth for researchers of previous similar surveys.

For instance, Kim (2005) conducted a study with 426 participants and found several ‘behavioural patterns’ in serialized uniform apartments. The work presented in this paper is valuable in terms of comparability and detailing; and is based on data collected directly from in-use apartments. The uniform approach would make a finer categorization of allocations possible. The implemented prototype framework is tested on conventional environments; including mobile/touch devices. This approach could not only be used to conduct an online survey, but also for data acquisition by a researcher. Thus, it would support Kim’s work by low technical requirements towards the equipment of the data collector. Several points of connection to further applications of the presented framework could be found on the field of design support; e.g. enabling a CAD system to recognise when a user draws a bathroom and thus suggest associated options like adding a sink. A further use case could be validation methods for automated designs by means of optimisation. A generated floor plan could be automatically tested to fit the features of a usable flat and in case it does not, the generating algorithm could abolish and continue generating.

In addition, the framework needs only moderate adjustments and extensions to fit the requirements of the study concepts by Monteiro (1997), Hanson (1998), Seo (2004) and Güney (2007) and numerous other research tasks. Hanson (1998 p. 8) showed that some activities in some cultures are not allocated inside the private housing. Hence, the configuration of the set of rules for the operation of the floor plan stages could be adjusted to allow to leave icons unconsidered. Güney (2007) suggested emphasising two alternative concepts to the convex break-up: end point spaces and movement spaces (according to Peponis 1997, 1998), which measures from grid cells could also be related to by means of the framework’s database. Hence, these additional spatial break-up classes to the implemented ‘room’ and ‘convex’ concept are easy to supplement, because they can be unified to the database structure via the entirely grid-based relational approach. Enhancing additional analysis methods to the framework’s infrastructure is possible with little effort. The named researchers always address only a part of what would be available, the framework enhances all their work by supplying all their advances to the state of the art at once. By means of a highly normalized database structure the framework additionally provides the intended efficient interfaces for advanced analysis that facilitate subgrouping, deriving data and generating automated visualisations for flexible and iterable statistics.

We modelled and conducted an exemplary test study utilizing the framework prototype. We asked participants online where certain activities would be located ‘best’ - and to mark these places with an activity icon. So far, we have omitted, what ‘best’ actually means in the context of the vague categories of activity like ‘Hygiene’, ‘Working’, ‘Leisure’ etc. (figure 3). We indeed intended that an intuitive image comes to the participants’ minds, because, using the work at hand, we wanted to prepare an algorithm that evaluates the degree to which a subjectively stated category eventuates from objective spatial properties. If an algorithm was implemented based on the test survey results, placing the activities could be controlled by rules like the following: ‘Hygiene’ is easy to identify - it is always segregated, needs no natural light and is situated in the smallest room. ‘Cooking’ is acceptable to be in a small room and is strongly related with ‘Eating’, while the latter is also closely associated to ‘Leisure’. ‘Leisure’ and ‘Sleeping’ are preferably situated inside the largest available rooms etc. However, at the current stage, this algorithm development needs more steps:

Until so far, we have neglected progressing the algorithm’s implementation in anticipation of a technical context (described later) that results in more reliable knowledge discovered in
databases. The aim of such an algorithm applied in a matching algorithm for “fuzzy search” in a digital floor plan reference repository (see introduction) is to fit ‘best’. That meets users’ expectations from being shown a specific verbal description and a pictogram. One could argue that it is not clear what is measured by surveys by means of the framework and the use cases of a derived algorithm would be very limited. However, we argue that it is possible to increase knowledge quality in comparison to the current prototype, which rather geared towards validation of larger effort that is given. Utilizing the test survey results would enable at least a majority of the survey’s participants to retrieve satisfiable search results from the repository. It is not surprising that the aggregations on local and relational spatial properties of the test study show direct reflections on the cultural codes beyond the floor plan categories and variations. It is a simple task for a human, but a hard one for a computer to meet human expectations towards allocating subjectively coded verbally stated meanings. Simply manually labelling spaces by their current usage for the repository is a priori ineligible - not only because of the huge effort for judging a comprehensive repository and deficient comparability of the applied labelling criteria, but also because another inhabitant could find, e.g., a former sleeping room to be suitable as living room or a former kitchen as bathroom and so forth. Thus we need to automatise such tasks, involve users or participants efficiently and enable an algorithm to make judgements on the suitability of a space/location to be occupied by any meaning that could be represented by an allocated icon.

We see a strong potential in offering surveys conducted by means of the framework together with the above described reference repository as a mixture of a design tool and social network data collection for planners and students. Besides, the search function, public and private communication and coworking in cloud engineering, they could upload their designs, analyse them and hereby progress in acquisition of reference objects to the public repository on the side. On the basis of this higher-quality data set, a self-revising algorithm could be implemented using ‘big data’. Therefore, the next step the envisioned algorithm would be checking its validity using a different data set. Since online services are available to everyone, the test survey examined the input quality of non-specialist participants. In our study, as a side note of our results, we found that laymen seemed to add only little noise to the data and just need a little more time and drag events for reflection. Besides, laymen are not out of focus, because a retrieval tool could also be used for an online real estate market. Nevertheless: one would know more about the participants’ personal data, because it is related to a user account. On that basis one could give participants a sophisticated weighting in statistics according to their background, optimize search results by user geolocation or setting and calculate models of populations in order to make knowledge more representative.

In conclusion, one could accelerate acquisition, increase data quality and make users and researchers profit from each other. This is the synergy effect we intend for the future. More bridges from abstract objective properties of spatial configurations towards understandable categories of cultural meanings will be established by the derivation of matching algorithms and decent case-based reasoning approaches will be within reach.
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APPENDIX

The participants of the survey were asked for:

- their year of birth - range of age: 18-78 years, average: 32(+/-10) years,
- Gender:
  - ‘male’ ~44%;
  - ‘female’ ~54%;
  - ‘I don’t feel represented by these categories’ ~3%,
- Country they grew up in (question: ‘What is the country you spent most of the time in between your 1st und your 16th year of age?’ ~81% from European countries),
- highest educational degree:
  1. ‘school of general education’ ~11%;
  2. ‘completed job training’ ~4%;
  3. ‘completed job training with additional qualifications’ ~1%;
  4. ‘University/College - study less than 4 years standard period’ ~19%;
  5. ‘University/College - study more than 4 years standard period’ 50%;
  6. ‘Doctor or comparable’ ~11%;
  7. ‘Professor or comparable’ ~6%;
  8. ‘not applicable’ ~1%,
- profession:
  1. ‘architectural design’ 50%;
  2. ‘interior design’ ~1%;
  3. ‘urban design’ ~14%;
  4. ‘design student’ ~6%;
  5. ‘no design related profession’ ~28%,
- and their experience (question: ‘How would you judge your experience in designing apartment/apartment houses/units?’, range: 1-5, level 3 and above ~55%).

The original task description participants got displayed was:

‘We will show you floor plans of apartments. Mark the distinct location (not just the room), where - in your opinion - typical activities (cooking, sleeping etc.) are located best.

The activities are represented by the icons from the table.

The icons do NOT represent the dimensions of a physical object (such as sofa, table), but the position of the inhabitant’s head while carrying out the activity.

Assume, that the flat is inhabited by only one person (age: between 20-40 years).

Don’t take care about technical questions like pipes and wires.

3 floor plans will be displayed on the following pages.’

The question after the survey was:

‘Please describe, how you came to your decision concerning the placements of the activity icons. What was on your mind? Languages: English, German’

Details on the floor plan categories:

1. ‘enforced overlap of activities’ (four spaces; 1-3)

   Floor plans with a smaller number of rooms than available activity icons, forcing one to combine more than one activity per room. The position of the smallest room and suppliance of an alcove was varied to find whether room proportion and geometry impacts the allocating behaviour.
2. 'closed structured' (five spaces, 4-6)
   Floor plans with closed spaces supplying one space more than category ‘1’ and one less than the number of available activities. The position of the entrance was varied to find whether a specific activity is preferred to be seen from the entrance or not. The area of one room was varied to find whether a small room with no windows is always predicting a ‘Hygiene’ space.

3. 'open structured' (one space, 7-9)
   Floor plans with one huge room for all activities and a segregated space for a private activity. This category was taken into account to guarantee a predominant impact of the local spatial properties over individual room properties.

Summary and interpretation of participants’ comments
Participants were widely consent in their following statements among each other:

- a spatial separation of the ‘hygiene’ space from the rest of the apartment to be a must-have for the purpose of intimacy and for this effect compromising it to be the smallest room with fewer demands on quality aspects such as view to the exterior or daylight
- high segregation/isolation between entrance and ‘sleeping’ also for the purpose of intimacy
- immediate proximity between ‘eating’ and ‘cooking’ for practical reasons, often paired with ‘leisure’
- ‘leisure’, ‘eating’, and ‘working’ needing more natural light and view to exterior than other activities
- ‘cooking’ to be close to the entrance for bringing in shoppings and getting rid of garbage easily
- long distance between ‘sleeping’ and ‘cooking’ to avoid odour nuisance
- ‘sleeping’ needing more space than ‘cooking’, if separated
- three participants named cardinal orientation as criterion

Some participants gave hints that no other participant disagreed with:

- no activity directly in the entrance zone
  - ‘leisure’ is closest activity to the entrance (least segregated)
  - ‘eating’ bridges ‘cooking’ to ‘leisure’
  - ‘leisure’ is seen as something that could be combined with ‘sleeping’
  - noise disturbance should be considered
  - cultural aspects might lead to different results
  - ‘working’ should be well lit

For some statements there was a contradiction between different demands

- ‘hygiene’ close to ‘sleeping’ but also ‘hygiene’ should be accessible from the entrance, yet ‘sleeping’ should be most segregated
- there are several preferences for ‘working’: some want to avoid to have it too close to ‘sleeping’ because it conflicts with the idea of a relaxation zone, some others see an advantage in double using the ‘sleeping’ space because it needs a comparable silence and privacy and one never sleeps and works at the same time, a separate ‘working’ space is a nice-to-have.
Figure 9 - local spatial properties of chosen grid cells - for all participants and comparison between applied and not applied north to south rotation
ENGAGING SPACE IN THE INCLUSIVE MUSEUM

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ABSTRACT
Museums are symbolic institutions as well as iconic buildings of our times, aspiring to become ‘inclusive’: to be spaces associated with social diversity and cultural innovation as well as meeting places in the contemporary world of plural identities and accelerated mobility. But what does it mean architecturally for a museum to be inclusive? Are these theoretical concepts about the museum’s role and function reflected in changes in the architectural and spatial form of real museums? Do museums engage the building to express such ‘inclusive’ museological concepts as accessibility, openness, and ‘being in the world’? And, in turn, do they through these engage visitors in cross-cultural informational experiences and social encounters? To explore these questions, we propose to look at a series of current case studies which show how through their physical and spatial nature, museums can be experienced as inclusive, diverse and engaging environments. Our spatial thesis is reflected in the structure of the paper that is organized around the spatial concepts of connectivity and unpredictability, which relate to the way the museum is activated as part of city space and works as social experience; and of the ideas of spatial embodiment and situated meanings, which relate to the emergence of new spatial typologies and concern its functioning as informational experience. The paper ends by discussing features of the current social context which suggest why the identified spatial changes are bringing about the realization of the inclusive museum.

KEYWORDS
museum space; connectivity; unpredictability; graphs; space-types; inclusive

1. INTRODUCTION
Museums are symbolic institutions as well as iconic buildings of our times, aspiring to become ‘inclusive’: to be places associated with social diversity and cultural innovation as well as meeting places in the contemporary world of plural identities and accelerated mobility (Basso Peressut and Pozzi, 2012, p.10). But what does it mean architecturally for a museum to be inclusive? Are these theoretical concepts about the museum’s role and function reflected in changes in the architectural form of real museums? Do museums engage the building to express such ‘inclusive’ museological concepts as accessibility, openness, and ‘being in the world’? And, in turn, do they through these engage visitors in cross-cultural informational experiences and social encounters?

The paper sets out from the idea that it is not only through ‘universal design’ or through its activities and programmes, that the museum manifests its intention of inclusiveness. It will be argued that it is also through its physical and spatial nature that it affects the way it is experienced as an inclusive, diverse and engaging environment. In particular the museum does this through the way architectural space is organised to create connections: between the building and its immediate environment, manifesting its role as a continuation of urban space; between displays privileging experience over abstract reasoning and visitors, so that meaning can be communicated to diverse audiences; and between visitors, so that the museum works as a generative social space.
To explore these arguments, we propose to look at a series of current case studies which illustrate the emerging inclusive transformations of the museum, from the point of view of the relation between spatial design, informational experience and socialization. Our spatial thesis is reflected in the structure of the paper that is organized around the spatial concepts of connectivity and unpredictability, which relate to the way the museum is activated as part of city space and works as social experience; and of the ideas of spatial embodiment and situated meanings, which relate to the emergence of new spatial typologies and concern its functioning as informational experience. The paper ends by discussing features of the current social context which suggest why the identified spatial changes are bringing about the realization of the inclusive museum.

2. SPATIAL AND VISUAL CONNECTIVITY

The idea of close relation, through spatial and visual links, between the museum and its immediate context, the city in particular, is not of course new. It dates back to the Altes Museum, Berlin (1823), and its upper floor loggia which offered a panoramic view of the urban context, a kind of collective space that linked the museum to the city (Basso Peressut, 1999, p.13). The New Nationalgalerie Berlin (1968) and the Centre Pompidou, Paris (1977) are two turning points in the history of this relation, with the former proposing the urban landscape of the metropolis as the background for the viewing of works of art, and the latter creating a new urban square, which extended inside the building. But what is striking today is the way the spatial link between museum and context is evolving, taking a variety of forms and rendering the relation more complex and richer.

Establishing continuity with the immediate environment and stressing the museum’s permeability and approachability by multiple routes and entrances is not only a recurrent theme in the spatial design of museums but also a favourite expression of their openness, their integration into people’s everyday life and their informality. Pioneering from this point of view is the 21st Century Museum of Contemporary Art in the centre of Kanazawa (by Kazuyo Sejima and Ryue Nishizawa of SANAA, 2004). The building was given a circular form, eliminating the
distinction between the main façade and the other sides and allowing approach equally from any direction and through different entry points (Figure 1). This was based on the concept that the museum should be open to the city like a park, in the sense of permitting different kinds of people to be together in the same space (Sejima, cited in Moreno and Grinda, 2007, p.361). In addition, its transparency and its low volume emphasize its accessibility and close relation to the city and its communities. The idea of a seamless relation between the museum's spatial structure and the urban context also shapes the shared ground-floor of the new building of the Musée de l’Élysée (Musée cantonal de la photographie) and the mudac (Musée de design et d’arts appliqués contemporains), Lausanne (by Manuel and Francisco Aires Mateus – planned to open by 2021). It is a space open on all four sides, a natural extension to the public esplanade outside, which, by accommodating the entrances of the two museums, relates in and out movement with circulation in them, contributing to a sense of urban density (Figure 2).

In addition to constructing connections to and from the city to facilitate movement, museums are also activated as part of the city space. They allow routes to pass through, rather than simply leading to the interior, and create urban spaces adjacent to or within the building, where visitors’ paths converge and informal encounters occur. The ARoS Aarhus Art Museum building (by Schmidt, Hammer Lassen Architects, 2004) (Figure 3a) is traversed by a 'street', an axial space which bridges two parts of the city and connects the entrance space of the museum to the network of streets outside, through ramps at both ends. Via the ramps the city is drawn into the museum (Schmidt, 2004, p.49). The interior ground floor 'street' is also reflected in the museum exterior by a glass incision that cuts through the compact red brick building along its whole height.
In contrast, in the Museum aan de Stroom, Antwerp, better known as MAS (by Neutelings Riedijk Architects, 2011), the 'street' is a vertical promenade that extends from the entrance to the tenth floor. It is made up of entirely transparent circulation spaces, which are separated from the ‘black-box’ display spaces, and create the rising spiral ‘MAS boulevard’. Visitors perceive changing views of the city surrounding the museum, with each floor altering the visual field by 90 degrees. The museum route represents a vertical ‘exploration’ of the city through movement.

In 2000, Tate Modern transformed its main space, the Turbine Hall, left intentionally void in the design proposal of Herzog & de Meuron, into a ‘covered street’, extending the active west side public space next to the building into the heart of the building itself. In parallel, it transformed its north side public space into a common ground, a natural space, where people like to go and, once they are there, they are encouraged to explore what’s going on inside the building (Vogt, 2016, p.123). After its extension in 2016, with the new pyramid building (Switch House), the
Turbine Hall determines even more powerfully the main axis of the interior of the complex. As shown in the schematic graph in Figure 4, the Turbine Hall provides links between the new and the existing building (Boiler House) on three levels (underground, first and fourth), and creates new ways of entering and exploring the museum. More importantly perhaps, this ‘covered street’ also works as a vast display space, which generated ‘a wholly new way of showing art’ (Herzog & de Meuron, cited in Moore, 2016), by inviting interpretations at that scale by artists. In spite of their different responses, in all cases, the work of art became seen as integral with the space, ‘an iconic image, inextricably enmeshed in the public memory with the experience of Tate Modern’s building’ (Wagstaff, 2012, p.39). By provoking thinking and raising questions, the art displayed is said to have enhanced the social nature of the space and contributed to its sense of community and sociability. According to the sculptor Juan Muñoz (commissioned in 2003), the Turbine Hall is ‘part of a city, rather than part of a museum. It’s a fragment of the urban experience... It’s a space of our time’ (ibid., p.35).

The idea of the museum creating a continuous space with its context is taken one stage further by the Moesgaard Museum (MOMU), an archaeological and ethnographic museum in Aarhus (by Henning Larsen Architects, 2014). Instead of incorporating a public space inside the building, the roof becomes itself an extended green public space (Figure 5a). Positioned on the side of a hill and inspired by the concept of an archaeological excavation, the building is partly submerged in the site, blending with the natural landscape. Its planted sloping roof seems to grow out of it, inviting visitors to wander around and use it as a continuation of the landscape, but of an intense collective character. The contemporary museum, more than ever before, is concerned with – and so designed to – provide social space.

3. UNPREDICTABILITY

Over and above linking their layout to local movement patterns, museums can also structure their own internal spaces so that they work like the street network of a city, introducing flexibility and unpredictability in the way space is used and explored. The layout of the 21st Century Museum of Contemporary Art (see above) is organised as a system of independent galleries forming the museum’s core (in grey in Figure 1), and a network of public spaces, serving a variety of programmes, as an outer zone, with glazed interior courtyards between them. They are all arranged so that glass corridor-like linear spaces, connected at right angles, pass among them, creating axial lines of sight. Some axes traverse the whole building, others are more localised, while key long axes are linked to the main entrance space. The ‘urban’ nature of this network

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Figure 5 - Moesgaard Museum, Aarhus: the green roof seems to grow out of the natural landscape (a); view of the darkened main space (b) (Photographs: Media Department, courtesy of ©Moesgaard Museum)

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facilitates orientation and allows visitors to explore and choose at will, actively discouraging a predetermined route and constantly enhancing visitors’ awareness of each other.

