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NEW BUILDING FOR A NEW WAY?
New School Pedagogic and its building spatial configuration in Paraíba (Brazil)

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ABSTRACT
This study is an initial phase of a research that analyses the influence of the New School (Escola Nova) education movement in the spatial configuration of Brazilian school buildings of the 1930s. This paper addresses specifically the Paraíba’s Education Institute, as a model of the educational reform being set in Paraíba state. The movement aimed to reform and modernize traditional education, indicating that the student should become central to education, which should happen with practical experiences, rather than the teacher simply transmitting information. The school should also be more open to society and cease to have distinctions between genders. Understanding that space configures movements and experience in buildings – being able to promote or hinder encounters between peoples and activities – this work studies the Institute’s spatial configuration and investigate whether, and to which extent, such principles express themselves in space. To do so, the New School foundation discourse – found in official documents of the time – was translated into spatial properties, then it was compared to the analysis of the topological structure of convex spaces of the Institution’s central building. Deciphering such documents into socio-spatial relations, some spatial attributes that might favour New School practices were identified, such as: little hierarchy and control by directors and teachers; and integrated classrooms in the overall structure, so that students could easily reach other areas that might encourage practical activities and interactions (e.g. spaces of recreation and exterior). The analysis shows that the exterior is the most integrated area. This indicates that circulation rings are formed with the exterior, showing flexible flows that facilitate outdoor activities, and that there was proximity to society at large, as low walls between the school and public space allowed visual contact. However, when the building was analysed disregarding the exterior, the boardrooms become more integrated. This indicates a privileged administrative sector, a situation that refers to traditional teaching, with greater disciplinary control of students. Overall, comparing the socio-spatial relations embedded in the pedagogic discourse with historic school buildings’ spatial structure, there were some points of innovation in Paraíba’s Institute, but also other traditions were kept. This reinforces spatial configuration analysis as a means to confront discourse with socio-spatial relations and shall be further explored at other pre and post Brazilian school buildings around the same time.

KEYWORDS
New School Movement, Socio-Spatial Discourse, Spatial Configuration, School Buildings
1. INTRODUCTION

By giving shape and form to our material world, architecture structures the system of space in which we live and move in. (Hillier & Hanson, 1984, p. ix).

Spatial configuration is intrinsic to social life by people’s tendency to move in lines, interact in convex spaces and see changing fields as they move in the built environment (Hillier & Vaughan, 2007). However other factors might affect people's uses, spatial configuration conditions peoples' experiences in space and activities.

This paper analyses the New School (Escola Nova) education movement influence on the spatial configuration of Brazilian school buildings in the 1930s, having as case study Paraíba’s Educational Institute buildings, model of such educational reform being set in Paraíba state (northeast Brazil). Hence, after presentation of the building and the education movement, the spatial attributes embed into discourse are extracted; the study case spatial configuration analysis is then presented; finally, this study verifies if there are coincidences between the buildings spatial structure and the pedagogic expectations.

The education renovation movement known in Brazil as New School, valued the children's self-training and spontaneous activity, inspired in ideas of John Dewey, Adolphe Ferrière, Édouard Claparède amongst others. Learning initiative should centre on the pupil, exchanging with the teacher through practical experience (Saviani, 2004).

Ideas of New School movement in Paraíba resulted in the Public Instruction Reform (1935), intending to create new models of school buildings, which should adopt modern architecture to adjusted new teaching methods (Mello, 1936). Paraíba’s Educational Institute was created (1937-1939) as a model establishment to form up-dated teachers, made of three buildings: kindergarten, application school and the main building (with the Secondary school and the teachers’ school). Figure 1 shows the newly opened Institute's main building, its modernist style and openness to the street.

Figure 1 - Paraíba’s Educational Institute main building, in 1939.
2. NEW SCHOOL MOVEMENT SPATIAL ATTRIBUTES

The publication of the New Education’s Pioneers Manifest (Manifesto, 1932) was a mark of New School movement in Brazil, gathering movement ideas to renovate education in the country. This document is adopted as representing New School discourse to extract spatial attributes favouring this pedagogy. This manifest advised that the learning process should happen “from inside out”, the child as centre of the school, respecting its personality, and to “open to the student its energy in observing, experiment and create all activities capable of satisfying himself”.

In the school’s spatial structure, this should result in the traditional rectangular layout of classrooms being replaced by centralized configurations, with easy to move furniture and create new arrangements (Alegre, 2012). Classrooms should be well integrated globally and to areas destined for free activities and playing, there should also be spaces to socialize and allow interaction of different interfaces.

Another principle is that the school should not be a formal and isolated institution, but extend its action to society and irradiate educational activities. For this recommendation to happen, it is hereby understood that the school should be spatially integrated with the exterior.

Furthermore, teaching should be equal for both genders, unseparated; buildings should no longer have to be separated in two quarters.

Complementary information is revealed by the Paraiba’s Educational Institute project memorial, another document explaining the building’s pedagogic attributions. It described that the new way - of comprehending the learner and its more equal relation with the teacher - demanded a new study environment to favour knowledge’s natural curiosity, with an educational mission (Joffily, 1937). In relation to spatial organization, classrooms were distributed along two wings centrally articulated, rather than the classic building type with central courtyard. This aimed to augment lighting and ventilation to improve comfort and health conditions, and reduce noise by separating corridors accessing the classrooms.