This idea of internal organization in the style of urban space is further emphasized by two recurrent museum tendencies. On the one hand, ‘inspired by the vibrant, open public spaces’ (Tate Modern, 2016), museums increasingly include, in their functional programme, spaces for unplanned activities, either initiated by the museum (as in the case of ‘Tate Exchange’, a dedicated suite of learning and research spaces for visitors, visual arts professionals and staff in Tate Modern) or by communities (as in the ‘People’s Gallery’ in the 21st Century Museum of Contemporary Art). On the other hand, they make the public spaces of the building accessible to audiences independently of the exhibition programme as well as of the museum opening hours. The outer free zone of public spaces in the 21st Century Museum of Contemporary Art is an illustrative example, as are also the top floor of the MAS and the new pyramid building of Tate Modern (2016). Both are entirely dedicated to a panoramic view of the city and directly accessible from the urban level. ‘The museum embraces the public as never before’ (Chris Dercon cited in Dercon et al., 2015, p.85) and aims to work as an open space for both museum visitors and urban explorers.

Displays can also extend beyond galleries and occupy the informal space of corridors and courtyards, as in the 21st Century Museum of Contemporary Art and in Tate Modern, expanding our sense of possibilities for experiencing art and enhancing the sense of unpredictability in the use of space. In 2006, the AROs Aarhus Art Museum launched a competition for creating a permanent work of art on the roof of the building. The winning project, Ofalur Eliasson’s ‘Your rainbow panorama’ (2011) (see Figure 3b), is a circular walkway in glass in all the colours of the rainbow, creating intriguing contrasts: it is a space at the top the building with a circular shape conceived in relation to the square museum building, and a work of art that maintains its autonomy as an object; it is a space inside the museum as well as outside; it intensifies the view of the city and is visible from the city; and, while offering a collective sensory experience for visitors moving along the walkway and perceiving the surrounding urban landscape through changing colour zones, it transforms the museum into ‘a beacon, visible throughout the city’ and ‘a compass in time and space’ for its citizens, ‘a lighthouse’ (Eliasson, 2014, pp.90–91).

By providing many options for being used and experienced, the museum layout can then feel like an urban space, explorable by a mix of people coming with different goals and interests, implying informality and the museum visit as a relaxed activity. In doing so, museum space becomes active in the structuring of social relationships over and above encounters in the public spaces. The more exploratory the visitors’ movement pattern, the more random their pattern of encounter and the more variable their co-presence, rendering the whole experience intensely social.

4. SPATIAL EMBODIMENT

Beyond shaping the experience of the museum as public space, open and informal, architectural and spatial design can contribute to new forms of curatorial representation, to ‘practices geared towards breaking up settled interpretative models’ (Basso Peressut, 2014, p.156). They stimulate new perspectives and encourage different modes of creating culture (ibid.), including embodied forms of knowledge, immersive experiences and affective engagement. By placing greater emphasis on the visitor’s own perception and experience grasped through spatially embodied sensation, and so on the individual rather than the normative, museums informalize their environments. This, it is proposed, is another way in which the museum seeks to engage a wide audience of varying ages, abilities, interests, learning styles and cultural backgrounds.

At an elementary level, museums seek to tell a bigger story, instead of a dominant art history. They extend the global reach of their collections beyond Europe and North America and create new patterns of connection by juxtaposing them spatially. Recently, both in the Centre Pompidou and in Tate Modern, the spatial arrangement of the permanent collections has been used to bring about alternative ways of looking at the history of art. Strikingly, this was realised through opposite approaches. Pompidou, in 2013–15, brought together the European
movements of art with artistic expressions developed in the States, South America, Asia, Middle East and Africa, in a chronological narrative from the beginning of the twentieth century to the 1920’s, under the idea of ‘Pluralités mondiales’ (Worldwide pluralities). In the place of the chronological and art-historical approach, Tate Modern opted for a more experiential arrangement, after the completion of the new building which lead to its entire and extended collection being rehung (2016). It proposed an overview of the twentieth century art though broad themes (e.g. In the studio, Artist and Society, Between Object and Architecture, Living cities) and a dialogue between past and present. One of the original aims in the creation of Tate Modern was ‘to make difficult art popular’, and in this, it has been argued, ‘innovative ways in which the Collection was and is displayed have also helped’ (Smith, 2005, p.21). By bringing disparate objects, experiences and viewpoints together, museum space works as a powerful connective space, and becomes an expression of the curatorial intention to show a more connected account of art. This approach also allows the possibility of multiple narratives to coexist and suggests alternative comparative contexts instead of a single way of seeing things.

At a deeper level, the design of museum space is used to complement the more rational, information-based content of the display with additional modes of understanding, creating responses which are embodied, sensory and affective. Two spatially innovative examples are the Museum of Palazzo Valentini, Rome (2010), and the Moesgaard Museum (see above). In these cognitive learning is complemented with embodied forms of knowledge and immersive sensory experiences, and interpretation is accompanied with affective and emotional engagement. More specifically, in the Museum of Palazzo Valentini, which is not a purpose-built museum, but an archaeological site (beneath the basement of a mid-sixteenth century palace, currently the seat of the Province of Rome), information is exclusively transmitted though an immersive visual and audio narrative and a powerful embodied experience. The architectural and archaeological remains of different structures, functions and periods (mainly a public building of Hadrian’s time, and two private buildings of the mid- and late Empire – see Napoli and Baldassarri, 2015), often overlaid, and visible through glass floors, passages and bridges, are organized in a visitable sequence. The visitor passes through the – darkened – spaces of the sequence and what is seen is complemented by audio narrative, combined with targeted illumination and digital graphic effects. These guide the viewer to focus on meaningful details in the remains or to conceptually reconstruct elements of the original setting by ‘drawing’ their original shape or defining their perimeters. There are also virtual reconstructions, as for example completions of partially conserved remains of floors, and projections on the walls, which extend the visual experience of the visitor beyond the space occupied and the physical remains displayed. They give a sense of life by presenting the visual experience moving from space to space, together with the acoustic experience of residents’ voices and surrounding sounds, or of neighbouring spaces and gardens. In spite of its character as an automated guided tour and the rigidly determined spatial sequence, the experience recreates a sense of the architectural and social past of the archaeological site, and of the life for the inhabitants (‘Innovative ICT solutions’, 2011). The resulting effect is both cognitive, in that the ancient structures can now be understood, but also affective, in that what has been created acquires cultural and social meaning through spatial embodiment. In this sense it becomes a more inclusive way of interpreting the past.

Like the Museum of Palazzo Valentini, the Moesgaard Museum reduces textual information and proposes instead a variety of modes of embodied nonverbal communication, including architecture and its sensory qualities, as well as the innovative use of technology, but combined with an explorable open environment. The display section devoted to the Bronze Age and Iron Age is organized on three levels as a series of experiences which are spatially separate, but at the same time intricately interwoven with each other. The complex as a whole is essentially an open space divided into sub-spaces, often characterized by curved geometries. A narrative is constructed as each experience builds on the previous one conceptually: the worship of moon and sun at the upper level; the cultural significance of bogs and examples of offerings in bogs, from rings to animals, at the ground level; the human sacrifice, the Grauballe Man, one of the world’s best preserved bog bodies and the museum’s highlight, at the lower level. Narrative synergies between spaces and levels are experienced through the carefully constructed visual connections between pairs of levels, and further supported by the spatial design. The darkened
spaces, the highlighted objects, the uneven floor that gives the sense of walking in a bog, the sounds in combination with the projection of short animated films on the walls of the building, activated by the visitor, all constitute an emotive atmosphere for the viewing of exhibits (Pallasmaa, 2014, p.246).

Two features of the museum layout are of particular interest from a spatial-syntactic point of view. First, it uses all types of spaces, sometimes as immediate spatial neighbours (Figure 6) to create this powerful integrative experience. Second, it proposes different interpretations of the same space type, in particular of a-spaces, by varying the spatial and visual relations within their context. For example, the double-height main space (Figure 5b) is spatially enclosed, but visually it is entirely open, so a tension is created between accessibility and visibility. The way it is defined by a curved low fence-like form, and at the same time enveloped at a distance by the walls of the building, makes visitors feel like being on a promontory offering an all-encompassing experience of the ground and the upper levels, and so a place where they can stop and see the life in prehistoric Jutland. Notably, the main space is also visually linked (through a glass opening in the middle) to the underground Grauballe Man gallery, another a-space but here an enclosed and intimate space. Thus, by creating different spatial conceptions within the same space type, the design of space in the Moesgaard Museum allows for quiet seclusion as well as open expanse, for static and dynamic, and for the intimate and the perceived from a distance.

So in these two cases, the museum, by privileging the lived over the conceptual or analytic, engages visitors and allows them to use their own resources for experiencing the display. This meaning making through sensorial and embodied experiences can, it has been argued, potentially lead ‘to a greater degree of understanding’ in the sense of knowledge that is ‘felt rather than rationally understood’ (Witcomb, 2010, p.41).

Figure 6 - Graph of the spatial layout of the Moesgaard Museum, with space types
5. SITUATED MEANINGS

Closely related to the tendency for sensory forms of knowledge (Witcomb, 2015, p.322) is the contemporary focus on subjectivity and experience, which also helps to make the case for openness and inclusion. New forms of art – for example in the fields of video art, light installation and interactive art – deal with experiential processes (rather than objects) where time is a key dimension in viewing and emphasis is placed on engaging visitors with their surroundings in ways which allow for differences in individual perceptions. The works, by being based on the sense of immersion, creating intense and complex experiences of light and colour, and amplifying visitors’ physical reality and sensory presence, mark a shift of engagement from ‘looking at’ to ‘being in’, and a transformation from the ‘viewer’ to the ‘navigator’ (Dyson, 2009, p.2). So museum space is required to display works where the main part of the work lies in the experience of it, in effect to exhibit something immaterial (Eliasson, 1995/2015). As suggested by the spatial layout of the Moesgaard Museum and as proposed elsewhere in relation to the spatial culture of performing arts museums (Tzortzi and Hillier, 2016), this phenomenon seems to interact with emerging spatial typologies, and in particular with the growing emphasis on spatial complexes favouring a-type spaces to accommodate lived experience, rather than complexes of different ratios of c- and d-spaces.

The Tanks in Tate Modern (the former oil tanks, enormous concrete cylinders that still retain their industrial feel) and The 9 Spaces in the ARoS Aarhus Art Museum (planned and specially designed from the outset of the creation of the building) can be seen as two indicative examples. In addition to the more ‘conventional’ layout that takes the form of a sequence of spaces supporting a curatorial narrative of some kind, both museums dedicate their underground spaces to large-scale installations, projected images or performance work. In The 9 Spaces, for example, each work tends to take over an entire space and immerse visitors in a different atmosphere, as in the case of Pipilotti Rist’s installation ‘Dawn Hours in the Neighbour’s House’ (2007), created especially for one of The 9 Spaces: through video, sound and light it makes visitors experience 24 hours in 8 minutes. Significantly, in both museums, the underground galleries are closed a-spaces, open to a common corridor or space, and homogeneous in syntactic terms (Figure 7a–b). By providing one permeability link to the other spaces of the complex, they intensify the sense of containment and enclosure, enveloping visitors in their embrace, and distance themselves from through-movement. These spatial properties can be seen as offering preconditions that facilitate the assimilation and understanding of the intense experiences they accommodate.

Figure 7 - Graphs of the spatial layouts of: Tate Tanks (a); The 9 Spaces, ARoS Aarhus Art Museum (b); the ‘Soundscapes’ exhibition, National Gallery London (c). White circles represent display spaces and grey circles intervening spaces.
6. CONCLUSION

As the role of museums in society changes, together with museological concepts and curatorial approaches, museum architecture and spatial design are changing with them. Our cases illuminate some of the different ways in which museum architecture can engage space to express the inclusive museum. It can: create museum approachability and openness and shape an informal environment that encourages random patterns of exploration and fosters visitors’ sociability; communicate the idea of cultural connectivity; provide the stage set and the means for experimenting with novel ways of presenting art and cultural heritage and new forms of viewer engagement; and generate layered experiences, in which the proprioceptive (related to the positioning and movement of the body), sensory, intellectual, aesthetic and social are interconnected for the visitor (Levent and Pascual-Leone, 2014, p.xiii).

We can then propose that what we are seeing are spatial interpretations of Manuel Castells’s (2001) argument that, in the contemporary network society, marked by ‘a lack of shared codes of communication between particular identities’, museums can play a key role as ‘cultural connectors’. They can contribute, Castells proposes, to ‘the reconstruction of public space’ and become ‘spaces of cultural innovation and centres of experimentation’, where people learn to communicate through shared experiences. The design of museum space can create the conditions that allow for individual perceptions, feelings and thoughts, and, at the same time, for staging a coming together, a collective experience. As argued by Basso Peressut (2015, p.103), the museum is now in parallel a piazza and a room (stanza), a public environment and a private space. Or, Using Olafur Eliasson’s words (2010), ‘we individually share the museum’.
REFERENCES


ABSTRACT
Over the past decade, there has been a growing awareness of architectural and spatial design in the functioning of museums and the creation of distinctive visitor experiences. This issue has itself become more complex as digital technologies offer new potentials to mediate between museum content and visitors, and in particular technologies which have the capacity to amplify senses and facilitate interactive, whole body, immersive and sensorial experience. The paper will explore for the first time the role of spatial layout in the sensory environments created through digital media in museums. Among the key questions raised are: how are they integrated into the museum itinerary spatially and conceptually? In what kind of spaces are they installed and how do they relate to them? Are they arranged so as to exploit key spatial properties? We investigate these questions initially through the identification and review of existing experimental projects, and then through the in-depth study of examples of the museum work of two well-established creative studios which combine architecture and interaction: Jason Bruges Studio and United Visual Artists. The analysis is based, on the one hand, on interviews with the designers involved in their creation and, on the other, on syntactic concepts and techniques. By looking in parallel at the work of the two studios, from their first installations until now, and through syntactic analysis, we unravel the way these projects become integrated in the museum, both in literal terms (spatial positioning) and in metaphorical (curatorial practice). The analysis shows that as these works become with time more symbolic, they also become less intrinsically spatial and their experience less dependent on movement. More interestingly, it brings to surface aspects of the design of digital sensory environments which have a relation of correspondence with syntactic properties, such as integration, and types of space. Having shown that space plays a key but variable role, the paper ends by proposing a model for the spatial understanding of these novel technology-mediated experiences and for rethinking museum space.

KEYWORDS
digital environments; museum spatial layout; interaction design; configurational analysis; space types
1. INTRODUCTION

Over the past decade, there has been a growing awareness of architectural and spatial design in the functioning of museums and the creation of distinctive visitor experiences. This issue has itself become more complex as digital technologies offer new potentials to mediate between museum content and visitors, and in particular technologies which have the capacity to amplify senses and facilitate interactive, whole body, immersive and sensorial experience. The paper will explore for the first time the role of spatial layout in the sensory environments created through digital media in museums. The aim is to contribute to a spatial understanding of their embedding in museum settings since they constitute curatorial challenges, in the sense that the exhibit is multimodal and there is no established knowledge about its arrangement or precedents to learn from. So key questions raised are: how are digital sensory environments integrated into the museum itinerary spatially and conceptually? In what kind of spaces are they installed and how do they relate to them? Are they arranged so as to exploit key spatial properties?

Here we present the first part of ongoing research in a field that is developing rapidly, though it is still largely underexplored from an architectural-spatial and museological-curatorial points of view. More precisely, we seek to investigate these key questions through examples of the museum work of two well-established creative studios: Jason Bruges Studio and United Visual Artists (UVA). After a discussion, in the first part of the paper, of the background and context of these digitally mediated experiences, including an identification and review of existing experimental projects of interest in this context, we focus, in the second, empirical part, on the analysis of the main case studies. The analysis is based, on the one hand, on interviews with the designers involved in their creation and, on the other, on syntactic concepts and techniques. By looking in parallel at the work of the two studios, from their first commissions in 2005 until now, and through syntactic analysis, we unravel the way they become integrated in the museum, both in literal terms (spatial positioning) and in metaphorical (curatorial practice). The comparative analysis brings to light a key shift from the playful digital experience which is independent of the museum narrative, to the informative which accompanies other exhibits and communicates semantic information. More interestingly from a syntactic point of view, it shows that as works become more symbolic, they also become less intrinsically spatial and the creation of experience less dependent on movement. The paper argues that, in our sample, aspects of the design of digital sensory environments have a relation of correspondence with syntactic properties, such as integration, and types of space, and relates these underlying correspondences to space syntax theory. Having shown that space plays a key but variable role, the paper ends by proposing a model for the spatial understanding of these novel technology-mediated experiences and for re-thinking museum space.

2. BACKGROUND AND CONTEXT

Since 2000, technologies, situated and mobile, have become part of most museum displays, not only as interpretative tools – for example, interactive touch-screen kiosks accompanying objects, or multimedia guides on portable devices – but as the exhibit and the key experience itself, for example by offering immersive and embodied mediated interactions. Emerging technologies tend to be creatively embraced by museums open to experimentation and exploring new possibilities. The fast growing area of tangible and embodied digital interaction, for example, has opened up new ways of mediating between visitor and content by breaking away from the screen, and developing instead more physical ways of interacting with computing (Hornecker, 2011). A wide range of systems based on embodied interaction, full body movement and tangible manipulation, are now designed in museums, at scales ranging from tangible interactions to immersive experiences. To cite just a few indicative examples in the increasingly growing range of projects: in ‘The Hague and the Atlantic Wall’ exhibition (2015) in Museon, The Hague (part of the meSch project – see below), an additional layer of narrative content was proposed by the use of ‘smart objects’ – that is, crafted reproductions of original objects related to the exhibition and embedded with digital content – that were activated by visitors when placed on hotspots; in an innovative installation based on gestural recognition, visitors to the UCL Petrie Museum (2012), manipulated 3D replicas of objects from
the museum collections through body movement in an Augmented Reality environment (Fatah gen. Schieck and Moutinho, 2012); at a different scale, in the Museum of the Palazzo Valentini, Rome (2010), which is not a purpose-built museum, but an archaeological site, technologies (virtual reconstructions, graphics and videos) are used to recreate the site’s architectural and social past; in the Rockheim, in Trondheim (2010), the national museum of popular music of Norway, visitors engage with museum content through interactive and immersive exhibits, ranging from touch screens to motion-sensing interaction and whole body movement; while a series of connected immersive sensory environments and interactive experiences evolve in real-time through visitor presence and participation, in the Future World, Art Science Museum, recently (2016) opened in Singapore.

The attempt to better understand the design of digitally mediated experiences, their functioning and their effects on museum visits, is reflected in an expanding body of literature in different fields, in particular human-computer interaction (HCI) and interaction design, and museum studies. Among the key issues raised we could distinguish indicatively: how technologies are used to represent culture and promote cultural heritage (see MeLa–European Museums in an age of migrations, and RICHES–Renewal, Innovation and Change: Heritage and European Society); how they influence the ways in which visitors examine and experience exhibits (e.g. vom Lehnn and Heath, 2009), allow personalised storytelling experiences (e.g. CHESS–Cultural Heritage Experiences through Socio-personal interactions and Storytelling), and enable co-designing by developers as well as stake-holders (e.g. Material EncounterS with Cultural Heritage–meSch); how they affect the social dimensions of the visit (Jafari, Taheri and vom Lehnn, 2013); what kind of usability issues and behaviour patterns they generate (e.g. Clarke and Hornecker, 2013), including evoking shyness in visitors (Scott et al., 2013); how visitors engage with digital content, ‘how interactivity as a medium produces meaning’ (Edmonds, 2006), ‘how the audience interacts with it’, and ‘the experience and the degree of participant’s engagement’ (Edmonds, 2010).

Interactive digital installations in museums and galleries are also increasingly discussed in the literature (see for example Bullivant 2006; 2007). But so far little research has been done in bringing together knowledge of digital interaction and museology by looking at both from a spatial point of view. Yet the problem of space is seen as a key parameter in the creation of the experience as well as its understanding. It is argued, for example, that the spatial dimension has an essential role in ‘the meaning-producing capacity of computer-based interactivity’. ‘The generation of meaning’ lies, it has been suggested, not just in interactivity in an abstract sense but in situated interactivity, and so ‘the site of exhibition can be seen... not as an auxiliary space for understanding certain aspects of an artwork, such as its social or practical implementation, but the central site for interactive art research’ (Edmonds, 2006, p.312). Research has also demonstrated that certain spatial characteristics of accessibility and visibility are more likely to bring visitors into contact, and perhaps engage them, more than others (Kortek and Grønbæk, 2008, p.616).

3. METHODOLOGY, KEY CONCEPTS AND TERMS

Reflecting this situation, we are interested in investigating the role of spatial layout in digital interaction through the first hand study of what we will call digital sensory environments in museums. This is not among the more commonly used terms, which include responsive environments or responsive installations (Bullivant, 2007, p.37), interactive spatial multimedia (Kortek and Grønbæk, 2008) or spatial interactive works (Bullivant, 2007, p.35). But using this term we seek to emphasise the idea of environments which both ‘inspire our sensory perceptions’ and are created through digital media. The ‘Poème Electronique’ along with the Philips pavilion, designed by Le Corbusier and Iannis Xenakis, for the Expo ‘58, Brussels, has been held to be their historical precedent in modern times: ‘the first electronic-spatial environment to combine architecture, film, light and music to a total experience made to

1 In contrast, the spatial environment’s role is explicitly discussed in media architecture literature (see for example Dalsgaard, Halskov and Nielsen, 2008; Dalton, Marshall and Dalton, 2010; Behrens, Fatah gen. Schieck and Brumby, 2015).
function in time and space’ (Lopez, 2001). The digital sensory environments discussed in the paper are designed by two London-based studios, Jason Bruges Studio and United Visual Artists (UVA). The analysis is based initially on semi-structured interviews with Jason Bruges and Alexandros Tsolakis, Head of Design and Development, UVA, combined with research in relevant literature and documentation of projects, and, in some cases, first hand study of the works. This is then followed by spatial analysis. We use the syntactic concepts of integration, axiality and visibility as qualitative measures to describe the configurational properties of digital sensory environments and provide a theoretical framework for spatial interpretation. This is coupled with the representation of the museum layouts as schematic graphs in order to make clear their positioning in the global spatial organization, and with space type analysis. By distinguishing spaces as four types (a-, b-, c- or d-spaces) in terms of how they are connected to the layout of which they form part (Hillier 1996), we capture key properties of spaces, which, as it will be shown, relate positively to aspects of the design of digital sensory environments.

Before moving to the presentation of the cases studies, a clarification of two additional key terms as used in the paper for proposing a taxonomy of the case studies (see below and Table 1) is needed. As often argued (Manovitch, 2001, p.71; Haque, 2007), ‘interactive’ is a ‘too broad concept’, and used in different ways, so here we employ attributes of interactivity – the notions of Dynamic, Interactive, Participatory, Communicative and Performative – proposed by Caldwell and Foth (2014) as characteristics of media architecture, and ‘understood as qualities that can occur in parallel or alongside one another’. We also adopt the concept of interaction styles, and in particular, movement, touch, or none, proposed by Dalsgaard, Halskov and Nielsen (2008).

4. DESCRIPTION OF CASES

The case studies are presented in chronological order and their key features, which form the background for the comparative analysis that will follow, are summarized in Table 1.

<table>
<thead>
<tr>
<th>PROJECT</th>
<th>INTERACTION DESIGNERS</th>
<th>DATE</th>
<th>MUSEUM</th>
<th>LOCATION</th>
<th>SPACE TYPE</th>
<th>VISUAL RELATIONS</th>
<th>AXIAL RELATIONS</th>
<th>ATTRIBUTES OF INTERACTIVITY</th>
<th>INTERACTION STYLES</th>
<th>CONCEPTUAL RELATION TO MUSEUM NARRATIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corey Duvvur</td>
<td>Jason Bruges Studio</td>
<td>2001</td>
<td>Tate Britain, London</td>
<td>indoor</td>
<td>c</td>
<td>axial</td>
<td></td>
<td>Dynamic, Interactive, Participatory</td>
<td>Touch</td>
<td>Independent, playful experience</td>
</tr>
<tr>
<td>High Arctic</td>
<td>UVA</td>
<td>2012</td>
<td>National Maritime Museum, Greenwich</td>
<td>gallery space</td>
<td>a</td>
<td>visual, auditory, moving, spatial, link</td>
<td>Dynamic, Interactive, Communicative</td>
<td>Body movement, UV, touch</td>
<td>Independent, communicating climate change awareness</td>
<td></td>
</tr>
<tr>
<td>Momentum</td>
<td>UVA</td>
<td>2014</td>
<td>Cork Gallery, Cork, Ireland</td>
<td>gallery space</td>
<td>c</td>
<td>visual, auditory, moving, spatial, link</td>
<td>Dynamic, Communicative</td>
<td>None</td>
<td>Independent, inspired by the concept of time</td>
<td></td>
</tr>
<tr>
<td>Orate</td>
<td>UVA</td>
<td>2010</td>
<td>ZKM, Germany, Darmstadt</td>
<td>gallery space</td>
<td>a</td>
<td>visual, auditory, moving, spatial, link</td>
<td>Dynamic, Communicative</td>
<td>None</td>
<td>Independent, inspired by the concept of time</td>
<td></td>
</tr>
<tr>
<td>The Great Arctic Orchestra</td>
<td>UVA</td>
<td>2016</td>
<td>Fondation Cartier, Paris</td>
<td>gallery space</td>
<td>a</td>
<td>visual, auditory, moving, spatial, link</td>
<td>Dynamic, Communicative</td>
<td>None</td>
<td>Information experience part of the museum narrative</td>
<td></td>
</tr>
<tr>
<td>Scen Constellation</td>
<td>Jason Bruges Studio</td>
<td>2008</td>
<td>La Grande Musique, Paris</td>
<td>gallery space</td>
<td>a</td>
<td>visual, auditory, moving, spatial, link</td>
<td>Dynamic, Communicative</td>
<td>None</td>
<td>Information experience part of the museum narrative</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 - Taxonomy of our main case studies, the museum work of Jason Bruges Studio and United Visual Artists, summarizing their key features
4.1 ‘DOTTY DUVEEN’

One of the earliest cases is the temporary installation ‘Dotty Duveen’ (Figure 1a) designed by Jason Bruges Studio for Tate Britain: an array of 40 wands, each two meters high, with a glowing sphere at the top that turned on only when the rods were touched and bent. It was installed in the central space (Sackler Octagon) of the Duveen Galleries. A second part of the installation involved tracking the interaction throughout the day. The resulting video provided an overview of the different movements occurring within this open circulation space. The design intention was, on the one hand, to engage visitors to touch these ‘moving playful objects’ and, on the other, to interrogate the space from above, seeing ‘how the space changed’, and how the ‘landscape of objects’ shaped visitors’ movements and interactions as well as their interrelationships with other visitors interacting with the objects.

![Figure 1 - 'Dotty Duveen' (2005) (a), and 'Mirror Mirror' (2009) (b), ©Jason Bruges Studio](image)

4.2 ‘MONOLITH’

In 2005 United Visual Artists designed ‘Monolith’ (Figure 2a) in the John Madejski garden of the Victoria and Albert Museum: a single block of LEDs (3 m. high), showing soothing colours and playing calming sounds. The pattern changed as visitors approached the installation, with the colour and sounds becoming louder and harsher. The simplicity and minimalism of its design was intended to create a contrast with the complexity of its visual background, the baroque museum building.

4.3 ‘VOLUME’

A year later, United Visual Artists created a larger installation, ‘Volume’ (Figure 2b), for the same space. It took the form of a grid of 48 luminous, sound-emitting columns (2.5m high) that responded to visitors’ movement, creating a series of audio-visual experiences. It was positioned in the centre of the garden and visitors could walk through this ‘sculpture of light and sound’, while lack of movement deactivated it. The whole configuration of columns and people was analysed by a digital camera with its own image-processing computer, placed high up in the courtyard, and complex emergent patterns were generated depending on the individual's path through the installation, as well as on the movements of people co-present around him or her.

4.4 ‘MIRROR MIRROR’

In the same space, the John Madejski garden, Jason Bruges Studio designed ‘Mirror Mirror’ (Figure 1b), as part of the 2009 exhibition ‘Decode: Digital Design Sensations’, showing the latest developments in digital and interactive design, from small screen-based graphics to
large-scale installations. Works were organized in three themes – ‘Code as Raw Material’, ‘Interactivity’ and ‘The Network’ – reminders of their characteristics, with ‘Mirror Mirror’ being part of the ‘Interactivity’ theme. A group of light panels, each containing a camera, were disposed in the pond of the garden, ‘in a pseudo-random arrangement’ (Jason Bruges, as cited in Victoria and Albert Museum, 2009), giving the impression of floating on the water. At a global level, the work was installed on the central axis of the building, so that it could be seen from the entrance through the museum shop. At the local scale of the garden, the panels were laid out so that each panel would see a different part, so as to give ‘a complete view of the whole space but fragmented across the different nodes’. The camera recorded movement, ‘giving back the visitor a different media visual feedback’, also reflected on the surface of the water. Thus the animated images created multiple reflections, becoming an expression of its design concept, of digital narcissism and the individual’s relationship with space, water and others.

Figure 2 - ‘Monolith’ (2005) (a), and ‘Volume’ (2006) (b), ©United Visual Artists

4.5 ‘HIGH ARCTIC’

To inaugurate the new Sammy Ofer Wing, and a new kind of exhibition, the National Maritime Museum, London, presented in 2011 the ‘High Arctic’ exhibition (Figure 3), designed by United Visual Artists. The exhibition was an immersive, responsive environment that filled an entire 820 square metre open space. It used a combination of sound (both soundscape music and voices), light in a dark environment, animations and 3000 sculptural ‘glaciers’ of different height, each representing a real glacier in Svalbard, to create a vast abstracted arctic landscape, set in 100 years in the future. As physical forms were integrated with digital projection, visitors were invited to explore the landscape using ultraviolet light torches, that allowed them to reveal hidden animations (for example, to activate the name of the glacier), to generate constantly shifting patterns of graphics and text on the floor that reacted to movement and interaction with the torch. An artificial horizon bordered the gallery as a seamless canvas of light, shifting in intensity and colour. An important part of the narrative were the voices of Arctic explorers and a commissioned poem about our relationship with the Arctic since the first explorers in the fourth century. The installation was conceived as a response to the UVA’s founder Matt Clark trip to the archipelago of Svalbard (between mainland Norway and the North Pole), together with a group of scientists, poets, musicians and artists, organized in 2010 by the arts and climate science foundation Cape Farewell. The aim was to provoke awareness, through the engagement of artists, to issues of climate change and human impact to the arctic environment.
4.6 ‘MOMENTUM’

The work ‘Momentum’ (Figure 4a) was created by United Visual Artists, in 2014, for the Curve Gallery of the Barbican Centre: an immersive installation carefully choreographing a sequence of light, sound and movement. The work continued a path set out by their previous work, ‘Chorus’ (2009), but it was redesigned to respond, both technically and conceptually, to the morphology of the tall and narrow space of the 90 metre long gallery. It consisted of a sequence of 12 pendulum-like elements (with changing white lamps), suspended from the ceiling, and swinging back and forth, sometimes moving in unexpected ways or even stopping, emitting sound and light and projecting shadows and planes of light across the walls and floor, in the completely dark gallery and misty atmosphere. ‘The sound was individual to each pendulum, prepared and tuned to seamlessly resonate as they moved within the Curve’ (Barbican, 2014). The arc shape of the gallery also inspired the theme of the work, the concept of time, and in particular the subjective experience of the passing of time, while the calming and contemplative environment created by the work (Brown, 2014) was intended to contrast with the surrounding urban environment and the hectic life in the City of London. It is of particular interest in our context that visitors’ comments (in Twitter), after their visit, consistently refer to their individual experience linked to their emotions and memories (for example, ‘Mesmerised and calmed by at points I was thinking about the sea...’; ‘this is how my dreams feel sometimes repeating the day I just had’), rather than the inherent qualities of the work. This has been related to the idea that ‘the more abstract the space the more people create their own, imaginative environment’.

4.7 ‘OUR TIME’

A variation within the series of kinetic sculptures that began with ‘Momentum’ and the theme of time, is the larger-scale installation ‘Our Time’ (Figure 4b) that United Visual Artists created, in 2016, for the Museum of Old and New Art (MONA), in Hobart, initially presented in the context of an annual festival and then integrated into the museum collection. ‘Our Time’ was installed in a vast square space, and defined a physical environment where 21 suspended LED pendulums, arranged in a grid, swing, each to its own rhythm, activating light and sound. Like ‘Momentum’ it was designed to be ‘a meditative, quiet piece but at the same time... very dramatic because of the sheer scale’ (‘Our Time’).
4.8 ‘THE GREAT ANIMAL ORCHESTRA’

An installation that was a response to a specific exhibition theme was created by United Visual Artists for the Fondation Cartier, Paris, in 2016. ‘The Great Animal Orchestra’ (Figure 5) was part of the exhibition that devoted to the work of musician, bio-acoustician and scientist Bernie Krause, who had been recording animals, ‘amassing a collection of more than 5,000 hours of sounds recordings of over 15,000 individual species in their natural habitats from all over the world’ (‘The Great Animal Orchestra’). The immersive installation gave a three-dimensional form to the recordings, through, among other things, soundscapes and spectrograms that created an abstract visual landscape and proposed an interpretation of the various locations and times of day that Krause made the original recordings, using two different kinds of spectrographic imaging. The work was installed in the basement space of the Fondation Cartier, with the left side showing ‘a dance of horizontal lines occupying different frequency bands in real time as Krause’s recordings play’ (Barry, 2016), and the right, ‘a more static ‘recorded’ image, like a print-out, from which one can grasp Krause’s point: the high tweets of the pine siskin at 6khz will not be troubled by the 1khz call of the American crow, nor the even deeper howls of the eastern wolf’. 
4.9 ‘SCENT CONSTELLATION’

Also in 2016, the Jason Bruges Studio was invited to create a work in response to a display narrative. ‘Scent Constellation’ (Figure 6) is a permanent installation at Le Grand Musée du Parfum, in Paris, opened in December 2016 and located in a mansion. The museum display is organized in three sequences, on different floors, with the ‘Scent Constellation’ being part of the last sequence, ‘The art of the perfumer’, on the third floor. The work recreates the perfumer’s organ and is intended to visualise the process of creating a scent. Five types of scent families are represented, and each generic recipe was represented as a constellation of light using white laser and mist, with corresponding sounds.

5. COMPARATIVE DISCUSSION

5.1 FROM A SPATIAL-SYNTACTIC POINT OF VIEW

If we first look at our cases comparatively from the point of view of their spatial arrangement in the museum setting, we find a variety of locations. More interestingly perhaps, we note a shift from movement and social spaces (main axis, garden), in the first examples, to the single and flexible open space for temporary exhibitions (Curve, Sammy Ofer Wing) and to the gallery spaces themselves (in the latest works, as in Le Grand Musée du Parfum).

This said, it is possible, on the basis of our sample, to distinguish three approaches in the way the majority of the cases take into account their spatial setting: morphologically, visually or conceptually. The morphological approach can be illustrated by ‘Momentum’ which works with the architecture, as light is projected on the walls and sound reflected off them. The predominantly visual approach is exemplified by the three works installed in the V&A garden. They create a play with the contrast of simplicity-complexity (see 4.2 above) and with the reflective qualities of the water, in particular ‘Mirror, Mirror’ which was designed so that through each mirror’s orientation and placement the whole court is collectively covered. Finally, we find cases where space becomes a conceptual inspiration either for the design idea (e.g. relating the arc shape gallery with the sense of time in ‘Momentum’) or for broader metaphorical relations (e.g. linking the calm gallery space with the hectic urban environment, also in ‘Momentum’). In the remaining cases, either space is treated as the neutral background for the works (as in ‘The Great Animal Orchestra’ and in the ‘Scent Constellation’) or the work itself creates the space for visitors to explore (as in ‘High Arctic’).
Space syntax concepts and techniques allow a deeper understanding of the configurational position of the works (see schematic graphs of layouts in Figure 7). The first four examples (1-4) are located in the centre or on the main axis of the museum, in strategic locations both in terms of spatial and visual links. The Sackler Octagon, in the middle of the Duveen Galleries, for example, is a d-space (offering route choice) and among the most highly integrated locations of Tate Britain (Figure 8a). The Madejski Garden is a well connected c-space (offering circulation but not choice) related to main rings of circulation in the V&A and on the main axis linking the museum entrance with the galleries. Intriguingly, the opposite is the case in the later examples. They tend to be created in a-spaces (dead-end spaces, without through movement) and found in relatively segregated locations in the layout. For example, the ‘High Arctic’ (5) and ‘The Great Animal Orchestra’ (8) are a-spaces on the underground floor of the museums. The ‘Scent Constellation’ (9) is on the third floor, in a space that essentially functions as an a-space since it constitutes the end of the display sequence. At first sight ‘Momentum’ seems to be an exception since the Curve Gallery that accommodated it is a c-space. However, the fact that it is an individual exhibition space, in a complex of spaces of different functions, gives it the separated nature of an a-space. In all these cases, the digital sensory environments are created in enclosed, ‘black box’ spaces which do not encourage visual relations with neighbouring spaces (compare the spiky visibility pattern of ‘Dotty Duveen’ in Figure 8a with the convex hierarchical pattern of the ‘Scent Constellation’ in 8b). It is worth noting that this emerging emphasis on a-spaces can be related to the findings of a previous syntactic study (Tzortzi and Hillier, 2016), which showed that this type of space is favoured for the display of performing arts collections because of its enclosed, static (rather than movement oriented) and immersive nature.
5.2 FROM A MUSEOLOGICAL-CURATORIAL POINT OF VIEW

If we now consider our cases in terms of their conceptual relation with the museum display, we find that in the majority of cases (1-7), works are created independently of the museum narrative (e.g. ‘Dotty Duveen’, ‘Volume’, ‘Momentum’) and ‘the source of meaning [lies] in situated action itself’ (Edmond, 2006, p.311). That is, meaning is created by exploring the sense of being there and is based on individual perception and experience. The works in the V&A garden, for example, invite visitors to explore an evolving composition of light and sound, shaping, through their movement, their individual experience. ‘Momentum’ and ‘Our Time’ also create spatial, visual and acoustic patterns that constitute meaning in themselves, but in this case independently of visitors’ movement. ‘High Arctic’ marks a shift in the sense that it makes complex patterns that are meaningful in that they substitute for the museum objects.