Such documents were deciphered into some spatial attributes that might favour New School practices, such as: undifferentiated spaces for male and female students, little hierarchy and control by teachers, classrooms integrated in the overall structure (so they could easily reach other areas – and exterior areas – e.g. to play, and a strong connection to the exterior, and public space.

3. METHOD AND ANALYSIS

Paraiba’s Educational Institute main building layout was represented and quantified by means of space syntax convex analysis at two levels (Figure 2): the minimal living – the system of interior spaces only – and the minimal living plus exterior – all connections between the interior spaces and the exterior were considered. The structure was read through justified graphs in the JASS1 program calculating integration (through Real Relative Assymetry). The minimal living considered only the first and second floor. The minimal plus external considered all the four floors and entrances. It was considered that originally all entrances were used as access by those who control space (directors and teachers) and by main visitors (children) since there were no doors – or indication of control– that could force students to enter in a particular place.

1 JASS. Created by BERGSTEN, L. et al. v1.0, 21 May 2003, GNU-General Public License.
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Figure 2 - Main building’s floor plants and convex spaces system with connections: (a) Minimal living; (b) Minimal living plus exterior.

The configuration analysis reveals the exterior as an important articulator of the buildings spatial structure. The system with exterior is more integrated (RRA 0.938²) than the minimal living system (RRA 1.093).

Circulation spaces are the most integrated ones in both situations, facilitating encounters between different interfaces, profitable to socialization and sharing experiences. Indeed, in the project memorial it is suggested that in classes intervals, students could remain in the balcony corridors, designed with a width of 3.4m (Joffily, 1937); the designed wide corridors indicate that interaction there was intentional.

In the minimal living analysis, most integrated functional spaces are the director rooms (RRA between 1.024 and 1.083), showing the administrative privileged situation. However, when the exterior is added, the exterior itself becomes the most integrated space (RRA 0.524), as it easily connects to many rooms (Figure 3). The classrooms also become more integrated in the system considering the exterior. The exterior’s high accessibility might very well be a reflection on New School ideology; its intention to integrate with society is further suggested by low walls and

² For justified analysis through JASS, the lower the RRA measure, the shallower in the system and, thus, more integrated.
many openings with public space. More access to exterior may indicate a will to learn through action, as the area serves to group activities, garden visits, etc.

Figure 3 shows that the main building spatial structure justified from the exterior is shallow, presenting seven levels - which is perceived as low given the system's four floors and many rooms. At the second level one can already reach the most important spaces in the school, as classrooms, auditorium, library and administrative rooms. One can also notice in this justified graph the many rings forming with the exterior, which shows less control and many access possibilities.

4. DISCUSSION AND CONCLUSION

Overall, comparing the socio-spatial relations embedded in the pedagogic discourse with historic school buildings' spatial structure, there were some points of innovation in Paraíba's Institute, but also some traditions were kept.

Moreover, the comparison with other Brazilian schools studied by Loureiro (2000), reveals that this building is a more integrated system than most schools, showing an intention to integrate activities, and people. Thus, the most latent finding revealing new pedagogic ways, is the high integration and importance of the exterior, easily connected to the classrooms; it also forms rings with various areas, indicating less control of potential movement and possible intermingling of people and activities. The exterior represents a space for active functions for the learner and a connecting role with society, as it allowed for visual and physical continuity with public space. The buildings many openings and the exterior strong hierarchy seems purposeful indeed as there was also a strong belief that catching some sun was healthy and necessary.

Likewise, the corridors seem idealized to promote encounters between different people, they were designed in a way that people could pass through but also remain there (wide areas and central position) and indeed were integrated within the system.

However, the role of administrative quarters has remained important, especially when only considering the minimal living. This trend denotes hierarchies read in traditional education. Teachers’ rooms have also maintained a controlling function over the classrooms, revealing that, although classrooms (and pupils) were well integrated with the exterior, they could still be controlled by teachers.
Spatial configuration analysis is thus also a means to confront discourse with socio-spatial relations. This research will be further explored at other Brazilian school buildings around the same time, which might enlighten similarities and contrasts of buildings of this type, as well as understanding better connections between discourse, uses and space, and relations between pedagogy and architecture.
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#179
THE BALANCE BETWEEN PHYSICAL CLOSURE AND OPENNESS IN OFFICE WORKSPACE AND THE RELATION OF THE INTERACTION BETWEEN WORKERS AND THEIR NEED FOR PRIVACY

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ABSTRACT
The scope of this research project is to develop a model indicating a balance between physical openness and closure in office working environments and the relation between physical attributes and their influence on possible interactions between office workers and their need of privacy. Interaction among employees takes place in cases of extensive visibility and accessibility. On the other hand, privacy is possible, most times, in enclosed spaces with defined physical boundaries. Literature confirms that both interaction and privacy are significant for the workers’ satisfaction and, at the same time, serve the management’s interests. The main research question posed is: What are the physical and geometrical/morphological components that enable the delicate balance between physical closure and openness in office workspace? The research objective is to uncover the characteristics of these issues.

In this paper we present the research in progress combining quantitative and qualitative methods and a comparative evaluation between both. The research method is a comparative study of variant case studies. In this paper we present two case studies: the traditional office, restricted office with closed rooms connected by corridors and an open space office. In both case-studies global integration was examined using axial lines map while at the same time behavioural analysis was conducted based on observations and employee interviews, culminating with a comparison of the results of the analysis. Partial results of this study indicate that combining the axial lines maps with additional analysis of behaviour maps may result in more comprehensive information. Preliminary outcomes of the study indicate reciprocal relations between size of corridors and interaction between office workers together with their feelings of privacy in space; also the location and accessibility of common functions in the public spaces and their usability. Strong relations were found between topological analyses and interview analysis regarding openness to external view in addition to location and orientation of seating regarding privacy and interaction. The research results and conclusions may serve as a basis for future studies in this area and a basis for practical directing guidelines for future office space design as well as office workers community and managements.
KEYWORDS
Physical closure and openness; interaction between workers and privacy; office-space morphological characteristics; office-space design; Space syntax.