Strikingly, a diametrically different approach is adopted by the more recent works in that they have a close relation to the dominant display narrative. Both the ‘Scent Constellation’ and the ‘Great Animal Orchestra’ are created to accompany other exhibits and support a pre-existing idea (the perfumer’s organ) or data (Krause’s recordings). So they become an integral part of the museum itinerary. Interestingly, in both cases the visitor experience is more ‘static’, compared to the previous cases, and the creation of meaning not dependent on movement.

5.3 FROM AN INTERACTION DESIGN POINT OF VIEW

If we finally focus on key aspects of the design of these digital sensory environments, we note that they all define a physical environment and create experiences where ‘the proprioceptive, sensory, intellectual, aesthetic and social’ are interrelated for the visitor (Levent and Pascual-Leone, 2014, p.xiii). The environments created are mainly visual and sonic spaces, in one case combined with tactile exploration. From the point of view of interactivity, and drawing on Caldwell and Foth’s attributes of interactivity (see above), their quality in terms of how they are used could be described (see Table 1) as Dynamic (in all the cases), Interactive (1-5), Performative (that is, promoting performance from visitors, as in ‘Volume’ and ‘Our Time’) and Communicative (related to the transmission of semantic information, as the more recent cases 5-9).
If we focus on the interaction styles, visitors’ movement (touching, moving or stopping) is critical in the earliest cases, and aims initially at an enjoyable experience (1-4) and later at a meaningful result (5). No interaction with visitors is ‘required’ in the more recent works (6-9) and the experience becomes with time less dependent on visitors’ movement (compare e.g. cases 6-7 with 8-9). But, in spite of these differences, the works consistently, tend to create experiences which are immersive – to a higher or lesser degree – and amplify visitors’ physical and sensory realities.

6. THE ROLE OF SPACE IN THE DIGITAL SENSORY ENVIRONMENTS IN MUSEUMS: A SYNTACTIC ARGUMENT

So both in spatial-syntactic and museological-curatorial terms (or in terms of integration into the museum itinerary spatially and conceptually), we find a range of case types which seem to have an evolutionary dimension, as shown in our two-dimensional model (Figure 9).

Figure 9 - The works of the sample on the spatial-syntactic and museological-curatorial model grid. In the spatial (horizontal) axis, the cases range from the 'integrated and d-spaces' to the 'segregated and a-spaces'. In the curatorial (vertical) axis, a playful or an informative experience are the two opposite poles of the continuum.

More specifically, it could be argued, looking at the cases chronologically, that we observe a series of shifts:

- from the playful to the informative experience, and from the primary embodied experience to that accompanied with an intellectual narrative;
- from the spatially independent digital sensory environment to the integrated into the museum itinerary;
- from the temporary installation to the installation that becomes part of a museum collection;
- from the weak design brief (designers are given a space to create an experience) to the strong brief (describing the message to be transmitted).

These arguments could perhaps be clarified by using the concepts, established by Basil Bernstein (1975), of ‘classification’ – meaning the strength of the boundaries between contents of knowledge – and ‘framing’ – the control of transmission from teacher to taught. In our context, ‘strong classification’ implies controlling the relations between exhibits to reflect pre-existing meanings, and ‘framing’ is strengthened through the control of spatial and visual relations connecting spaces. In these senses, the shift from the playful to the informative is

2 For interpretations of the two concepts in syntactic literature, see for example Pradinuk, 1986; Zamani and Peponis, 2010.
7. CONCLUDING REMARKS AND FUTURE DIRECTIONS

This study and analysis of the museum work of the two major creative studios, from their first installations in museums until today, contributes a significant finding about the role of spatial layout in the emerging design field of digital sensory environments. It suggests that space not only has a key role to play in our digital era, as acknowledged in the literature (see above), but that this may be a highly variable role.

More specifically, the analysis brings to light a relation between space, people and digital interaction, in the form of correspondence between spatial layout design and the design of digital sensory environments. Playful experiences are created in integrated locations and in movement spaces (d- or c-spaces in syntactic terms) which support and generate movement. Informative experiences are created in segregated (deep from the entrance or outside the main route) spaces and in particular in a-spaces, which, by being distant from through-movement, privilege a more static immersion. Playful experiences are to be enjoyed in themselves and not through any communication they offer, as is the case with the informative experiences. In the former, the visitor is active in creating patterns through movement interaction. In the latter, the visitor is receptive, and space, by controlling movement, supports that. These underlying correspondences can be related to findings of space syntax theory. For example, in domestic space we often find a distinction between spaces for everyday interaction and spaces for special occasions (see Hillier and Hanson, 1984). In simple terms, integrated spaces let things happen, while segregated spaces, where we find more order, are about defining things.

These observations about a development over time are of course related to the study of the museum work of the two studios. It will be interesting to follow future developments in the creation of digital sensory experiences in museums, taking this proposed model as a foundation and as a comparative framework for spatial understanding, of interest to all three fields of knowledge involved: museum studies (new curatorial challenges), and space syntax and human-computer Interaction (a new kind of findings relating spatial design and interaction design).

Taking a more distant view of our cases, it is clear that digital sensory environments can bring back the aura of the museum exhibit, by creating singular experiences that must be lived at that time and space. No less interesting are, in many cases, the ways they enhance the sense of shared space and collective experience, since it is about experiencing in individual ways but together, in the company of other visitors, who become part of the experience itself. Lastly, and spatially speaking, they invite us to rethink museum space, by augmenting physical space perceptually, replacing it, interacting with it, complementing it, in short, by adding through digital interaction a new richness of perception and embodiment.

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‘Momentum’, http://uva.co.uk/works/momentum
‘Our Time’, http://uva.co.uk/works/our-time
‘The Great Animal Orchestra’, http://uva.co.uk/works/great-animal-orchestra
A CONFIGURATIONAL APPROACH TO VERNACULAR DOMESTIC ARCHITECTURE
‘Traditional’ Houses in Turkey, Japan and Britain

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ABSTRACT

Most vernacular and traditional buildings are considered as ‘timeless’ meaning that their forms and styles are accepted as ‘objects’ that do not change over time. This leads to rigid definitions of domestic architecture by assigning definite cultural meanings to physical forms. While vernacular domestic spaces naturally represent the culture and society that they are constructed in, where these are interpreted in the light of fixed notions of ‘culture’ and ‘tradition’, the possibility that ‘vernacular’ does not necessarily mean ‘timeless’ or ‘unchanging’ is left unexplored.

This paper re-examines the boundaries of nation-specific ‘vernaculars’ through a comparative cross-cultural analysis of traditional housing. It interrogates the use of notions such as ‘culture’ and ‘tradition’ in vernacular housing typologies in Turkey, Japan and Britain in order to provide a better understanding of ‘the vernacular’ as a dynamic concept in domestic architecture. It proposes a comparative interpretative framework for studying the vernacular by considering how the relationship between the social and spatial patterns is shaped under diverse regional and historical conditions. This approach raises questions for conventional definitions of the ‘vernacular’ by analysing similarities as well as differences between the different traditions.

The research applies space syntax methodology to 30 different vernacular housing examples built between 17th and 19th centuries in different regions of Turkey, Japan and Britain, each held to represent the ‘national’ values and traditions of their particular culture. The results of the analysis show how the traditional typological approach to housing forms remains insufficient to fully understand vernacular architecture, since it tends to elide differences in social mores and the use of domestic space into a single ‘vernacular’ tradition. Overall, this study shows how the conventional classifications of vernacular architecture depending on cultural and national traditions do not go much beyond creating normative statements that are mainly taken for granted. By contrast, the research presented here proposes the ‘vernacular’ as a fluid, rather than a fixed description of national traditions of domestic architecture.

KEYWORDS
Tradition, Culture, Vernacular Architecture, Domestic Architecture, Space Syntax
1. INTRODUCTION

Conventional studies of vernacular domestic architecture tend to classify spatial forms based on predefined notions such as the ‘tradition’, ‘culture’ and ‘nation’ in which they were built. This results in domestic spaces being labelled reductively as physical end products of their societies and geographies. The relation between vernacular architecture as cultural representation and as spatial form itself remain vague and inadequately understood to do justice to an important area of research in understanding the relationship of society and space. The research framework deployed here investigates the extent to which qualitative categories of ‘traditional’ and ‘vernacular’ architecture correspond with the configurational properties of ‘vernacular space’. The uncertainties involved in translating the vernacular as a generic normative idea into a particular physical form are analysed through quantifying the configurational description of key vernacular statements around culturally-defined notions such as ‘privacy’, ‘flexibility’ and ‘introverted-ness’ within a range of selected case studies.

The idea of ‘tradition’ can be broadly summarised as the continuity of habits and attitudes that are transmitted through successive generations within the same community. Similarly, the notion of ‘culture’ represents ‘the ideas, customs, and social behaviour of a particular people or society’ (Oxford Dictionary). Arnold (1869, p.11) describes ‘culture’ as a ‘study of perfection’ rather than deriving its origins from curiosity. The distinctions made between different groups on a cultural basis are said to be the results of human minds’ idealisation. Gellner (1988, p.123) claims that, ‘Clearly, the nature of the customs and beliefs acquired is variable and non-genetic, but the capacity to acquire them does seem to be part of human nature.’ This approach follows Gellner in understanding ‘culture’ as non-genetically transmitted codes that result in definite social reproductions. The concept of ‘nation’ represents the sum of political communication and mobility that is created between people in a society where they share the same ‘culture’. Benedict Anderson (1986, p.6) claims that ‘nation’ is ‘an imagined political community – and imagined as both inherently limited and sovereign.’ In that respect, he questions the authenticity of the ‘nationality’ concept where the individuals of a society become a part of a nation not because it emerged ‘naturally’, but through various historically specific necessities and reasons behind its invention. These ideas suggest why it worth considering the extent to which the idea of vernacular has been ‘invented’ concepts in national contexts seeking to assert a degree of social continuity.

The flexibility of the concepts of ‘tradition’, ‘culture’, ‘nation’, and the fixity in the ways in which these have been applied to the study of the built environment is notable. This study, by contrast, approaches the built environment through a more flexible conceptual framework that allows the formal spatial description of a building to be relatively independent of any normative statement regarding its origins. The spatial analysis presented here is particularly focused on ‘vernacular’ architecture where the term ‘vernacular’ signifies regional, small and ordinary buildings that are mainly designed anonymously. Domestic vernacular architecture therefore is selected to analyse the ordinary homes of ordinary people in a range of cultural contexts.

Architectural interest in ‘vernacular architecture’ emerged following the immediate consequences of the Industrial Revolution of the nineteenth century. Johnson (2010, p.4) argues that the emergence of new lifestyles and migration to urban centres during this period evoked the fear of losing ‘tradition’ within the community. Today, the conventional approach to vernacular architecture suggests focusing on cultural and social properties in order to define the ‘traditional’ built form of a society. Rapoport (1969, p.16) claims that; ‘The question, in effect, is concerned with how changes in culture, expressed in behaviour, relate to changes in the environment, as shown by physical form.’ This approach suggests a perspective on architecture as an ‘object’ or a ‘product’ that reflects society. In contrast to being merely objects, other studies suggest that the built environment can be regarded as systems of relations that accommodate social behaviours and cultures. Levi-Strauss in ‘Structural Anthropology’ (1963) focuses on human behaviours as systems of structures. Relating the notions ‘culture’ and ‘language’ he argues that regardless of their differences there is a common structural system behind every culture in all societies. A similar approach is reflected in Bourdieu’s ‘Kabyle House’ (1977) through the spatial arrangements of a domestic house and its impacts on socio-cultural
lifestyles of the inhabitants. These ideas focus on spatial factors as well as the social and cultural properties of a built environment.

Architecture is said by Hillier to do more than assigning specific spatial patterns to cultural types but instead it is the ‘taking into conscious, reflective thought of these non-discursive and configurational aspects of space and form, …’ (1996, p.3). This argument is developed in the context of vernacular architecture, summarised by the diagram that shows the relation between ‘a building’ and ‘architecture’ (Fig.1). According to that, vernacular buildings are considered as architectural practices that embed certain information and innovation inside. However, the reproduction of vernacular forms is not considered as part of architecture, as it is mainly focused on the ways in which these forms emerge instead of the types of forms themselves (1996, p.36). Space Syntax theory proposes a novel way to interpret vernacular architecture by analysing it configurationally rather than typologically. The approach taken in this study is to analyse ‘vernacular’ domestic spaces using Space Syntax methods in order to determine the extent to which the cultural differentiation of vernacular types is matched by configurational differentiation in spatial layouts that embed the architectural rules particular to those cultures.

2. METHODOLOGY

There have been previous domestic spatial studies within the field of Space Syntax theory, the obvious example being Decoding Homes and Houses by Julienne Hanson (1998). Also, the theory has been applied to the study of domestic architecture in particular countries. Traditional Turkish houses were analysed by Orhun et al. in ‘Spatial Types in Traditional Turkish Houses’ (1995) and ‘Socialising Spatial Types in Traditional Turkish Houses’ (1996). These studies overall have focused on the analysis of changing vernacular houses over time. These exemplify the approach taken by the majority of studies that focus on a single culture and with an inevitable emphasis on defining aspects of national tradition. As a consequence there have been fewer studies conducted in a comparative, cross-cultural framework.

This paper comprises of spatial analyses of 30 ‘traditional’ single-family houses built between 17th and 19th centuries that are equally sampled from different regions of Turkey, Japan and Britain (Fig. 2). The case studies were sampled from houses that are considered as ‘traditional’ or ‘vernacular’, at least six different regions are included in each national context. The specific
countries were chosen on the assumption that they would be strongly culturally differentiated from each other, being part of distant geographies, societies and beliefs. The individual case studies were selected from various resources in which the main focus was to identify a specific definition of a particular ‘traditional’ house in each regional context that is most prototypical of vernacular housing in that particular region. Therefore, the primary criteria for selecting the case studies consisted of their level of significance in representing ‘tradition’ and ‘culture’. Also, the anonymity of the builder, single-family occupancy, diversity in size and region played an important role in the selection process. The case studies from Turkey range from small village houses and vineyards to mansions in order to receive a wider image of the ‘typical’ configuration in this specific culture. Similarly, Japanese houses include farmhouses and merchants’ town houses also differing in sizes and regions. Lastly, British houses are selected from a variety of ‘traditional’ farmhouses, cottages and terraced houses.

The study is divided into two parts where former represents qualitative definitions of ‘traditional’ houses described in multiple historical sources and the latter involves quantitative spatial analyses of the case study plans using Space Syntax tools. The first section consists of definitions of ‘traditional’ Turkish, Japanese and British houses from which certain traditional and cultural aspects are derived and related to a spatial setting in each context. This analysis then enables further investigation of culturally predefined concepts such as ‘privacy’, ‘flexibility’ and ‘introverted-ness’ through an evidence-based analytical approach using Depth, Connectivity and Integration measures of the Space Syntax tools.

Firstly, Justified Graphs were created in which each space of the house is represented with a node and the access routes between each node as links. This analysis was then used to measure the depth between each space to all other spaces within a building. The entrance of each house is taken as a reference point in order to define the ‘deepness’ or ‘shallowness’ of each space in relation to the rest of the configuration. Also, Space Type Analysis was used to define the number of connections of each space within the configuration. Space Syntax theory classifies spaces as types A, B, C or D based on the number of links that each node possess.

Secondly, Convex and Axial Maps were used to measure accessibility and movement values of each space. Convex maps represent areas that are visible to and from all points within a single space; and Axial maps represent the longest and fewest straight lines within a spatial layout which shows the accessible routes that one could see and move from one space to another in a configuration. Space Syntax theory suggests that movement within a space can be predicted through the degree of their ‘integration’ to the whole system. (Hillier, 1996, p.98)

Thirdly, visibility measures are analysed using Visibility Graph Analysis where a pattern of visual field is created on the existing spatial layout where each grid cell represents the level of visual connectivity and integration to the rest of the configuration. Also, Isovist Areas are measured to capture the visibility area of a person in a defined sight angle and a defined point within a space. For this study, two isovist points of 360 degrees are captured within entrances and living rooms of each vernacular house.

Finally, each analysis is mainly discussed through two main quantifiable measurements that are the Integration and Connectivity values. The Integration value represents the degree to which a space is integrated globally within a configurational system. On the other hand, the Connectivity Value signifies the number of spaces that are locally connected to all other neighbouring spaces. The graphs of these analyses are presented through a colour scheme that changes from ‘red’ to ‘blue’ where the warmer colour represents the most connected and integrated values and the vice versa.
## CASE STUDIES

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<td>14</td>
<td>Kudo House</td>
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<td>Iwate</td>
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<td>15</td>
<td>Emukai House</td>
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<td>Toyama</td>
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<td>16</td>
<td>Shibuya House</td>
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<td>Yamagata</td>
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<td>Kanda House</td>
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<td>Gifu</td>
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<td>Kusakabe House</td>
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<td>19</td>
<td>Matsumoto House</td>
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<td>Yoshijima House</td>
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<td>21</td>
<td>Style Cottage</td>
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<td>Oxfordshire</td>
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<td>Birmingham House</td>
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<td>23</td>
<td>Chiners Farm</td>
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<td>Northamptonshire</td>
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<td>24</td>
<td>Estate Cottage</td>
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<td>Norfolk</td>
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<td>25</td>
<td>Hart’s Cottage</td>
<td>17</td>
<td>Dorset</td>
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<td>26</td>
<td>Fontmell Magna House</td>
<td>17</td>
<td>Dorset</td>
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<tr>
<td>27</td>
<td>Spring Cottage</td>
<td>19</td>
<td>Banbury</td>
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<tr>
<td>28</td>
<td>Old Farmhouse</td>
<td>17</td>
<td>Lanchashire</td>
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<tr>
<td>29</td>
<td>Dial House</td>
<td>18</td>
<td>Lanchashire</td>
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<tr>
<td>30</td>
<td>Green Close Farm</td>
<td>19</td>
<td>Cheshire</td>
<td></td>
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</table>

Figure 2 - The list of case studies
3. ‘TRADITIONAL’ HOUSES IN DIFFERENT CONTEXTS

The selection of the case studies in Turkey, Japan and Britain enabled the analytical focus to be around traditional housing examples from distant geographies with diverse beliefs, cultures and societies. The country-specific vernacular studies showed a great difference in terms of traditional and cultural descriptions in architecture. In that respect, Turkish and Japanese houses are represented through more specific statements, whereas the concept of a ‘traditional’ British house remains relatively less defined. However, certain cultural notions have been used and linked repeatedly to ‘traditional’ houses in these different countries by a vast amount of resources. In that context ‘privacy’, ‘flexibility’ and ‘introverted-ness’ have been addressed as the main thematic focus of this study.

A ‘traditional’ Turkish house is defined by Eldem S.H. (1954, p.16) as referring to housing types that emerged during the reign of Ottoman Empire and that spread over the empire during the 17th and 18th centuries. During these periods the majority of the houses in Turkey are believed to reflect similarities in layouts regardless of their regional, climatic or socio-economic conditions. In that respect, the living room, ‘sofa’ is described as the most important space where all the major family activities take place and it links all other rooms providing a circulation space within a Turkish house.

The second most emphasised element of a ‘traditional’ Turkish house is the room, ‘oda’ where Küçükerman Ö. (1978) relates its origins back to the nomadic lifestyle of Turks prior to settling in Anatolia. He claims that a ‘…family-based society is inherent in nomadic society’ (1978, p.29) reflecting on the similarities between the layout of Central Asian dwelling tents and the room layouts of Turkish houses. The multifunctional character of the rooms in Turkish houses are seen through the diverse use of each unit during the day and night times where the rooms are transformed daily from inward facing sitting areas to sleeping areas. As the rooms are formed around at least one common use room, ‘sofa’, where the seating area consists of inward facing fixed furniture, they are argued to be ‘introverted’. Also, the ‘privacy’ notion in a traditional Turkish house is discussed through the spatial configuration of the bedrooms and their intentional distant allocation from the main entrances where they are mainly placed on the upper floors and visually and spatially hidden. This principle of ‘privacy’ for the bedrooms can also be tested in other case studies in Japan and Britain.

A ‘traditional Japanese house’ is described as a house that reflects the conventional use of structure, materials and spatial layout principles of the 16th century architecture that is applied from diverse buildings including large royal palaces to small tearooms (Alex, 1963, p.32). Besides the spatial configuration of a Japanese house, its material and physical characteristics also give characteristic definition to this ‘traditional’ entity. In that respect, the use of modular elements as sliding walls in a Japanese house named ‘tatami’ creates flexibility to adjust the spatial configuration to accommodate multi-functional uses. According to Engel (1964, p.90) the design of a traditional Japanese house is never finished. It possesses the flexibility to grow organically since it is based on rectangular grid system. The notion of ‘flexibility’ is further explored through the cultural structure of Japanese family lifestyles.

Similar to Turkish houses, the multifunctional uses of rooms, family oriented activities and collective living rituals are also common in ‘traditional’ Japanese houses. Given the fact that many rooms in Japanese houses can be expanded and connected to each other through sliding tatami units, the whole house can be interpreted as one single space that is closed to outer world but open to the interior (Engel, 1964, p.230). However, the relation between the indoor and outdoor is also emphasised by the Japanese Zen belief suggesting that nature is an inseparable element of domestic lifestyle and therefore its use is essential to traditional domestic space. Harada (1954, p.55) claims that, ‘No house is considered complete without a garden of some sort, and the garden is almost an integral part of the house.’ In that regard, open spaces in traditional Japanese houses is suggested to have a key role in integrating interior spaces with nature.

In comparison with the previous case studies, a ‘traditional British house’ remains harder to define through a specific period or location, as there are various housing types described by
different sources based on regional differences. Peter Guillery (2011, p.1) argues that ‘In British architectural history the word vernacular has tended to evoke a narrow range of stereotypical forms and features – cruck frames, cross passages, scarf joints and the like.’ Therefore, it is mainly described in a structural context rather than cultural, where vernacular houses are classified based on different regions and periods mainly for conservation purposes. ‘The Royal Commission of Historical Monuments England’ prepared by Eric Mercer (1975) treats the term ‘vernacular’ as a notion that differs from a region to region as well as from a time to time by focusing on structural and materialistic property of various domestic buildings. However, Brunskill (1981, p.24), argues that vernacular buildings are more than just structural classifications and inhabits another layer by describing ‘vernacular’ as sort of a building that is ‘...traditional rather than academic in its inspiration, which provides for the simple activities of ordinary people, their farms and their simple industrial enterprises, ...’ In that perspective, he focuses his interest on the farmhouses and cottages of low-class groups that is also the basis of the ‘traditional’ British case studies in this study.

Focusing on the term of ‘privacy’, and in contrast with the other two case studies, public and private spaces in a ‘traditional’ British house are separated from each other through different floors emphasising more individualistic lifestyles. Bedrooms are located on the upper floors facing private corridors or staircase landings and not any public area such as halls or living rooms. Moreover, having a split in living rooms into two different spaces one of which is called the ‘parlour’ originally derived from the French word ‘parler’, meaning ‘to talk’, shows a different kind of ‘privacy’ to host guests in a separate space than the ordinary living room or kitchen that is served for households more formal and private gatherings (Logan T., 2001, p.13).

The following analytical part of the study focuses on the themes of ‘privacy’, ‘flexibility’ and ‘introverted-ness’, and tries to reframe the understanding of these concepts through configurational analyses. The quantification of these notions allows for an analytically based comparison to take place. The comparative framework of verbal definitions in combination with configurational analysis should help us to gain a better understanding of the typical traditional house types in three contrasting cultural environments, as described below (Figure 3).
4. CONFIGURATIONAL ANALYSES
Each domestic space type from different country and case study has been classified according to the same scheme of space use to create a common comparable framework (Figure 4).

<table>
<thead>
<tr>
<th>Colour</th>
<th>Space</th>
<th>Inclusive Areas</th>
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<tbody>
<tr>
<td></td>
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<td><strong>Turkey</strong></td>
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<td><strong>Common Use Rooms</strong></td>
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<td>Buddhist Alter Rooms</td>
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<td></td>
<td><strong>Circulation Spaces</strong></td>
<td>Corridors</td>
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<td>Hall (ha)</td>
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<td></td>
<td><strong>Open Spaces</strong></td>
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<td></td>
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<td>Courtyards</td>
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<td>Terraces</td>
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<td></td>
<td><strong>Service Spaces</strong></td>
<td>Kitchens (ke)</td>
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<td>Bathrooms</td>
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<td>Storages</td>
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<td></td>
<td><strong>Bedrooms</strong></td>
<td>Bedrooms (br)</td>
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</table>

Figure 4 - Spatial use per country, top, middle, bottom: Traditional Turkish, Japanese and British houses
The first analysis involves Justified Graphs of the 30 vernacular houses where the depth of each space is measured from the roots of the graphs defined as the entrances to the houses (Fig. 5). As a result, British houses are the shallowest to entrances followed by Turkish and Japanese houses with average levels of 4.5, 5.9 and 6.2. Overall, considering different spatial uses, the living rooms in Turkey are relatively deeper to entrances than the living rooms in Japanese and British houses. In addition to the statement that a typical ‘traditional’ Turkish house plan grows around the living room, it can also be argued that this core space, namely the ‘sofa’ is also ‘private’, protected and not easily accessible from the exterior. This additional layer of information gathered from spatial analysis creates a value to understand the notion of ‘privacy’ in vernacular houses more precisely. The analysis also shows that the bedrooms in Japanese houses are both shallower to entrances and to all other spaces than the other examples. This data can also be interpreted as Japanese bedrooms being less private and easier to access than the bedrooms in Turkish and British houses. Entrances and their relations to internal spaces do, of course, configurationally transform over time. However, the layouts examined in this study do not seek to identify the change between interior and exterior but instead prioritize comparative range for elucidating the transformation of interior relations.

Secondly, the Space Type Graphs show that the Turkish and British houses are formed of similar types of ‘tree’ shape graphs, whereas the Japanese houses present comparatively more ringed graphs. In that respect, within the total 202 spaces Turkish houses contain only four rings, whereas within the same amount of total spaces, Japanese houses contain 71 rings. On the other hand British houses contain only 1 ring within the total of 99 spaces. This shows that, compared to Turkish and British houses, spaces within Japanese houses are the most interconnected with the highest number of D type spaces that is also aligned with the previously described idea of ‘flexibility’ notion in Japanese houses. Breaking down the spatial uses in Japanese houses; living rooms, open spaces, circulation spaces and bedrooms are indicated as spaces with the most connections to neighbouring spaces.

Looking at spatial uses independently, the space types of Turkish houses reflect mainly A and B type spaces, where the bedrooms, open spaces and service rooms are formed of A spaces and 70 percent of ‘sofa’s and 90 percent of circulation spaces are B-type spaces. This result shows that bedrooms, service spaces and open spaces are not used as connection spaces but rather
as dead-end spaces. By contrast, living rooms in Turkish houses function as connection spaces as much as corridors. Also, British houses show similarities to Turkish houses by mainly being formed through A and B type spaces. The main difference between the Turkish and British house space types are only seen in the living rooms whereas the rest of the functional results are the same. In contrast to the living rooms with B-types space in Turkish houses, the living rooms in British houses are seen as A-type spaces which indicates that the living rooms or parlours in British houses do not function as connecting spaces but rather as spaces with single entrances.

The importance of the living rooms in the spatial configuration is also highlighted through high spatial accessibility levels shown both in Convex and Axial Map analyses (Fig. 6, 7). According to the Convex Map results, living rooms are the most integrated spaces in Turkish and Japanese houses whereas it is the circulation spaces that are the most accessible in British houses. Also, Axial Map analysis shows that, the most connected spaces are the living rooms for Turkish houses, open spaces for Japanese houses and circulation spaces for British houses. Another interesting finding is that the internal circulation in each house is spatially provided through different spaces other than corridors or halls. The spaces that are defined as ‘circulation areas’ in Turkish and Japanese houses remain less connected than the other spaces. In Japanese houses circulation spaces are even more segregated than the bedrooms. As a result in both analyses, Japanese houses overall are the most connected and integrated houses.

Even though, the spatial findings may seem fixed and definite, analysed over the periods of time graphs show that the Integration values of living rooms, circulation spaces and bedrooms have evolved differently in each case over time (Fig. 8). The living rooms’ values rose between 17th and 18th centuries and fell towards the 19th century in Turkish houses while it showed the opposite change in Japanese houses and greater stability in British houses. This analysis also shows that there is a changing pattern to way in which these spatial values are defined over time. Therefore, the fixity of any configurational notion of essential vernacular architecture is arguable, to say the least.

Figure 6 - Convex Map Analysis - Integration (HH) for Turkish, Japanese and British Houses
Figure 7 - Axial Map - Integration (HH) for Turkish, Japanese and British Houses

Figure 8 - Time based Axial Map Analysis - Integration (HH) per century and per country
Lastly, visibility levels are measured through Visibility Graph Analysis and Isovist Maps. Living rooms are visually the most integrated spaces in both Turkish and Japanese houses. Japanese houses contain visually the most integrated living rooms whereas British houses have the visually most integrated circulation spaces and bedrooms. Despite the fact that the bedrooms of ‘vernacular British houses’ were described as ‘private’, they are visually more integrated than the ‘flexible’ Japanese houses.

The Isovist areas are captured from both entrances and the centre of the living rooms in all houses with a degree of 360 (Fig. 9). The isovist areas allow comment on: first, the level of visibility upon entering the house, and secondly, the extent to which the living rooms in each house provide visual accessibility to other spaces within the configuration. The results of the analysis show that, Japanese houses contain the largest areas of isovists overall. The overall average Isovist area value for Japanese houses is given as 119,61 sqm, followed by values 78,65 sqm and 34,77 sqm for Turkish and British houses. Considering the spatial functions, the results show that the Isovist areas in living rooms in both Japanese and British houses are larger than the Isovist areas in entrances. By contrast, in Turkish houses, the Isovist areas in entrances are larger than the ones in living rooms. In other words, a person entering the Turkish house has the possibility to capture more areas than that could be seen from the centre of the living room.

5. DISCUSSION AND CONCLUSION

The main purpose of this study was to investigate the extent to which conventional studies of the ‘traditional’ and ‘vernacular’ corresponded to the actual properties of ‘space’. This approach has been enabled through a comparative study between the narrative definitions of ‘traditional’ houses as discussed in Section 3 and the evidence-based spatial analyses in Section 4 where the same concepts were explored quantitatively. In particular, the notions of ‘flexibility’ and ‘privacy’ have been discussed using a more analytical approach and the results of the spatial analyses
have been compared with the initial qualitative studies done in the field of vernacular in order to see if an alternative and complementary approach can be suggested to study vernacular buildings.

Firstly, the ‘sofa’ in traditional Turkish houses is often said to be the most important room in the whole spatial configuration in terms of the multi-functional collective activities that take place in, and for its role in connecting the majority of the rooms to each other. However, the Justified Graph analysis has also shown that ‘sofas’ are in fact deeper to both main entrances and to the rest of the configuration than many other spaces within a Turkish house. Although, acting as a connecting circulation space between the other rooms, corridors are found to be shallower to other spaces than ‘sofa’s. Moreover, the study shows that living rooms in Japanese and British houses are easier to access with fewer steps than in Turkey. This analysis suggests how it might be possible to arrive at a more nuanced understanding of ‘privacy’ and further proposes that the ‘sofa’ could also be considered as a private space in parallel to bedrooms. On the other hand, the findings on the ‘privacy’ concept of bedrooms showed similarities to the initial narrative study, as they are the least connected and integrated spaces alongside with service areas in all analyses.

Secondly, Japanese houses were described through the concept of ‘flexibility’ where it refers to organically growing, expandable interior spaces that houses multi-functional and collective activities and where nature is a very important part of the vernacular code. Although Japanese houses can be considered ‘flexible’ in terms of the interconnectivity and the number of possible linkage between interior spaces, the analyses show that spaces overall are much deeper to the main entrances compared to other two cultural case studies. Despite the number of rings in Justified Graphs and D-type spaces, most spaces in Japanese houses require more steps to be reached from the exterior. Open spaces in this sense, remain as transition areas between the interiors and exteriors, which might further suggest ‘traditional’ Japanese houses to be ‘introverted’ and hard to access from the exterior.

Not only open spaces but also the circulation spaces in Japanese houses require a further understanding in terms of their functions within the spatial configuration. Although there are specific places designed for the circulation purposes such as corridors or verandas, the circulation is mainly provided through all other internal spaces where these spaces do not reflect such definite functions. Even the bedrooms are more visually and spatially integrated than the circulation spaces. The shallowness of the bedrooms to entrances also proposes a distinctive spatial definition of the ‘privacy’ notion in different cultural perspectives, as well as reconsidering ‘flexibility’ not only in physical sense but also in spatial and functional senses.

Thirdly, the ‘traditional’ British houses were described as individualistic and private in terms of spatial split between the household and guest reserved spaces; including the two separate living rooms for formal and informal gatherings as well as the location of bedrooms on the upper floors in order to create a sense of ‘privacy’. The bedrooms in British houses facing private corridors can be argued to be ‘more public’ than both Turkish and Japanese houses where they are located around the living room in a single floor as the analyses show that British bedrooms are visually the most integrated spaces in the whole configurations. The two split living rooms on the other hand do not differ from each other that much in terms of ‘privacy’ as they are both have low spatial integration values as opposed to circulation spaces which are the most integrated spaces in British houses. Also, the notion of ‘flexibility’ can be reconsidered among all case studies, as the overall visually integrated spaces are much higher in British houses than in Japanese houses which are most known for being ‘flexible’.

Overall, the notions of ‘privacy’, ‘flexibility’ and ‘introverted-ness’ remain inadequate to be explained through only qualitative studies. The results suggest that each vernacular domestic space might consider these terms in different ways. Therefore, these concepts might not be verbally highlighted but could still be embedded in the spatial configuration, where a further analytical approach would be needed to tease out particular variations. Despite the number of inconsistencies analysed between qualitative and quantitative approaches, certain similarities are also identified. Therefore, this study does not set itself up in opposition to existing
approaches to domestic vernaculars but rather proposes a configurational perspective as a starting point to rethink current understanding of the vernacular architecture. Rather than taking conventional qualitative studies for granted, the analyses here propose to approach to ‘vernacular’ studies with a more critical perspective through the analytical reconsideration of normative standardisations concerning the spatial qualities of national housing layouts.

In conclusion, the study argues that, the definition of ‘tradition’ in vernacular architecture needs re-examination. In contrast to considering vernacular houses as ‘timeless’ objects, the time-based analyses show that there are also variations within the ‘traditional’ houses and that they reflect certain spatial changes over time that speak to assumed national characteristics such as ‘privacy’. Despite the common assumption of considering traditional houses as fixed products of societies, these results suggest a greater focus on the patterns of continuity and changes within each national sample in order to fully understand the characteristics. Instead of treating ‘vernacular’ architecture as a unitary notion with specific characteristics for each nation, considering it as a fluid proposition gives greater scope for more precise results combining both qualitative and quantitative analyses.
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APPENDIX: CASE STUDIES REFERENCES

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A CONFIGURATIONAL APPROACH TO VERNACULAR DOMESTIC ARCHITECTURE

‘Traditional’ Houses in Turkey, Japan and Britain


http://www.british-history.ac.uk/report.aspx?compid=127523&strquery=vernacular%20plan%20through%20house


ABSTRACT

Notable gains have been made in understanding the factors that influence student experiences in higher education, particularly in the area of spatial configuration. Indeed, studies have found that spatial configuration affects spatial behaviour and movement patterns (e.g., Hillier et al., 1993). Increasingly physical and spatial supports are provided to ensure the efficacy and efficiency of learning activities in higher education (Higgins et al., 2005; Brown & Long, 2006; Dugdale & Long, 2007; Dugdale, 2009). Consequently, the informal learning spaces became a pivotal architectural design strategy for universities to enhance interior design quality and improve learning environments. It is definitely an effective way to improve learning performance in the higher educational facilities if well-designed informal learning spaces could improve student experiences within them. Even though the development of purpose-built informal learning spaces is a strategy to enhance student experiences, it is becoming more prevalent. The empirical research in this area is still lacking. What appears to be missing in this enquiry is how the built environment, namely the shape of the learning environment, influences student activities.

Using Hillier’s (2007) definition of intelligibility as the relationship between local and global configurational factors, this paper aims to examine the impact of spatial configuration upon frequency of student activities in an educational complex based on space syntax theory and behavioural observation. In order to achieve this assumption, we correlated the data between the observation data of the frequencies of six student activities: Focused Informal Learning, Serendipitous Encounter, Intermittent Exchange, Focused Socialising, Dietary Related Activities and Ambient Sociality. The spatial attributes were derived from space syntax theory in an educational complex of the University Park campus in the University of Nottingham: Coates Building - Pope Building - ESLC area. More specifically, there are five informal learning spaces in the educational complex in total. The frequency of the six types of student activities were
examined in five informal learning spaces in this educational complex. The findings confirm that spatial configuration and patterns of spatial usage are related to each other. The main finding is that there is a correlation between the degree of connectivity of the area and frequency of student activities. The finding suggests that spatial configuration may play an important role in determining frequencies of students socialising and informal learning activities.

KEYWORDS
Informal Learning Spaces, Space Syntax, Student Experiences, Educational Complex

1. INTRODUCTION
Due to technological advancements, there appears to be an increasing amount of blended learning experiences happening in informal learning spaces. Learning is moving towards being more collaborative (active learning with hands-on experience), integrated (multidisciplinary), blended (learning take place anywhere/anytime, mobile technology with social activity), immersive (with simulated or real-world experiences) and Hybrid (activities, combining online with fact-to-face, augmented with mixed reality experiences) (Dugdale & Long, 2007). Combining Informal learning within social spaces is an effective way to improve learning experiences in the campuses. What appears to be missing in this enquiry is how the built environment, namely the shape of the environment, influences informal pedagogy. This paper looks at an educational complex – the Coates Building - Pope Building - ESLC area of the University Park campus in the University of Nottingham. The roles of the informal learning spaces on student experiences are compared. Three stages of the study were conducted separately. Firstly, the observational data of student experiences, including six degrees of learning processes and consisting of Focused Informal Learning, Focused Socialising, Intermittent Exchange, Dietary Related Activities, Serendipitous Encounter, and Ambient Sociality, were accumulated through behavioural mapping in these informal learning spaces, to record where and what behaviours happened. Secondly, investigations of spatial configuration were analysed using space syntax accessibility and the intelligibility of buildings through the space syntax methodology. Lastly, the relationship between the space syntax indices and observed behavioural data were correlated.