1. INTRODUCTION
The scope of this research is to develop a model dealing with the balance between physical openness and closure in office working environments and the relation between physical attributes and their influence on possible interactions between office workers and their need of privacy. Interaction takes place in cases of extensive visibility and accessibility. On the other hand, privacy is possible, most times, in enclosed spaces with defined physical boundaries. Literature confirms that both interaction and privacy are significant for the workers’ feelings of satisfaction which coincides with serving the management’s interests.

This study focuses on issues of privacy and interactions in office environments of various types: The traditional office with closed rooms connected by corridors, where employees are sited individually or in pairs, and the open-spaced office, where each employee is sited individually in a cubicle, of various types: completely open with no partitions or open with different height partitions that do not reach the ceiling as in closed rooms. All case-studies have similar tasks and functionality.

In the last decade, studies on the topic revealed that employees have been complaining of lack of privacy such as acoustic privacy, visual privacy and a sense of personal loss (Vischer, 2002, 2005, 2006, 2007b). With that being said, different studies affirm that open-space areas contribute to collaboration and interactions among employees (Rashid and Zimiring, 2003, Rashid et al, 2005, Rashid et al 2006, Rashid et al 2007, Rashid et al 2009, Steen & Markhede, 2010, Suckeley & Dobson, 2014). It appears that the employees’ content, regarding privacy, in complete open-spaced offices resembled the content of employees, regarding privacy, in completely closed offices, in contrast to employees working in open-spaced offices with partial partitions.

The research objective is to uncover the geometrical/morphological characteristics in office workspaces that enable the delicate balance between both: to encourage interaction and cooperation between workers, while supporting their privacy needs.

2. DATASETS AND METHODS
This article presents a research in progress combining quantitative and qualitative methods and a comparative evaluation between both. The quantitative methods are based on powerful space syntax (Hillier, 1996, Hillier and Hanson, 1984) axial maps analyses and geometric metrics analysing accessibility, visibility, connectivity, interaction and intelligibility of variant office working environments. The qualitative methods are based on conducting deep interviews among dozens of office workers and observations on the variant public spaces of this workspace. The research method is a comparative study of variant office spaces with similar tasks.

The article presents a traditional office with closed rooms connected by corridors, comparing two corridors, one 1.5m wide and the second 2.5 m wide, in the same office building. The study also compared the global integration using axial maps analysis with interviews in another office building designed as an open space. This office building combines closed rooms with open spaces containing partitions of various heights including extremely low partitions in the height of computer screens. Results and conclusions are presented from the comparison between workstations in different open space offices (Totally open with no partitions and totally open with different height partitions).
3. RESULTS

The results of a comparison between two corridors in a traditional office building are as following: figure 1 an axial line map examining global integration is presented. The analysis is relating to the rooms and the corridor with the focus on the contrast between the two. It seems that in both corridors, the wider and the narrower, the potential for integration exists in a similar way. (In both corridors, red axial lines were found in comparison to blue axial lines located in the rooms). This indicates a forecast of interactive activities that can occur in these corridors.

![Figure 1 - Top - site view and photo of the traditional office space building. Down - Axial line map – global integration in a wide corridor (2.5 meter-top) and in a narrow corridor (1.5 meter-below)](image)

Behavioural maps were charted indicating various activities in different locations in the corridors. These maps are based on observations and describe employee behaviour in these particular areas. Figure 2 shows a comparison between Axial lines and a behavioural map in the wider corridor on the entrance floor. The cluster of red dots seen on the behavioural map indicate that the main activity, is that of private individuals talking on their cell phones.
Figure 2 shows a comparison between Axial lines and a behavioural map. The behavioural map displays multiple grey dots indicating interactive activity taking place in the corridor of both work and social related conversations. From employee interviews, it is apparent, that there is less integration in the corridor on the entrance level than in the corridor on the upper floor. As an example, one of the employees working in an office along the wider corridor, on the entrance level affirms: Occasionally there are noises that bother me…. Sometimes I go out of the room into the corridor to make a private call. According to interviews, it is clear that the conversations among the employees are conducted in the rooms or in intimate recesses, but not in the corridor. However, an employee in the upper floor, facing the narrow corridor said: In the corridor, one bumps into colleagues that haven’t been seen in a long time, we greet each other and catch up on the latest. Another employee states that, in the corridors, the kitchenette, the copy-machine room, the coffee stands, even in the lavatories, there are rendezvous. The same employee states that when she needs privacy she doesn’t go out to the corridor.

Figure 3 shows a comparison between Axial lines and a behavioural map. The behavioural map displays multiple grey dots indicating interactive activity taking place in the corridor of both work and social related conversations. From employee interviews, it is apparent, that there is less integration in the corridor on the entrance level than in the corridor on the upper floor. As an example, one of the employees working in an office along the wider corridor, on the entrance level affirms: Occasionally there are noises that bother me…. Sometimes I go out of the room into the corridor to make a private call. According to interviews, it is clear that the conversations among the employees are conducted in the rooms or in intimate recesses, but not in the corridor. However, an employee in the upper floor, facing the narrow corridor said: In the corridor, one bumps into colleagues that haven’t been seen in a long time, we greet each other and catch up on the latest. Another employee states that, in the corridors, the kitchenette, the copy-machine room, the coffee stands, even in the lavatories, there are rendezvous. The same employee states that when she needs privacy she doesn’t go out to the corridor.
In an observation conducted on the two corridors it is apparent that in the upper level, where the corridor is narrower, work related interactions and cooperation among employees exist. However, in the corridor on the entrance level, where the corridor is almost twice as wide, the main activity viewed was talking on the cell phone, which is a private activity. The employees were satisfied in both corridors: the wider corridor provide anonymity enabling a kind of privacy and the narrow corridor provide intimacy and enables interaction, while privacy is realized in the closed office rooms.

The result of a comparison conducted in an open space office with various height partitions are as following: Strong relations and similarities between the results of the axial maps analysis and observations and interviews were found. The interactive axles which appeared on the axial maps were found to be interactive in the observations which portrayed movement of employees through passageways, between stations, and employee cooperation which takes place in these areas. Observation revealed that in the passages and between the work stations employees ask and advice one another in work related issues along with social activity.

In the cubicles where the partitions reach 1.6-1.8 meters there is more interaction and cooperation among employees in the passages because they seem higher. An employee operating in a cubicle, states that, *everybody hears everybody else... There is no quiet, not even for a minute, when I want to sit quietly, I put on headphones.* In contrast, an employee who sits in a complete open space with very low partitions explains, yes, we see. *The truth is that it hardly bothers, maybe just a little bit - the lack of privacy, but I am pleased with the fact that I can see...*
others. Another employee in an open space station affirms, On the whole, I consider everyone my friends, those sitting in the adjoining stations a bit closer, in the department, on the floor. I don’t feel crowded at all. I don’t feel that I hear the noise. I don’t feel exposed despite the open space. Another employee expresses that it is easier to cooperate. It appears that in open space offices the highest satisfaction is where no partitions or very low partitions that enable maximum visibility and interaction. It appears that visibility influences a silent behavior due to awareness to the neighboring employees.

4. CONCLUSIONS
Preliminary outcomes of the study indicate reciprocal relations between size (width and length) of corridors and interaction between office workers and their feeling of privacy in the traditional office space; also the location and accessibility of common functions in the public spaces and their usability.

The Behavioural Map shows that in spite of similarities in the topological maps in both corridors, the activity observed was different: In the narrower corridor, there was interaction activity and cooperation between employees. Whereas in the wider corridor there were private activities of talking on the cell phone. The combination of axial lines and behavioural maps have stronger relations to the employee’s response according to interviews.

In an open office space, there is general satisfaction concerning the issues of privacy in various aspects, when partitions do not exist at all, or when the partitions are very low. Similar results were found during observations. These findings strengthen the conclusions of recent work taking place in the last decade which discuss the satisfaction of privacy.

These research outcomes and conclusions may serve as a basis for future research in this area. The suggested model may become a basis for practical directing guidelines for future office space design as well as for the office workers community and managements.
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CONSIDERING PATTERNS AND MECHANISM OF PUBLIC SPACE USE WITHIN COMMERCIAL MALLS IN CHANGSHA CITY, CHINA

A syntactic approach

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ABSTRACT
With recent studies beginning to establish a more quantifiable understanding of the qualitative properties of commercial areas, this paper presents a preliminary investigation into how spatial configuration and service provision may influence the behaviour of visitors to selected commercial malls located within the central area of Changsha City, China. Placing space syntax methodology at the centre of this approach, and supported with detailed ethnographic observations, data analysis and interpretation reveal a more in depth understanding of local consumer phenomenon and the significance of spatial configuration and service provision upon this. The cases presented here suggest that China's consuming mode is entering into a new stage, as where young people have become the prevalent visitor group, their focus has shifted from product per se to quality of experience. As spatial relations may afford the potential for varying degrees of co-presence and movement, the ability of these commercial malls to effectively adapt to this ongoing transition may have an impact on their long term popularity and performance.

KEYWORDS
Space syntax; commercial mall; spatial configuration; service provision

1. THEORETICAL BACKGROUND
In recent years new shopping behaviours have stimulated a rethinking towards the design of commercial space. With enriched methodologies, recent studies measuring urban design begin to establish a quantifiable understanding of the more qualitative properties of commercial areas (Ewing and Handy, 2009; Xiao et al, 2016). Central to this investigation is the idea of spatial configuration and service provision, as configuration and network connectivity have been shown to have a strong influence on human activities –from movement to co presence and way-finding (Hillier and Hanson., 1984; Chiaradia et al., 2012; Porta et al., 2012). Spatial configuration, combined with service provision and people’s perception based on it are perhaps more important for commercial malls as dense activities have agglomerated in a small place and are potentially influenced by the artificially designed space. The potential of these
configurational relations both at an urban scale and within a spatial layout of a commercial mall to influence movement, co-presence and accessibility, coupled with other socio-economic factors require more critical inquiry.

2. RESEARCH FRAMEWORK

2.1 STUDY AREA

The study draws upon empirical research and ethnographical observations taken from three commercial malls located within the Wuyi Commercial Area of Changsha city, China. Changsha is the provincial city of Hunan province and has long been famous for its centred retail facilities, with the Wuyi Commercial Area being one of the largest retail areas in the country. The selected malls within this area are: Yue Hui Mall, ID Mall and La Nova Mall, which although are located in close proximity to each other (Figure.1), all have differing structures of service provision.