In complex educational buildings, spaces such as cafeteria, atriums and courtyards, cannot be solely understood as simple passageways or links between formal learning spaces, since they achieved another role in the everyday life of the learning environment - informal learning. Both social interactions and informal learning consist of student experiences in the complex educational buildings. The importance of a non-designated space for students to work together outside the classroom is increasingly being recognised for its educational value and contribution to creating a sense of community (Dugdale & Long, 2007). In order to create informal learning spaces to improve student experiences, it is imperative to recognise where and what students do when they are staying outside of the classrooms by means of revealing the relationship between student experiences and spatial configuration for the educational complex design and plans. This research seeks to identify the usage of informal learning spaces in the learning environments and to examine the value of the spatial configuration of informal learning spaces in all the learning environments for student`s activities.

2. LITERATURE OVERVIEW
One strand of enquiry in the built environment is the application of space syntax methods in educational settings. These techniques were found to be appropriate metric for studying spatial usage (see Bullock et al., 1968), wayfinding (Bafna, 2003; Hölscher, Brösamlke & Vrachliotis, 2012; Montello, 2007) and in relation to social effects such as social and spatial organisation, complexity of circulation, and adaptability in educational spaces. (Coelho & Kruger, 2015; Da, Dong & Guo, 2015) “Social transformations and technological innovation encouraged the rising of new ways of working and socialising almost without functional space layout constraints...
challenging typical patterns of space usage in educational environments by considering the diversity of behaviours where socialisation plays a central role in learning processes (Pera Vieira & Kruger, 2015). Educational practices require a more advanced and innovated learning environment to achieve pedagogical goals.” This innovation changes the spatial configuration of campus planning and results in transformations of people’s study and work habits (Capille & Psarra, 2013). In other words, spatial configuration is reshaping students’ habits in the educational settings through technology. Therefore, more informal learning opportunities are required outside of the classrooms.

Crook and Mitchell (2012) propose a more nuanced conception of the ‘social’ in learning and engagement. Focusing more on student activity in the informal learning spaces. They use audio diaries, behavioural observations and on-task conversations (including individual interviews and Focus Group interviews) to suggest that informal learning spaces should be designed for a mixed economy of student choice and a consideration of modes of encouraging diversity in their use. The research identified six categories of activities and the sub-categories, which were coded in each case. From an informal learning process to socialising, four types of social engagement and interaction were listed and layered, based on different degrees of learning processes as shown in Table 1.

![Four types of social engagement and interactions](image)

**Table 1 - Four types of social engagement and interactions**

<table>
<thead>
<tr>
<th>Focused collaboration</th>
<th>Occasions of traditional, and relatively intense joint problem solving. There are likely to be planned and strongly outcome-oriented.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermittent exchange</td>
<td><em>Whereby students convene for independent study that permits an occasional and improvised to-and-fro of questioning or commentary.</em></td>
</tr>
<tr>
<td>Serendipitous encounter</td>
<td>That is, chance meetings with peers in which study-related issues (and perhaps other matters) are discussed briefly and on the fly.</td>
</tr>
<tr>
<td>Ambient sociality</td>
<td>Students identify the importance of simply ‘being there’ as participants in a studying community.</td>
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The research explores a strategy to identify specific student activities in the informal learning spaces. There is also research on specific activities in public spaces (Jung, et al., 2009; Mehta, 2013; Lee, & Lee, 2013) and learning environments (Nair & Gehling’s, 2010; Muslim, 2011). Based on their contribution and a pilot study, this research divided socialising and informal learning activities into six sub-categories according to the degree of the informal learning processes (Table 2). The degree of frequency of the socialising and informal learning activities cannot represent the student preferences of selecting and using the space while it can be determined to examine the degree of engagement. The more the frequency of socialising and informal learning activities occur, the higher the rate of using the space and thus the more the communication happens. There is a series of factors impacting the frequencies of socialising and informal learning activities. The design quality of informal learning spaces is one of the most important factors based on the environmental psychological theory. The next session will focus on what the design quality of informal learning spaces should focus on and what methods researchers use to examine the impact of the frequency of socialising and informal learning activities.
3. DATASETS AND METHODS

In order to answer this research question, this paper aims to examine the extent to which informal learning occurs and the impact spatial configurations have upon student experiences in an educational complex based on space syntax theory. Space syntax is a set of theories and techniques which link space and society (Hillier & Hanson, 1984; Hillier 2006). It addresses where people are, how they move and how they adapt. It also addresses how they decorate space and how they are fundamentally influenced by the geometry and the configuration of space. Space syntax views buildings as geometry that orders spatial relations. These are represented as graphs in network science where centrality indices could then be applied. In order to answer the research question, we compare the correlation between the observation data of student experiences and the spatial network properties. Through this we attempt to discover insights for the creation of informal learning spaces to improve student experiences.

3.1 CONTEXT

The studied educational complex was based in the University of Nottingham. The research fieldwork occurred in them with 24/7 access. Despite their discipline specialisms for engineering, the Coates Building - Pope Building - ESLC area includes the most popular and recognised informal learning spaces. Their informal learning spaces were widely used by the students. The work occurred in the main five informal learning spaces (see CA/CB/CC/TEH/ESLC in Figure 1). They are core informal learning spaces in this area. The spaces were intended to support

Table 2 - Student activities based on the degree of informal learning process

<table>
<thead>
<tr>
<th>Different degrees of informal learning process (Learning Process &amp; Socialising) (adapted from Crook and Mitchell, 2012)</th>
<th>Learning activities: (The letters in brackets refer to the used sources)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Focused Informal Learning</strong></td>
<td>Prepared coursework</td>
</tr>
<tr>
<td></td>
<td>Discussed ideas from reading books or lectures</td>
</tr>
<tr>
<td></td>
<td>Worked with others on coursework</td>
</tr>
<tr>
<td></td>
<td>Study alone</td>
</tr>
<tr>
<td></td>
<td>Talked about career plans</td>
</tr>
<tr>
<td></td>
<td>Study alone, but with occasional interaction with others</td>
</tr>
<tr>
<td></td>
<td>Worked with others on activities other than coursework</td>
</tr>
<tr>
<td><strong>Intermittent exchange</strong></td>
<td>Received prompt feedback from faculty on your academic performance</td>
</tr>
<tr>
<td></td>
<td>Tutored or taught other students</td>
</tr>
<tr>
<td></td>
<td>Had serious conversations with students of a different program or department than your own</td>
</tr>
<tr>
<td></td>
<td>Taken a call</td>
</tr>
<tr>
<td></td>
<td>Study alone, but with occasional interaction with others</td>
</tr>
<tr>
<td></td>
<td>Worked with others on activities other than coursework</td>
</tr>
<tr>
<td></td>
<td>Received prompt feedback from faculty on your academic performance</td>
</tr>
<tr>
<td></td>
<td>Tutored or taught other students</td>
</tr>
<tr>
<td></td>
<td>Had serious conversations with students of a different program or department than your own</td>
</tr>
<tr>
<td></td>
<td>Taken a call</td>
</tr>
<tr>
<td></td>
<td>Had a meal</td>
</tr>
<tr>
<td><strong>Focused Socialising</strong></td>
<td>Had a snack</td>
</tr>
<tr>
<td><strong>Dietary related activities</strong></td>
<td>Taken a break from studies with friends</td>
</tr>
<tr>
<td><strong>Serendipitous encounter</strong></td>
<td>Had a meal</td>
</tr>
<tr>
<td>(Seeing, greeting or short chats with each other because of encounter)</td>
<td>Had a snack</td>
</tr>
<tr>
<td><strong>Ambient sociality</strong></td>
<td>When you meet a friend of someone you know, but neither of you planned to</td>
</tr>
<tr>
<td></td>
<td>Attended event such as Exhibitions, Open Day or Coursework Show</td>
</tr>
<tr>
<td></td>
<td>Found a way to lecture room or gathering for going to another place together</td>
</tr>
<tr>
<td></td>
<td>Used as a meeting point before or after lectures</td>
</tr>
<tr>
<td></td>
<td>Peoplewatching</td>
</tr>
<tr>
<td></td>
<td>Had a rest</td>
</tr>
</tbody>
</table>

Source from: Adapted by author
Informal learning activities and socialising but in a form that could be more fluid. The spaces offered seating facilities. As social corridor spaces, Wi-Fi was provided and students were encouraged to communicate in comfortable conditions.

![Figure 1 - Five social informal learning spaces in educational complex (CA, CB, CC, TEH and ESLC) (CA=Coates building space A; CB=Coates building space B; CC=Coates Cafe; TEH=Telford Exhibition Hall; ESLC=Engineering Science Learning Centre)](image)

3.2 PROCEDURES

Fieldwork would take place over 10 days spread across one month in the term week. Prior to starting, notices were displayed announcing the presence of a researcher across the specified dates. Student activity and attitude data were collected according to the following three methods. All student participants were voluntary.

- Behavioural Observations

Behavioural observations are used to generate objective behavioural records, randomly sampled across users of informal learning spaces. The observations of informal learning spaces were carried out in the educational complex for a whole standard semester week (from 21st Nov, 2016 to 25th Nov, 2016). The walk-bys and timed observations could be employed in selected hours over 5 working days (from 8am to 10am, from 12pm to 2pm, from 5pm to 7pm and from 8pm to 10 pm). Each ‘session’ lasted two hours and there were $4 \times 10 \times 120$-minute observations sessions in each case. One session occurred in the evening and three in the day during every day. Four vantage observation points were selected to ensure comprehensive coverage: a single observation session thus comprised six 20-minute ‘cycles’ of recording. The activity of each student in an area was scan-sampled (Altmann, 1974) four times, once every five minutes. A laptop was used to manipulate a visual map of the space which was constructed afresh and conducted in a PowerPoint file for each observation cycle. The spatial characteristics, six types of student activities, the location of each student and notes could be made using the PowerPoint note-taking tool. Pilot sessions using phone pictures presented a poor result while using PowerPoint software on the laptop proved to be a better way for managing data. The observation occurred in the core informal learning spaces. The participants were made aware of the observation process through the usage of posters displayed in the building. The posters were displayed on the information boards and other visible places. The posters illustrated the purpose of the usage of the data and the contact details of the researcher. All the methods used were strictly in accordance with the University of Nottingham’s code of conduct and research ethics approval. Through the observation, the data of six types of student activities like: Focused Informal Learning; Focused Socialising; Intermittent Exchange; Dietary Related Activities; Serendipitous Encounter; and Ambient Sociality, were obtained. Finally, once during each observation cycle, the number of students was counted and the length of stay within the spaces of each student was calculated.
• **Space Syntax Methodology**

In order to examine the relationship between spatial configuration and the six types of student activities, the method of space syntax would be employed in the complex building. We would first construct what is known as a convex map graph (G) in space syntax made up of rooms as the nodes and the connections between rooms as edges. This study in particular would employ the space syntax measure of integration also known as closeness centrality in the network science literature (Hillier and Hanson, 1984; Hillier et al., 2012). The index measures the reciprocal average shortest topological path between every origin (i) to every destination (j) or, more simply, the average distance to reach all nodes in the system (Freeman, 1977). Empirically, closeness centrality had been found to associate positively to movement demand.

\[
CC_i = \frac{N - 1}{\sum d_{ij}}
\]

Where \(N\) is the number of nodes in the network

\(CC_i\) is the closeness centrality at \(i\)

\(d_{ij}\) is a measure of impedance between \(i\) and \(j\)

Equation (1)

### 4. RESULTS

<table>
<thead>
<tr>
<th>Activity</th>
<th>CA</th>
<th>CB</th>
<th>CC</th>
<th>TEH</th>
<th>ESLC</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIL</td>
<td>0</td>
<td>0</td>
<td>163</td>
<td>160</td>
<td>11</td>
<td>334</td>
</tr>
<tr>
<td>FS</td>
<td>33</td>
<td>54</td>
<td>144</td>
<td>183</td>
<td>124</td>
<td>538</td>
</tr>
<tr>
<td>IE</td>
<td>9</td>
<td>13</td>
<td>78</td>
<td>62</td>
<td>53</td>
<td>215</td>
</tr>
<tr>
<td>DRA</td>
<td>15</td>
<td>20</td>
<td>231</td>
<td>151</td>
<td>11</td>
<td>428</td>
</tr>
<tr>
<td>SE</td>
<td>97</td>
<td>80</td>
<td>57</td>
<td>64</td>
<td>87</td>
<td>385</td>
</tr>
<tr>
<td>AS</td>
<td>13</td>
<td>15</td>
<td>31</td>
<td>36</td>
<td>34</td>
<td>129</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>167</td>
<td>182</td>
<td>704</td>
<td>656</td>
<td>320</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Table 3 - Frequency of six activities in five core informal learning spaces (Number of people involved)

*Focused Informal Learning (FIL); Focused Socialising (FS); Intermittent Exchange (IE); Dietary Related Activities (DRA); Serendipitous Encounter (SE); Ambient Society (AS)*

Based on the observation methods, it can be clearly seen that CC, TEH and ESLC are informal learning spaces with more blended student experiences in the educational complex (Table 3). The main activities in the informal learning spaces are for socialising and the informal learning process require a higher requirement on basic facilities. More specifically, CC and TEH held over 67 percentage students in the whole educational complex, which included 42.3 percentage and 43.6 percentage of informal learning activities, respectively. The convex map is shown in Figure 2. There appears to be association between spatial configuration and student behaviours (Table 4). Spaces with greater integration such as CC, THE and ESLC have a greater frequency of student activities. This is logical as these are spaces that are more central and thus more accessible and legible to everyone. These are central spaces to wait in before classes start, to socialise with other students, to study, to eat and to meet others.

CC and TEH had more DRA activity. CC is the main food court in this educational complex while only vending machines are provided in the TEH. However, there are lots of spare and comfortable chairs and tables provided, which creates more attraction for students who may want to have a lunch, for example.
The correlation analysis of the six types of activities and spatial configurations reveals that global integration has a significant impact on the patterns of FS ($r=0.971$), IE ($r=0.952$) and AS ($r=0.961$) in the educational complex while there is no correlation between the spatial configuration and FIL, DRA and SE.

5. CONCLUSIONS

Within observational analysis, it can be seen that students conduct diverse types of learning activities within the common areas of the educational complex (CA, CB, CC, TEH and ESLC). Therefore, spaces that originally are intended to be just links between the main academic areas, frequently provide areas for students to cross, to sit and to communicate, where they can encounter and interact with each other. The connectivity of educational complexes can indicate and promote frequent casual interactions. The most segregated areas in the educational complex were mostly the end spaces of corridor spaces (CA and CB), emphasising that the complex should be able to provide students with both formal and informal learning spaces,
where they can sit and focus on learning relatively with activities and social spaces where they can also relax and socialising.

The study on the usage of space made it possible to notice that the ‘link’ spaces happen to be the key parts meant for spaces to have social and informal learning activities, therefore it can be concluded that they are in fact social informal learning spaces. In this space, socialising and informal learning activities can emerge where students can socialise and exchange knowledge. The study concludes that space configurative properties on educational complexes, in particular the system of spaces for social and informal activities, are an important component of both informal and incidental interactions between students.

This study has shown five social informal learning spaces in one educational complex, which have different functions in usage and hold different number of different student activities. What is perhaps surprising is that the space deepest in structure or the least integrated such as CA, CB had the greater number of serendipitous encounter. The limitation of the size of space prompted an increase of greetings. That is to say, in general student activities correlate with the spatial configuration measure. This research also suggests there are also greater complexities when one disaggregates the student activities into types where different types of activities might be associated with different spatial conditions. Due to the sample size further work is needed to confirm the original hypothesis.
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ABSTRACT

With intensification of urban development in Chinese cities, mixed land use in urban centres extends vertically into 3-D and expands its scale from a single building to commercial clusters. The multi-level pedestrian system in urban centres also changed its role from one of traffic isolation to spatial integration, where transit nodes, street sidewalks, squares, building entrances, atriums, and corridors are interconnected both horizontally and vertically into a whole spatial system. As commercial facilities would like to take advantage of such spatial system to locate themselves for a better market competition, the question is, are there any relationships between socio-economic variables and spatial design characteristics of the multi-level shopping complex?

This paper applies space syntax and investigates the effects of spatial pattern on pedestrian movement and clustering of tenant types in the high-density Nanshan Commercial Cultural District (NCCD), a multi-level system consisting of a cluster of commercial buildings located in Shenzhen, China. The research findings point to the importance of interactions between syntactic variables and other spatial variables, in particular the interplay of local integration measure and location of escalators, which not only contributes to a powerful explanation on the movement distribution, but also has certain effects on the clustering and business performance of tenant types in the multi-level spatial system.

KEYWORDS
Multi-Level, Commercial Complex, Movement Distribution, Tenant Types, Spatial Pattern

1. SPACE SYNTAX RESEARCH OF MULTI-LEVEL SPACE

Contemporary urban development in China is characterized by high density and mixed land-use. In big cities like Shenzhen, where density and mixed land use are highly intensified, commercial space not only extends vertically into multi-levels but also expands its scale from a single complex into cluster of buildings. Such cluster of commercial complexes is usually integrated with urban streets and public transport nodes, with elevated circulations linking them together into a huge multi-level spatial system which by itself functions as a centre or sub-centre of the
city (figure 1). As commercial facilities would like to take advantage of such spatial system to locate themselves for a better market competition, the question is, to what extent does the multi-level spatial structure of commercial building clusters influence distribution of movement flows and the clustering of commercial facilities?

Previous empirical studies of space syntax have established that the configuration of a spatial system influences different kinds of behaviours and cognitive processes in building and urban layouts. More specifically, movement flows tend to be more biased towards better accessible spaces measured in terms spatial integration (Hillier et al, 1993; Hillier 1996).

Chang and Penn (1998) applied the space syntax method to investigate a multi-level urban context of London. They found that, due to the unintelligibility of the multi-level space, pedestrian movement is less predictable from integration measures but strongly biased by other spatial design factors and their interactions, such as entrance location, height variation, main route, and vertical transitional space. They put forward research direction to unveil the significance of local urban design parameters in modelling the patterns of movement. Their analytical framework was extended into the study of a high-density vertical commercial complex in Hong Kong (Parvin et al, 2008). They developed an integrated model including both integration and other spatial parameters like metro stations, level variations, and the location and type of vertical transitions that are characteristic to the site, in order to account for the effects of urban design parameters observed in statistical analysis. This integrated model was elaborated further and used to evaluate the configuration of multi-level commercial complexes in Shanghai (Zhang et al, 2012). In recent years, there has been an increasing interest in the space syntax on multi-level systems (Ueno et al, 2009; Fujitani & Kishimoto, 2012), and a wider scope of reach (Kong & Kim, 2012; Ook et al, 2015; Penn, 2005).

Despite of the success of these studies, research on multi-level spaces is still limited to a few cases, and confined to individual buildings. Little is done about the effect of spatial patterns in the more complex multi-level settings in which commercial buildings are clustered and interwoven with the urban context as mentioned above. How spaces in this setting are configured is a crucial issue of urban design, not only for the reason that pedestrian flows can be guided with accessibility and legibility, but also for the reason that functional activities can be better arranged.

This study attempts to investigate these issues through a characteristic case study of Nanshan
Commercial Cultural District (NCCD) in Shenzhen, China. The study is an extension of a pilot research, conducted in conjunction with Space Syntax Ltd. in May 2013 and reported partly in Yin et al (2016). We hypothesize that the interactions between syntactic variables and other design parameters would not only contribute to more robustly address the patterns of movement, but also have an effect on the clustering and performance of shopping facilities in the multi-level commercial space.

2. THE STUDY AREA

NCCD is located in the west of the main city of metropolitan Shenzhen. Developed rather recently in 2002, NCCD has now become a major urban centre of the metropolitan area, and consists of four buildings: Coastal City, Baoli Culture Square, Tianli, and Hai’an Mansion. The former two buildings are shopping complexes, and the latter ones are a mixture of shops in podia with offices and hotels in high-rise towers. Figure 2 shows the location of these buildings.

The street pattern of the site is characterized by a small grid size, contrary to the super grid structure surrounding the site. In order to accommodate large retail complexes and separate vehicles from pedestrians, a huge elevated platform is created along the central axis of the area, running from east and west. Vertical connectors such as escalators, staircases and lifts, are deployed in multiple locations linking the elevated platform with its surrounding streets. The whole spatial system has 98 escalators and 47 lifts, which are distributed rather evenly across building interiors and exteriors to facilitate vertical transitions between levels (figure 3). In comparison, the number of staircases is much lower. They are predominately used for evacuation purposes, and thus recede from the main circulation areas of building interiors.

![Figure 2 - The site of study area, showing locations of the four commercial complexes from bottom left in clockwise: Coastal City, TianLi, Hai’an Mansion and BaoLi.](image-url)
All the 4 commercial buildings are designed in a similar layout fashion to that of shopping malls, with one or more spacious atriums, double-to-quadruple-height circulation spaces, and wide corridors formed into various shapes from case to case. Although varied in size and commercial marketing strategy, all the commercial buildings have a rich tenant mix. The multi-level spatial complex with its highly mixed commercial facilities offers rich experiences of shopping, and brings with it the reputation as the most popular commercial area of the city of Shenzhen with annually increasing number of shoppers and rising rental prices.
3. METHODS

The study applies the axial model to analyse the spatial configuration of NCCD. Axial lines of individual floors are linked together at locations of vertical transition (figure 4). Staircases are modelled according to the number of flights in an individual staircase in order to simulate the actual number of directional turns involved in movement. Lifts, which are usually across multiple levels, are represented by one single axial line, and thus height change between any floor levels is counted as one syntactic depth.

Movement data of the shopping area were collected on a sunny weekend in April, using the “gate count” method. There are 134 gates surveyed, of which 114 are located in building interiors and 20 in exteriors. Each of these gates was surveyed 5 times and 5 minutes per session, from 10:30am to 6:30pm. Figure 5 shows the average rates of movement flow passing through each gate presented in terms of adults per hour.

Tenant mix is used as an indicator of commercial market segmentation. In this study, shops are categorized into 8 types: retail store, catering, costume, jewellery, educational service, cosmetic, electrical appliance, and entertainment. Locations of each type of shops were determined by on-site investigation. Tenant mix is measured in terms of the percentage of each type of shop occupying the total rentable floor area of a commercial building. Business performance of shops is evaluated based on their rental prices and vacancy rates. Although we are unable to get actual lease prices for individual shops or shop categories, we could finally obtain a quarterly average rent and shop vacancy rate for individual shopping complexes, as offered by a local real-estate agency. The rent data were derived from the agency’s monthly reports between 2012 and 2014, and we double-checked them by consulting with the managerial department of each shopping complex. In spite of imperfections, these data allow a qualitative evaluation for the performance of individual building, and will be presented in the analytical sections accordingly.
Figure 4 - R3 integration analysis of the multi-level commercial system, with bolding lines showing the top 30% integrated spaces.
Figure 5 - Location and density of observed pedestrian flows in the study area.
4. MODELING MOVEMENT DISTRIBUTION

4.1 INDEPENDENT SPATIAL VARIABLES

The previous reach of space syntax suggests that pedestrian flows in the multi-level spatial system are highly biased by a number of local spatial parameters such as functional attractors, vertical transitions, level variations and entrances (Chang & Penn, 1998; Parvin et al, 2008; Zhang et al, 2012). Effects of those local spatial parameters are accounted by measuring the step depth away from these spatial parameters. The following summarizes all the independent variables adopted in the study.

4.2 SYNTACTIC VARIABLES: CONNECTIVITY, R3 AND RN INTEGRATIONS.

Vertical transition variables: including 2 variables, step depth from escalators (SDE) and from lifts (SDL), which measure the distance from a space to its nearest vertical transition.

Functional attractor variables: measuring the step depth from the nearest major functional attractors (SDFA) in NCCD, including the supermarket (JUSCO) located on the underground floor of Coastal City and the KTV and cinema on the upper floors of Baoli and Coastal City. A parallel dummy variable (0 for "no attractor" and 1 for "with an attractor") is created with respect to these functional attractors (DFA) in order to determine which description would better capture their influence on movement.

Level variation variables: accounted by 2 factors, step depth from the elevated platform (SDP), and level (L) measured in floor numbers.

4.3 PRELIMINARY BIVARIATE CORRELATIONS

Preliminary linear regressions between the density of movement flows and each independent variable are provided in table 1. Syntactic variables produce moderate to relatively strong correlations with the square root of movement, and their coefficients are all significant. The strongest correlation is given by R3 integration, with an $R^2 = 0.49$, indicating that nearly half of movement variations in the shopping area can be explained by this single variable. Following are measures of Connectivity and Rn integration, which display moderate strong correlations with movement density.

In contrast, correlations of local spatial variables are rather weak and thus less influential on movement patterns. They are all negatively correlated with the dependent variable. However, only three out of five are significant: step depth from the elevated platform, step depth from functional attractors, and step depth from escalators. Only one of these, step depth from the elevated platform, accounts for more than 10% of the movement variation. Other variables, such as step depth from lifts and level changes, are not only insignificant but also so weak as to be negligible.

The bivariate correlation analysis of the present study shows R3 integration is the strongest singular variable influencing movement patterns in the multi-level spatial system of NCCD. This finding is similar to the result of the pilot study examining Coastal City only in 2013 (Yin et al, 2016). In spite of the much-expanded study area and the more complicated spatial model involved, strong correlation with movement distribution stays with the same syntactic variable and the strength of its correlation remains almost at the same level. We consider this as a proof of the consistency and validity of the reach methods used in these studies.
4.4 MULTIVARIATE CORRELATION ANALYSIS

Since one purpose of the present study is to examine how the dependent variable is influenced by interactions of independent variables, we apply a sequential regression method rather than a normal “step-wise” multivariate regression analysis. In short, the independent variables are grouped into 3 blocks: The first block includes functional attractor variables and level variation variables; the second block includes vertical transition variables; the last block includes syntactic variables of connectivity, R3 and Rn integrations. Each block of variables is added step-wise into the multiple regression analyses in order to foreground any model variations.

Table 2 summarizes the statistical results of the multiple regressions mentioned above. When only those variables in the first block are considered, the multivariate regression suggests two variables are significant: step depth from the elevated platform and functional attractors as a dummy variable. They together explain about 23% of the variation in movement flows. Adding vertical transition variables in the second block into the model results no change at all. This indicates that there is almost no interaction between these variables that can contribute to the variation in movement flows. However, when syntactic variables are then added into the model, we observe strong multiplicities of syntactic variables and other independent variables, of which connectivity (in square root) and R3 integration, in conjunction with SDE, DFA and SDF, results in a correlation coefficient (R2) of 0.64. In other words, nearly two-thirds of the variation in commercial flows can be explained by the independent variables used in this study.

Table 1 - Bivariate correlation coefficients of movement flows (in square root) and spatial variables.

<table>
<thead>
<tr>
<th></th>
<th>Connectivity</th>
<th>R3 Integration</th>
<th>Rn Integration</th>
<th>SDP</th>
<th>SDE</th>
<th>SDL</th>
<th>SDFA</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>R²</td>
<td>0.415</td>
<td>0.493</td>
<td>0.305</td>
<td>-0.166</td>
<td>-0.028</td>
<td>-0.002</td>
<td>-0.091</td>
<td>-0.008</td>
</tr>
<tr>
<td>Sig.</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.027</td>
<td>0.308</td>
<td>0.000</td>
<td>0.160</td>
</tr>
</tbody>
</table>

Table 2 - Effect tests for multivariate regressions estimating square root movement flows.

Note: all presented coefficients are significant at P < 0.01.
As expected, given the results of bivariate analysis, the R3 integration has the strongest impact on the movement distribution (Std. Beta 0.472), followed by connectivity (in square root, Std. Beta 0.342). Higher volume of movement density is associated with a space that offers not only better accessibility within a larger spatial environment, but also more immediate neighbours. In the third place, the presence of functional attractors (as a dummy variable) is associated with higher movement distribution in the multi-level shopping complex. The remaining two significant factors are related to the vertical transitions: SDE and SDF, with Std. Beta values of 0.211 and 0.185, respectively. The result of the model indicates a negative relationship between step depth from escalators and movement distribution. However, what is slightly unexpected is the positive sign of correlation given by lifts. In the final regression model, Variable Inflation Factors (VIFs) are in all cases no more than 2.8, indicating there is no prohibitive degree of collinearity between those independent variables.

The results of the multivariate regression models highlight the importance of studying the interaction of various spatial variables when seeking to explain movement distribution in high-density multi-level commercial space. A few points can be drawn from the analyses. First, the syntactic properties of spatial configuration, namely, accessibility within a few step depths from a space, and the number of other spaces directly linked to that space, have the highest predictive power of movement distribution in the multi-level spatial system. Second, a multiplicity of syntactic variables and some other spatial parameters together contribute to a more robust address of the distribution of movement flows. Particularly noteworthy is the interaction between R3 integration and step depth from escalators, as these two variables explain 55% of the variation of the dependent variable, which is noticeably larger than that of any of the other variables. This result points to the importance of considering the escalator as a more important vertical transitional space than the lift or the staircase in a multi-level shopping system. In the design of modern commercial buildings, the escalator has been increasingly used as the major device to transport commercial flows between lower and upper floors. The large quantity of escalators presented in the study area is apparently in accordance with this practice. On the other hand, step depth from lifts, when examined in conjunction with syntactic variables, acquires a relevance that was not observed either in the bivariate correlations or in the multivariate analysis that takes into consideration only those variables in the first block. We suggest that the lift is a moderating factor that exerts an impact on movement patterns indirectly, by intervening in the relationship between syntactic variables and movement flows. We estimate this is the case for a few reasons. Waiting is perhaps a major reason prohibiting lifts from becoming important attractors to movement, especially during rush hours. Actually, lifts in the shopping complex are used as a complementary vertical connector, and thus usually are located in the gap spaces between escalators in order to facilitate a faster connection across more than 2 level changes. In the study area, a significant number of lifts are located on less integrated spaces or are hidden from the main circulations of building interiors, due to the building regulation that requires a buffer area or independent lobby associated with lifts for evacuation purposes. It is also perhaps because of these reasons that the correlation sign of lifts, when studied in conjunction with other independent variables, is inverted to positive, which is contrary to the priori expectation.

Functional attractors are found to be significant as dummy variables instead of as continuous variables, measured in syntactic depth from them. This seems to indicate that when taken as a whole, the presence of functional attractors has no apparent radiation effect on the distribution of commercial flows, partly because these attractors are not well integrated with other spaces in the system. Intuition suggests this may be the case. For example, the supermarket located on the underground floor of Coastal City, the KTV on the 3rd floor and the cinema on the 4th floor of Baoli, are rather isolated from other spaces with limited access directed to them. Moreover, when R3 integration is introduced into the multivariate regression, step depth from the elevated platform, the principal integrator of the whole spatial system, is no longer a significant predictor of the dependent variable. This is mainly because the elevated platform is well structured with the surrounding urban context and building interiors, and a description of the syntactic structure of the overall spatial system is already a description of the relationship...
with respect to the platform. Finally, level variation measured in floor height is not significant in all cases of bivariate and multivariate regressions. This result is in contrast to some previous research (Parvin et al, 2008; Zhang et al, 2012). We suggest this is due to the case difference between these studies. The multi-level spatial system presented in this study consists of a cluster of 4 shopping buildings organized in the fashion of an urban space itself, instead of as an individual building with limited access from urban space. What can be inferred from the present study is that, for a complicated multi-level spatial system like NCCD, the integration of streets and building interiors, the strategic distribution of vertical connectors, and the presence of functional attractors can overpower the barrier of floor change and effectively direct commercial flows onto upper floor levels.

5. CLUSTERING OF TENANT TYPES

The next question we ask is whether the impact of those spatial variables on movement distribution can also be related to the clustering and performance of shopping facilities operated in different business modes in the multi-level commercial system. We examine this by starting with a review of the business performance of shops. The business performance is evaluated at the aggregated building level in terms of rent and vacancy rate. Coastal City and Hai’an Mansion have the highest rent and the lowest vacancy rate, followed by Tianli with a medium level of rent and vacancy rate. Baoli, on the other hand, presents an almost inverted example to the former two buildings, and performs as the worst case by having the lowest rent and the highest vacancy rate.

The sharply varied commercial performance among these shopping complexes cannot be simply explained their available space. For example, Baoli and Tianli have a noticeably larger floor area than Han’an Mansion, but their advantage in size apparently has not been turned into business success. Moreover, although Baoli and Tianli are comparable in size, they perform quite differently in terms of shop rent. The study suggests the performing difference in the retail market could be explained by examining the movement influencing factors, in conjunction with the clustering patterns of shops presented in each individual building. We first investigate the integration structure of the multi-level spatial system, and its relationship to the vertical transitions and entrances with respect to each commercial complex, given the observation that the interaction between these variables contributes to a more robust address of the distribution of movement flows.

We define the axial lines whose R3 integration values lie within the top 30% in terms of the total number of lines as the “core structure” of the multi-level spatial system. We ask how many vertical transitions such as escalators and lifts, and entrances are directly linked to this core structure. The results are presented in table 3, along with the average syntactic values for each individual commercial complex. Coastal City and Hai’an Mansion, which have a better performance in the retail market, outperform Tianli and Baoli in every aspect of the syntactic properties, especially for R3 integration (above 4.62 vs. below 3.68), connectivity (above 1.87 vs. below 1.76), and intelligibility (above 0.30 vs. below 0.16) measures. The core structure of R3 integration covers a more extensive area in Coastal City and Hai’an Mansion in the form of continuous loops, which is particularly prominent on the first and second floors. It is noted that Coastal City is the only building in which the core structure spreads vertically up to the fourth floor and above. Moreover, more than 85% of the escalators in Coastal City and Hai’an Mansion are linked directly to the core integration structure, whereas the percentage of core-linked escalators at Tianli and Baoli is less than half of the former. The difference in strategic locations of entrances between these buildings is also pronounced, although to a lesser degree.
MOVEMENT DISTRIBUTION AND CLUSTERING OF TENANT TYPES IN THE MULTI-LEVEL COMMERCIAL COMPLEX

Table 3 - Syntactic properties of individual commercial building, and the percentages of their vertical transitional spaces and entrances located on the core structure.

Table 3 - Syntactic properties of individual commercial building, and the percentages of their vertical transitional spaces and entrances located on the core structure.

Figure 6 - Distribution of the 8 tenant types of shop in the spatial system.
These results indicate that Coastal City and Hai’an Mansion are better embedded into the overall spatial system. These complexes support higher connectivity of space at both local and global levels, and are organized in a more intelligible way; their more expansive core structures are associated with legible orientation to vertical transitions and entrances, either by access or by eyesight. It is concluded that a stronger interaction between syntactic properties and other spatial parameters creates an interface upon which pedestrian flows are guided to the core structure and directed to various floor levels, such that the commercial space is effectively presented and commercial flows are balanced.

We then examine the clustering patterns of shops in each building, based on 8 the tenant types of shop: retail store, catering, costume, jewellery, educational service, cosmetic, electrical appliance, and entertainment. In a broad sense, the former 4 types can be roughly characterized as non-purposeful shopping, and the latter 4 types as thematic or purposeful shopping (Applebaum, 1968). An important difference between them is that the former is more spatially dependent on accessibility and tends to convert passing commercial flows into potential shoppers, while the latter is more goal-oriented and less dependent on location.

The four shopping buildings display both similarity and difference in terms of tenant mix, measured in square meters of each category of rentable space. In Coastal City and Baoli, tenant mix is dominated by costume, catering and entertainment, and they together take up about 80% of total rentable area. Hai’an Mansion is dominated by catering, education service and entertainment, of which catering alone occupies more than half of total area. Tianli appears to have a more even composition of tenant mix, with its primary functions of catering, cosmetic and education services taking up about 72% of total rentable space. When the 8 shop types are aggregated into larger categories defined as “purposeful” and “non-purposeful” shopping, we see a clearer picture of tenant mix among these buildings. For all buildings except Tianli, the proportion of non-purposeful retailing shops is about two-thirds of the total rentable area, while it is only slightly more than one-third in Tianli.

In terms of spatial pattern, large shops of retailing store (supermarket), electrical appliance, entertainment and high-end restaurant are in all cases located either on upper levels (3rd floor and above) or at a far end of building interior. Small shops are likely to locate themselves on the ground and second floors, and they become more intensified and diversified along the large elevated platform. There is an obvious increase in shop size when moving to the upper floors. When compared with the syntactic structure of the spatial system, catering, costume, jewellery and retail stores in general tend to be more closely related to the core structure of R3 integration, with their shops directly opened to that structure. On the other hand, education services, cosmetics, electrical appliances and entertainment appear to be distributed slightly more distantly from the core structure, although they are no more than 1 or 2 step depths from it (figure 6).