![Figure 1 - Wuyi Commercial Area and location of selected malls](image)

2.2. DATA AND METHODOLOGY

2.2.1. PART 1: RECORDING USE PATTERNS OF PUBLIC SPACE IN COMMERCIAL MALLS

Gate counts were taken twice every two hours, over a 12 hour period (See Figure 2). To record visitors’ movement and co-presence, static snap shots were taken respectively in the midday, afternoon and evening on a Saturday. Individual patterns of visitor’s movement from selected entry points into each building were recorded as movement traces for a duration of 10 minutes. For a semi-structured survey, 100 questionnaire forms were delivered in each commercial mall on Sunday 19th June, 2016, seeing 95 valid questionnaires returned for La Nova Mall, 88 for Yue Hui Mall and 99 for ID Mall. These different data sets offer a quantized description of the patterns of use of public space in the selected cases.

2.2.2. PART 2: MECHANISM OF USER PATTERNS OF PUBLIC SPACE IN COMMERCIAL MALLS

Space syntax techniques are utilized as the principle methodology to investigate which factors may impact upon the user patterns throughout the public spaces. To begin to understand the configurational relations of these selected malls, the spatial layout of each has been divided into convex spaces: 36 for YueHui, 169 for La Nova and 187 for ID Mall, allowing different measures to then be highlighted (Figure.2). Static snap-shots give an indication of the number of visitors within the convex spaces of all public areas.
Figure 2 - Convex analysis showing measures of integration (HH)
The model is built to simulate the impact of spatial configuration and services provision on the visitor number within each convex space, with the following variables being highlighted and analysed through a multiple stepwise regression method (Table 1).

<table>
<thead>
<tr>
<th>Category</th>
<th>Variable</th>
<th>Quantification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Link to other parts of the commercial mall</td>
<td>integration</td>
<td>convex analysis measuring integration (HH)</td>
</tr>
<tr>
<td></td>
<td>mean depth</td>
<td>convex analysis measuring mean depth</td>
</tr>
<tr>
<td></td>
<td>choice</td>
<td>convex analysis measuring choice</td>
</tr>
<tr>
<td></td>
<td>step depth to nearest gate</td>
<td>number of spaces between the target space and the nearest gate</td>
</tr>
<tr>
<td>Service provision</td>
<td>step depth to nearest anchor shop</td>
<td>number of spaces between the target space and the nearest anchor shop</td>
</tr>
<tr>
<td></td>
<td>step depth to food centre</td>
<td>number of spaces between the target space and the food centre</td>
</tr>
<tr>
<td></td>
<td>step depth to recreation centre</td>
<td>number of spaces between the target space and the recreation centre</td>
</tr>
<tr>
<td></td>
<td>spatial size</td>
<td>standardized area of the convex space</td>
</tr>
<tr>
<td>Structure</td>
<td>shops directly connected</td>
<td>number of shops attaching with the target space</td>
</tr>
</tbody>
</table>

Table 1 - Variables and their Quantification

3. ANALYSIS AND RESULTS

3.1. USE PATTERNS OF PUBLIC SPACE IN COMMERCIAL MALLS

3.1.1. GATE COUNT

Similar total visitor numbers were recorded for gate counts from all three malls: 40124 for Yuehui, 49416 for La Nova and 34570 for ID mall. However, the number of visitors for each gate within the same mall varies significantly.

<table>
<thead>
<tr>
<th>Gate</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yuehui Mall</td>
<td>3582</td>
<td>1986</td>
<td>3854</td>
<td>1368</td>
<td>3778</td>
<td>8492</td>
<td>5010</td>
<td>12054</td>
</tr>
<tr>
<td>La Nova</td>
<td>7080</td>
<td>6515</td>
<td>11004</td>
<td>12156</td>
<td>4188</td>
<td>6792</td>
<td>1392</td>
<td>288</td>
</tr>
<tr>
<td>ID Mall</td>
<td>1440</td>
<td>3825</td>
<td>5180</td>
<td>7250</td>
<td>2920</td>
<td>5575</td>
<td>4745</td>
<td>3635</td>
</tr>
</tbody>
</table>

Table 2 - Gate counts for three commercial malls

3.1.2 SNAP SHOTS AND MOVEMENT TRACE

Compared with all visitors, groups of three people or more are less than 10% in all malls. Visitor’s behaviour changes throughout the day, seeing higher numbers to area of service provisions at midday and evening. Larger convex spaces correlate to higher numbers of visitors in particular where these area are utilized as event spaces. The first floor of Yue Hui acts more as a transition space, seeing higher number moving towards the main circulation core, and significant numbers of visitors concentrated at the entrance of the cinema on the 4th floor.
Figure 3 - Static snap shots and movement traces within the three malls
### 3.1.3 QUESTIONNAIRE