In order to further highlight the spatial pattern of variation among those shop clusters, we compute the integration value of each commercial type in the tenant mix of individual buildings. Each shop is assigned to the R3 integration value of the axial line to which it is attached, and this value is weighted by the percentage of square meters that a shop takes up in a commercial category. When summing up the weighted values of all shops within a category, we obtain the commercial type integration measure for each individual building. With the assistance of numerical values, a finer scale of variations can be observed in the spatial patterns of shop clustering. Coastal City and Baoli, while sharing a similar configuration of tenant mix, have rather different internal structures. The former is spatially dominated by non-purposeful shopping facilities, in the sense that jewellery, costume, retail and catering occupy more accessible spaces; the latter gives its advantaged spaces to goal-oriented shopping such as cosmetics, educational services and electrical appliances. Tianli, with a tenant mix focusing on purposeful aspects of shopping, has a similar spatial pattern of distributing commercial types to that of Coastal City. Hai’an Mansion, on the other hand, has a less differentiated structure, with spatial accessibility being allocated to each category of shops in a relatively even manner.
When space, size, tenant mix and business performance are considered together, their relationship in individual shopping complexes can be diagrammed by a matrix shown in figure 7. The horizontal axis represents accessibility measured by spatial variables and their interactions, and the vertical axis displays commercial performance evaluated with rent and vacancy rate of shops at the aggregated building level. In short, better business performance seems to be associated not only with buildings that have better spatial accessibility, but also with the degree to which the pattern of tenant mix in a shopping complex is aligned with movement flows drawn by that accessibility. When a positive relationship of spatial configuration and tenant mix is presented in a building, such as in Coastal City and Hai’an Mansion, an enhanced business performance can be observed. When such a relationship is absent or becomes negative, as in the case of Baoli, a decreased level of performance is also observed. It should be noted that the present study does not relate the business performance of a shopping complex to its size or market strategy of tenant mix. It does not mean these are not important factors influencing the performance of shopping; instead, because a discussion of their effects is beyond the scope of this study, these should be addressed by additional research.

Figure 7 - Relationship between spatial accessibility, tenant mix and business performance at the aggregated building level.

6. CONCLUSIONS

The study investigates the effects of spatial patterns on pedestrian movement and clustering of tenant types in the multi-level commercial system that consists of a cluster of buildings in a high-density urban context. The key objective is to better understand the interactions between the socio-economic variables and spatial design parameters of shopping complexes. Although the study reveals that the patterns of pedestrian flow are in the main influenced by the syntactic properties of space, it also points to the importance of interactions between the
syntactic variables and other spatial variables in shaping the pedestrian flows and the clustering of tenant types in the highly complex commercial system.

Nearly two-thirds of the variation in commercial flows distributed in the shopping area can be explained by the interaction of spatial variables. Among these spatial variables, the syntactic variables, namely, accessibility within a few step depths from a space, and the number of other spaces directly linked to that space, have the highest predictive power of movement distribution. A multiplicity of syntactic variables and other local design parameters together contribute to a more robust address of the distribution of movement flows. Particularly noteworthy is the interplay of R3 integration and location of escalators, which explains 55% of the variation of the dependent variable and has a noticeably stronger effect than that of any of the other variables.

The empirical results lend some supports to the classic shopping mall design principles, i.e., the importance of considering the locations of particular spaces such as functional attractors and vertical connectors when designing the circulation system. On the other hand, however, it is the ways that the local spatial parameters are spatially organized, rather than those parameters per se, are highly important in structuring commercial flow distribution in the multi-level spatial environment. Whether those functional attractors can create artificial pedestrian flows depends on whether they are well integrated with the overall spatial system. Moreover, the integration of space and certain local design parameters such as vertical connectors can somehow counterbalance the floor variations and effectively direct commercial flows onto upper floor levels.

The study also suggests the importance of considering the ways individual commercial buildings are embedded in the overall multi-level system. As indicated by the research findings, an integration of building interiors and urban context, with an alignment of local design parameters, is more likely to result in a shopping interface within which positive interactions between spaces, movements and functions can be activated and developed. These provide useful implications for the strategic design decision to create the vertically effective mixed land use in high-density built environments.

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SPATIAL SCHEMATA IN MUSEUM FLOORPLANS

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ABSTRACT
The study introduces a method for a novel representational technique for spatial and visibility conditions that promotes the identification of categories of spatial experience, here for museum plans. This representation of spatial experience is built atop approaches from schema theory, which seeks to create models to represent mental categories that arise from continuous sensory-motor experience. Several schema are identified for the experience of museum space using clusters of syntax metrics as evaluated using Visibility Graph Analysis.

KEYWORDS
Space syntax, cognition, museum, experience, schema

1. SCHEMA
Sets of architectural representations often include both images that capture the overall organization of space (through orthographic drawings and diagrams) and images that capture specific moments of situated experience (through perspective drawings, renderings, and photographs). These representation types are manifestly useful to central activities in architectural practice, such as evaluating design proposals, providing an informational basis for technical solutions, and communicating with clients, builders, and critics. However, common forms of architectural representation neglect what might be called the middle scale, which is neither as gross as the overall organization of building form nor as fine as the individual percept or detail. This paper is aimed at using Visibility Graph Analysis data to represent such a middle: namely, the dimensions of architectural form that exist but often go undescribed, that are real but open-ended, that are patternly but varied in form.

Rafael Moneo and Aldo Rossi both propound the idea of the obscure as a key dimension of architectural type. In Rossi’s account, type is a pre-existing principle, but not a specific form. For Moneo, type has a generative potential that arises from the capacity of refinements and combinations of formal structures to produce great relational richness. In his 1978 essay on type, Moneo distinguished between Quatremère de Quincy’s development of type, as restating primordial links to nature and history without providing models for form, and that of J.N.L. Durand, for whom type could be boiled down to a compendium of overt formal models meant to assist the newly professionalized architect in dealing with a proliferation of building functions. Moneo, acute to the Modernist rejection of type, recognized the modernist project of “form-space” (32) as calling attention to the conceptual dimension of space itself through the architectural qualities of buildings. Mies, at IIT, is his exemplar.

Moneo’s description of form-space is interesting as an instance of a moment when the sensory experience of space is organized into something that can be recognized as a concept, category, or scheme. Schemata are useful for describing such emergent categories. Shema theory originates in Kantian philosophy on the productive imagination (1998/1781, 240) and is concerned with conceptual knowledge and how it is represented and used. From the point of view of learning and psychology, schema refers to cognitive building blocks that are vital to
processing information and that represent generalizable chunks of knowledge individuals use to make sense of things. Schemata are, in short, formal structures for representing information. Music theorist Robert Gjerdingen has used schema theory as part of a program of formal analysis for things that unfold over time, like listening to a piece of music (1986); he used schema theory to identify the prevalence of specific and subtle middle-level conventions in music over time.

The specific approach from schema theory used in this study is of analogic matching, which maps approximate matches between the constituent elements of events occurring at distinct points in time (Becker, 1973). In analogic matching, for some sequence of events, one kind of occurrence has somehow become prominent, memorable, and mappable onto other similar occurrences occurring in other times or places (Rumelhart, 1980). The present investigation introduces a novel representational technique for Visibility Graph Analysis (VGA) data that draws on schema theory and recurrent patterns of combinations of syntactic variables from points along pseudo-algorithmically generated paths through museum floorplans.

2. MUSEUM SPACE

One of the fundamental functions of museums is as spaces of pedagogy (Hooper-Greenhill, 1994). The space syntax literature has described how spatial structure conditions encounters with artwork, stages social dimensions of museum space, and embeds the logic of its own visual structure. Cues from the artwork, whether of co-visible paintings (Lu & Peponis, 2014) or facing direction of sculpted figures and paintings (Stavroulaki & Peponis, 2003; Tzortzi, 2004), appear to have the capacity to condition physical engagement with the manifest work and cognitive engagement with its content.

Space itself, apart from the art exhibited, influences patterns of use and understanding in museums. Part of the cognitive content of museum space comes through a primarily social channel, for example, through implied codes of spatial use and knowledge acquisition (Peponis & Hedin, 1982), as well as through conditioning patterns of knowledge transmission through relationships of cross-visibility (Peponis, Conroy-Dalton, Wineman, & Dalton, 2004). In several studies, syntactic analysis has been used to illuminate non-discursive dimensions of curatorial intention (Psarra, 2009; Psarra, Wineman, Xu, & Kaynar, 2007; Zamani & Peponis, 2010). More concretely, syntactic measures of spatial integration and connectivity have tended to be good predictors of distributions of museum goers (Choi, 1997; Hillier & Tzortzi, 2006). Aside from this, the dynamics of visual structure of spatial paths themselves appear to differentially activate the intensity of imaginative engagement with the scene observed (Bafna, Losconczi, & Peponis, 2012).

As a functional type, museums provide enough points of contact between program and spatial conditions to support a study that seeks to represent recurrent categories of spatial event. In a previous study on imaginative engagement in the Seattle Public Library, we used contrived paths related to building function to organize a study of how variously-motivated users would experience the library in distinct ways (Zook & Bafna, 2012; Zook & Bafna, 2017). For points along each path, we evaluated several syntax measures from VGA conducted in Depthmap software (Turner, Doxa, O’Sullivan, & Penn, 2001). Using multiple parameters is expected to allow for identification of recurrent spatial schema that are more informative than visualizing single syntax metrics (e.g., integration) or the syntactic pair commonly used to describe intelligibility (i.e., connectivity and integration).

The present study evaluates spatial schema by simultaneously visualizing mean depth, connectivity, maximum radials, and occlusivity for points along a path. Mean depth is used here to model how one cognizes the publicness of specific locations, with the idea that cognized publicness arises from one’s apprehension of being in a spaces of social and informational centrality (Zook & Bafna, 2017). Measures of integration have been associated with higher distributions of users in a number of studies (e.g., Grajewski, 1993; Penn, Desyllas, & Vaughan, 1999). In addition, highly integrated parts of plan arrangements also appear to anchor the mental maps we use in wayfinding activity (e.g., Peponis, Zimring, & Choi, 1990). Connectivity, which is assessed in VGA analysis as isovist neighbourhood size, reflects, following Goffman (1959) the
notion that with increased exposure comes modulation of behaviour that reflects a direct sense of being in public. To restate, mean depth is taken to represent publicness as cognized, while connectivity is taken to represent publicness as directly perceived. Both depth and connectivity have observed relationships to the social life and experience of museum space; for example, Choi (1997) found that museum goers tended to spend time where they were in visual co-presence with a high number of other museum goers, and this occurred in areas attached to highly connected and well-integrated portions of plans. While VGA connectivity indicates the area, and here the perceived publicness, of a space, combining it with maximum radial is aimed at providing some sense of the form this area takes, in terms of whether it provides deep or shallow views. Occlusivity reflects “perceptual uncertainty” (Benedikt, 1979, 53) or the capacity of a given view to admit dynamic information from portions of the edge of the view not lying along hard boundaries, such as walls.

The analysis of spatial schema was initiated with the expectation of identifying two schema that can be viewed as reciprocal to one another; the first has to do with well-connected and well-integrated spaces, whose significance has already been well-described in the syntax research on museums. The second is the opposite: the spaces that are peripheral. A third schema, having to do with spaces that diverge along the dimension of integration and connectivity was also tracked. Typically, positive correlations between integration and connectivity are taken as indicators of intelligibility, in the sense that in such configurations, the nearby environment will give meaningful cues about the spatial structure of the greater building (or street network) (Hillier, 1996; Bafna, 2003; Peonis & Wineman, 2010). However, this study is interested in the properties of spaces that bend away from such correlations, as they may reflect a particular spatial schema, rather than the mere failure to contribute to the intelligibility of the system.

Figure 1 - Eight museum plans with paths
3. MUSEUM SPATIAL SCHEMATA

Identifying spatial schemata depends on having representations that promote the recognition of patterns. For example, in Gjerdingen’s work on conventions in classical music, musical notation supports the visual identification of schema. To get to such a representation for museum VGA data, four main steps were taken. First, a pseudo-code was created to guide the generation of paths through all eight museums. The purpose of the pseudo-code was to create comparable paths through floorplans that varied in size and form, and main instructions in the pseudo-code governed turning decisions, distances from architectural elements, path termination, the completion of major rings, and the avoidance of backtracking. Second, after paths were established, points were plotted at 5-foot intervals and spatial analysis data was captured for each point using UCL Depthmap (Turner, Doxa, O’Sullivan, & Penn, 2001). (See Figure 1.) Third, each of these measures was normalized relative to the highest value (i.e., as a percent of the maximum value). Fourth, line charts were created from the normalized values of the spatial variables for each path point. In the line charts, each tick on the horizontal axis corresponds to 20 sequential points along the museum path (or 100 feet of path length). The y-axis represents the percent of the maximum value.

For the purposes of the present study, the output of the line charts are examined visually. In future work along this line, it may be valuable to develop methods that use data mining or other statistics-based identification strategies.

Eight museum floorplans are represented. J.N.L. Durand’s published plan for a museum (1813), the original building of the Cleveland Museum of Art by Hunnell and Benes (opened 1916), the Whitney by Marcel Breuer (opened 1931), the Museum of Modern Art by Phillip Goodman and Edward Stone (opened 1939), I.M. Pei’s Emerson Museum (opened 1968), James Stirling’s Sackler Gallery (opened 1985), the Nasher Sculpture Center by Renzo Piano (opened 2003), and Herzog and de Meuron’s DeYoung Fine Arts Museum (opened 2005). The Durand museum was selected as a reference case, an “overt model” of conventional museum space. The remaining museums were selected as representing a variety of museum sizes and layout properties in the United States.

3.1 AN OVERT MODEL FOR MUSEUM SPACE – DURAND, BIG CENTRALITY, AND MARGINALITY

Figure 2 shows the line chart representation of path points for Durand’s plan for a museum. One recurrent pattern appears on the top row, where connectivity (dark blue) peaks over a relatively stable occlusive perimeter (light blue), with mean depth forming a valley (light orange), and maximum radial forming a small peak within a valley (dark orange). This spatial condition can be described in more everyday terms as one of markedly large views, spatial and perceptual centrality, and a potentially dynamic view; in a setting that is in use, it is likely that animation by other museum goers would be both directly perceived, in people entering and exiting a loosely bounded view and sensed at a more cognitive level, as one anticipates the presence of others in spatially central locations. The points along the path displaying this arrangement of values are located in the central crossing of the plan. It recurs whenever that path passes back through the central crossing, and it appears not to occur elsewhere in the plan. Let’s call this particular pattern of values “big centrality”.
A different, but similarly distinctive pattern is bracketed in Figure 3. In it, mean depth peaks, and occlusivity, connectivity, and maximum radials dip, especially connectivity. Views are short and small in area and can be expected to be relatively less prone to be animated by in-movers; the spatial position relative to the rest of the floor is peripheral. We will call this pattern of values “marginality”. Unlike big centrality, marginality is not tied to a unique location in Durand’s scheme, but recurs where the path enters the boxcar-like rooms that line the museum courtyards.
A number of additional patterns could be observed from Durand’s scheme. This is, however, enough to begin a discussion of the set of plans. Before doing so, however, a third attribute of the Durand line chart merits mention, and that is its overall patternliness and geometric order. Figure 4 shows the path values for all museum paths compressed to the same width. The values for the Durand scheme are visibly repetitive and orderly, with the schema often showing symmetrical distributions of syntactic values.
The Nasher Sculpture Center (Figure 5) evidences the big centrality schema. The moments of big centrality are, in this case, toward the geometric centre of the plan, where the four open galleries are crossed by the horizontal corridor. Again, the distinctive spatial condition is tied to a specific location, but in the Nasher the location is not defined by as perceptible and easily-conceivable space, as it was in Durand, as the Nasher’s big centrality spreads horizontally and is not associated with a recognizable geometric figure, as in Durand. In further distinction from Durand, there are not locations in the Nasher plan that are clearly marginal.

3.2 REMOVAL

The Everson (Figure 6) shows the same marginality schema at the beginning and end of the path, in the short, fat corridor that leads from the spiral stair the ring of exhibition space. The space of the Everson also offers a pattern of space in its gallery spaces that is characterized by a peak in mean depth and a valley-shaped connectivity line, which nonetheless represents a relatively high visible area and ranks second, after mean depth, among the spatial metrics. Maximum
radials dip and isovist occlusivity hits rock bottom. Such a schema may rightly be thought of as a space apart; there is some sense of self-importance in the isolated nature of the space, which screens out distractions within the context of isolated, static, and generously-sized views. This schema, which I am terming “Removal”, should be regarded as having a flavour that is distinct from that of marginality. The removal schema instances occur in the large gallery rooms of the Everson, perhaps supporting the art-viewing dimension of the function of museums. Removal can also be observed in the path representation at the Sackler Gallery, in the several largest galleries of the plan (Figure 6).

Figure 6 - Removal at the Everson (above) and the Sackler (below)

3.3 OTHER KINDS OF PHENOMENA

Apart from the identification of schema, the representation of syntactic variables in a simultaneous format allow for observation of other kinds of phenomena. For example, taken as wholes, one can see that MoMA and the Whitney line charts show a bifurcation in the distribution of values across the course of the path (Figure 7). In both cases, all of the syntactic values are constrained to a narrow, middle band through the first portion of the trajectory, then, in the second half, all of the values swing into new highs and lows. For both building plans, the change marks the transition from an open floorplan (punctuated by freestanding partitions in the Whitney and by columns at MoMA) to one or more cellular rooms. In both MoMA and the Whitney, the rooms can be characterized by the marginal schema of the peripheral rooms in the Durand plan (Figure 9). The first half of the trajectory through MoMA is remarkably stable, with most variable values nearly flat, raising the possibility that this may be what is meant when Modernist architecture is described as “boring” (e.g., Venturi’s dismissal that in Modernist architecture, “less is a bore”).
However, for its apparent attempts to be, if nothing else, stimulating (Jencks, 1977), post-modernist architecture also has static spatial attributes. In the Sackler, almost without exception, mean depth is not only high, but the highest value of the four spatial parameters. Almost without exception, isovist occlusivity is the lowest value, with some flip-flopping between maximum radial and connectivity as the middle values, with all values tending to rise and fall together. The Sackler is a museum of rooms, of somewhat isolated rooms (Figure 6).

The linecharts for the conventionally planned Cleveland museum and the DeYoung, a museum with a difficult-to-conceptualize plan, appear similar. The central crossing at Cleveland shows big centrality. Otherwise, both museums are “noisy” insofar as the visual identification of schema (Figure 4). Both show a range for all variables, without readily apparent repetitive patterns. The connectivity value for the Cleveland sometimes flatlines for long stretches, indicating a notable duration in a fairly enclosed room. However, the differences between the two plans are not as pronounced as one might expect. Although, a close look indicates that within the spatial variety of the two plans, something approaching the marginality schema is frequently apparent, though fleeting. In general, the style of plan geometry seems to matter less than spatial order to the identification of syntactic schemata.
4. CONCLUSION

Inspired by work in music theory, this study set out to test a novel method for representing spatial data, specifically values for VGA-derived space syntax measures. Several spatial schemata were readily identifiable from inspection of line charts that allowed for simultaneous visualization of multiple syntactic variables.

Spatial schemata may provide a useful approach to multidimensional or quantitative investigation of how type or category arises from continuous spatial experience. Recurrent patterns of clusters of spatial variables related to well-studied ideas of centrality and peripherality appeared as expected, with the present approach enabling a nuanced look at the patterns of distributions of these conditions. The schemata-based approach also supported the identification of certain clusters of variables—namely one including high connectivity but low integration—as having a particular experiential quality—as features rather than bugs, to borrow an expression from software development. The present study is exploratory in nature. In addition to there being room to develop further theory on spatial schema, there is also scope to validate the idea of schemata-dependent experience using empirical research. Future research with more advanced quantitative methods could also make a more rigorous, less eyeball-dependent study of repetition, rate, and apparent precedent-antecedent spatial schema, among other things.
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