Evidence from the survey reveals a higher proportion of the visitors are female, young (under 35) and highly educated, although Yue Hui appeals to a younger group, with targeted entertainment facilities. Reasons given to visit vary significantly for each mall.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Yue Hui</th>
<th>La Nova</th>
<th>ID Mall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>male</td>
<td>38.64%</td>
<td>35.79%</td>
<td>64.65%</td>
</tr>
<tr>
<td></td>
<td>female</td>
<td>61.36%</td>
<td>64.21%</td>
<td>64.65%</td>
</tr>
<tr>
<td>Age</td>
<td>&lt;20</td>
<td>38.64%</td>
<td>30.53%</td>
<td>31.31%</td>
</tr>
<tr>
<td></td>
<td>20-35</td>
<td>56.82%</td>
<td>61.05%</td>
<td>59.6%</td>
</tr>
<tr>
<td></td>
<td>36-50</td>
<td>3.41%</td>
<td>6.32%</td>
<td>9.09%</td>
</tr>
<tr>
<td></td>
<td>51-65</td>
<td>1.14%</td>
<td>1.05%</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>&gt;65</td>
<td>0</td>
<td>1.05%</td>
<td>0</td>
</tr>
<tr>
<td>Education</td>
<td>college and above</td>
<td>51.14%</td>
<td>81.06%</td>
<td>80.81%</td>
</tr>
<tr>
<td></td>
<td>high school and</td>
<td>48.86%</td>
<td>18.94%</td>
<td>19.19%</td>
</tr>
<tr>
<td></td>
<td>below</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purpose</td>
<td>shopping</td>
<td>29.55%</td>
<td>54.74%</td>
<td>53.53%</td>
</tr>
<tr>
<td></td>
<td>food services</td>
<td>31.82%</td>
<td>16.84%</td>
<td>28.28%</td>
</tr>
<tr>
<td></td>
<td>entertainment</td>
<td>53.41%</td>
<td>45.26%</td>
<td>41.41%</td>
</tr>
<tr>
<td></td>
<td>bypass</td>
<td>7.95%</td>
<td>8.42%</td>
<td>5.05%</td>
</tr>
</tbody>
</table>

Table 3 - Attributes of the questionnaire’s respondents

### 3.2 MECHANISM OF USE PATTERNS OF PUBLIC SPACE IN COMMERCIAL MALLS

Literatures have highlighted that location, development densities, services types and scale are all influential to the popularity of a commercial mall (Kim & Sohn, 2002; Nie & Jia, 2011), but in a descriptive way. To quantize spatial configurations and services provision and then to explain what factors may influence the number of visitors in convex space, all quantized variables have been analysed utilizing a multiple stepwise regression method in SPSS with table 2 illustrating the modelling output of the linear regression model for all three commercial malls. In addition to the size of the convex space which significantly influences visitor numbers for all three commercial malls choice, step depth to the nearest gate, step depth to the nearest anchor shop have also been observed to be influential in two of the three malls. Interior spatial design and service provision is arguably weaker for the La Nova Mall seeing visitors concentrate in the north and middle part of the mall, as integration and mean depth become key elements to attract visitors. For Yuihui Mall key attractors are the cinema and Superplay Game Centre located on the 4th. Floor.
CONSIDERING PATTERNS AND MECHANISM OF PUBLIC SPACE USE WITHIN COMMERCIAL MALLS IN CHANGSHA CITY, CHINA - A syntactic approach

<table>
<thead>
<tr>
<th>Variable</th>
<th>Variable</th>
<th>Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yuehui Mall</td>
<td>La Nova Mall</td>
</tr>
<tr>
<td></td>
<td>Coef.</td>
<td>Sig.</td>
</tr>
<tr>
<td>Constant</td>
<td>1.138</td>
<td>0.752</td>
</tr>
<tr>
<td>Integration</td>
<td>17.077***</td>
<td>0.000</td>
</tr>
<tr>
<td>Mean Depth</td>
<td>-0.478**</td>
<td>0.019</td>
</tr>
<tr>
<td>Choice</td>
<td>-3.746**</td>
<td>0.014</td>
</tr>
<tr>
<td>Step Depth to the Nearest Anchor Shop</td>
<td>0.95**</td>
<td>0.012</td>
</tr>
<tr>
<td>Step Depth to the Nearest Food Centre</td>
<td>4.098**</td>
<td>0.015</td>
</tr>
<tr>
<td>Spatial Size</td>
<td>6.449***</td>
<td>0.000</td>
</tr>
<tr>
<td>Shops Directly Connected</td>
<td>0.515**</td>
<td>0.02</td>
</tr>
<tr>
<td>N</td>
<td>35</td>
<td>168</td>
</tr>
<tr>
<td>R²</td>
<td>0.78</td>
<td>0.627</td>
</tr>
<tr>
<td>D-W</td>
<td>1.910</td>
<td>1.800</td>
</tr>
</tbody>
</table>

*** Sig.<0.01   ** Sig.<0.05   * Sig.<0.1

Table 3 - The multiple regression coefficient analysis

4. CONCLUSION AND DISCUSSION

In brief, a possible interpretation of the evidence presented here suggests that China's consuming mode is entering into a new stage: as people under 35 years old became the predominant group to visit these particular commercial malls. It would appear as people's habits and methods of consumption evolve to suit global and local retail trends both old and new spaces have to adapt to afford maximum provision of service and user experience of these facilities. Anchor stores are situated at a relatively shallow location within the layout, as integration is perhaps even more essential to generate higher levels of footfall through these retails spaces. However the draw of attractors – from global cinema brands to local entertainment and food services– sees these located in less integrated and deep spaces within the spatial complex. For the younger generation, as shopping is not the only or even the primary reason to visit commercial malls, their focus has shifted from product per se to quality of experience. Commercial malls without big retail stores also attract similar amounts of visitors when food and recreational services are a significant draw to this sector.

Taking the methodologies applied in this research and extending the study to encompass a wider range of malls within this area, would allow a more accurate statistical analysis of the impact of factors on the popularity of these commercial spaces. Data from which would support an evidence based approach to delivering effective design and operational management that responds effectively to ongoing changes in retail trends.
REFERENCES


ENHANCING THE SPATIAL VISIBILITY OF PEDESTRIANS TO THE HIDDEN EATING PLACE THROUGH VERTICAL SPACES AT JALAN AMPANG, KUALA LUMPUR

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ABSTRACT  
This paper reports the application of space syntax methodology in the design studio works undertaken by architectural students at Universiti Teknologi Malaysia. The design challenge poses the possibility to enhance the spatial visibility of the project’s site; the hidden pocket space of a local informal eating place, which is situated in between the two high rises, the Safuan and Sunway towers within the vicinity of Kuala Lumpur City Centre, Malaysia. The visibility of the site is analysed in accordance to the different topographical structure of the area based on the different levels of the building heights within the parameter. The result showed that the connectivity and visual integration values correlate strongly as the site is elevated higher from the ground level. This finding helps equipped students in determining the appropriate and scientific evident-based design decision on the suitable development of the particular context of the area. The strategies chosen had brought together the explorative application of space syntax tool in the urban morphology and spatial configuration analysis to issues related to architectural and urban theory.

KEYWORDS  
Space Syntax, Spatial Properties, Pocket Space, Spatial Visibility

1. REVEALING THE HIDDEN POCKET SPACE: THE INFORMAL EATING PLACE  
The capital city of Malaysia, Kuala Lumpur is in the rapid urbanization and is now in the succeeding level of development. The rise of urbanism has faced various dilemma in making the city to be well connected in having to provide the metro lines, and express ways circulating within the metropolis. At the inner city core, in a short distance from the iconic Petronas twin tower of Malaysia, a tiny left over portion of land, a small pocket space emerged over time.

The little lot sits itself beautifully right at the top edge of Klang River bankside, where from the initial life journey of the city began. This is the place, the ‘informal public space’ where the local workers, corporate members, and the locals alike would gather to enjoy their morning breakfast, afternoon lunch, making the area as a place to mingle, to meet and greet. The scenario sets
with itself the formal and informal social activities happening in the everyday life of the locals in the neighbourhood. Amongst other informal eating places emerging, the pocket space holds and sustains a meaningful and colourful journey of the people around it.

Since the stretch of Ampang-Kuala Lumpur Elevated Highway (AKLEH) became a strong edge in the city fabric, it split the local context surrounding the site into several part (see figure 1). The little site is trapped and squeezed, hidden and unseen, not just by the AKLEH, but also by being in its position; in between Sunway and Safuan towers around it. Seemingly, the rich mixed-presence of the corporate, school children, taxi drivers, were unattended. The majestic locality with the social diversities it manifested seemed unimportant and unnecessary to the fast growing development all around it. This particular pocket space was left abandoned and inefficiently explored of its potential to be integrated with the surrounding activities. And so, the rich of production of the hidden public space; the social landmark of the area, emerging from the community spirit of people from the old village, became neglected. It becomes a story untold to many.

In revealing the potential of the site, this paper investigates the spatial properties of the surrounding area in seeking how best it could function within the constraint context of the location. Firstly, the spatial configuration of the connectivity of the locality is examined by using axial line analysis in order to determine the integration values of the surrounding streets within 500 m radius. Next, the level of visibility is measured by using the Visual Graph Analysis (VGA). In this case, the build-up of the site topography is studied incrementally by layering up the site topography (in accordance to the solid and void derived from the different building heights) within the surrounding 500 metre radius of the site. Subsequently, the strength of relationship (correlation) is analysed between the connectivity of the surrounding based on the movement of pedestrian flow in the area to the visibility of the pedestrians coming to the site.

2. MACRO ANALYSIS BY USING AXIAL MAP TECHNIQUE

![Proposed Site](image)

<table>
<thead>
<tr>
<th>Street</th>
<th>Integration Value</th>
<th>9 am</th>
<th>12 pm</th>
<th>3 pm</th>
<th>6 pm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ampang (1)</td>
<td>0.948</td>
<td>5</td>
<td>12</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>AKLEH (1)</td>
<td>1.665</td>
<td>5</td>
<td>25</td>
<td>26</td>
<td>5</td>
</tr>
<tr>
<td>Ampang (2)</td>
<td>2.068</td>
<td>13</td>
<td>25</td>
<td>21</td>
<td>12</td>
</tr>
<tr>
<td>Sultan Ismail (1)</td>
<td>2.904</td>
<td>16</td>
<td>21</td>
<td>21</td>
<td>7</td>
</tr>
<tr>
<td>Sultan Ismail (2)</td>
<td>2.229</td>
<td>18</td>
<td>35</td>
<td>24</td>
<td>15</td>
</tr>
<tr>
<td>Sultan Ismail (3)</td>
<td>2.563</td>
<td>19</td>
<td>30</td>
<td>31</td>
<td>19</td>
</tr>
<tr>
<td>Dang Wangi</td>
<td>1.794</td>
<td>5</td>
<td>14</td>
<td>24</td>
<td>19</td>
</tr>
<tr>
<td>Raja Abdullah</td>
<td>1.794</td>
<td>21</td>
<td>14</td>
<td>19</td>
<td>13</td>
</tr>
<tr>
<td>AKLEH (2)</td>
<td>2.339</td>
<td>17</td>
<td>25</td>
<td>26</td>
<td>26</td>
</tr>
</tbody>
</table>

Correlation co-efficient ($r^2$) = 0.7022, 0.6057, 0.7393, 0.5782

Figure 1 - shows the low integrated line of sight in 2d dimensional and 3 dimensional experiencing of this site. It also shows the value of $r^2$ of this observation is 0.5782 which is the lowest among the four occasion of observation was made. This shows that there is other influence in movement pattern of pedestrian that attracts people to this site (Mahdzar 2008).
In understanding the context, the spatial configuration and connectivity of the locality is determined via axial line analysis within 500 m radius of the area. The morphological structure of the area has shown that the site is surrounded by high integrated roads, the main roads of Jalan Ampang and Jalan Sultan Ismail. However, these high integrated roads are not directly linked to the site as clearly it is hidden by the two towers as described earlier. The axial analysis helped to prove that the site has been hidden from the main flow of the pedestrians not only due to its locality which is at the back of the towers but also by the configuration of the overall grid structure of the area due to its locality. Figure 1 also shows the integration value of the other surrounding streets within the site area and its neighbourhood.

3. MICRO ANALYSIS BY USING VISUAL GRAPH ANALYSIS (VGA)

The second aspect of this analysis seeks to find the way to reveal the potential of the site by experimenting the topography by analysing its 3D morphological structure through several layers of visual graph analysis.

![Visual Graph Analysis](image)

Visual graph analysis is utilised in measuring the spatial characteristics as well as in understanding the full utilization of the morphological structure of the site. As shown in figure 2, the build-up of the site topography is studied incrementally by layering up the site topography (in accordance to the solid and void derived from the different building heights) within the surrounding 500 metre radius of the site. The visibility of the site is then derived separately in accordance to the different topographical levels in according to the building heights. Overall, it is demonstrated that the connectivity and visual integration values correlate strongly as the site is elevated higher from the ground level. The analysis confirms the significant value of visibility properties of the site.
ENHANCING THE SPATIAL VISIBILITY OF PEDESTRIANS TO THE HIDDEN EATING PLACE THROUGH VERTICAL SPACES AT JALAN AMPANG, KUALA LUMPUR

The analysis shows that the pattern of connectivity is transformed from blue to yellow highlighted colour when the level increases from 0.000m in ground level to 25.200m in 8th level. The development area is directly visible from the main road. Through this 3rd step of analysis, we found the correlation between connectivity and visibility to rebuild the layers upwards making the place more visible from a distance.

The results in figure 3 shows that the correlation increases upwards, therefore it helps to acknowledge the presence of the site. The prospective site has been used by the locals as an informal eating place during the day time. This leads to the question on the fabrication (morphology) of how the built environment give impacts to the pedestrian movement. This question belongs to the area of social science investigating the often-unforeseen social effects that spatial structures have back towards society (Hillier 1985). Once a spatial structure such as an urban area has been formed, it seems to offer unpredictable social potentials and problems.

The way that people use an area does not depend on what planners or architects might be expecting but rather on these potentials offered by the spatial structure. One significant approach in which the environment might be shown to influence social activities is in the investigation of pedestrian movement and behaviour.

5. CONCLUSION

This paper has attempted to seek the appropriate method to enhance the everyday function of a hidden site of a small pocket space, the local informal eating place, within the vicinity of Petronas Tower in Kuala Lumpur City Centre, Malaysia.

The analysis has proven that the spatial visibility of pedestrians could be investigated objectively through applying two syntactical measures. In doing so, firstly, the macro aspect of the morphological structure of the area was studied by applying axial line analysis in conforming to meter radius. The results on the integration values had shown that the site was located in a segregated area within the configurative grid system of the area. Next, the visibility graph analysis was applied in examining the potential of raising up this small site vertically in order to increase the visibility of the pedestrians within the parameter. The layers of visibility of the site were analysed in accordance to the different topography as formed by the different morphological structure, which are based on the different building heights within the parameter of the studied area.
As discussed, the design strategies has taken account the need to enhance the hidden eating place through vertical spaces. This approach has brought forward a new interpretation and gave a new meaning to the development of the pocket space. The analyses have also enabled the students to suggest an alternative approach in designing the appropriate usage of the site by optimising its vertical uses.

The strategies chosen has also brought together the explorative application of space syntax tool in urban morphology and spatial configuration analysis to issues related to architectural and urban theory. The association shows a strong movement pedestrian space vision when it comes to higher plane level. Hence, crafting the space through axial analysis and visibility graph analysis can be a good argument and able to explain and predict the movement from the immediate surrounding into the building.

In conclusion, the study has found the way through which the combination of axial line and visual graph analysis could be used to seek the potential of a certain aspect of site constraint. In particular, the analysis has helped the students in making a design decision more objectively. Further research could be suggested that the 3d vga analysis can be analysed in accordance to the integration value to the specific function (or hierarchy of space function) of the building type. the flow of pedestrian movement into the area within 500
REFERENCES


Mahdzar, S. S. S, (2008). *Sociability vs Accessibility, Urban Street Life, Bartlett School of Planning*, University College London


ABSTRACT
This study addresses a design process to convert an existing single-family house in order to create a more sustainable and safer environment under permaculture guidelines supported by space configuration and visibility analysis. Zone planning in permaculture design, according to Mollison (1988), consists on the definition of abstract boundaries around a home to cover certain functions of the landscape according to the frequency and the need to use them. Those zones are usually intuitively designated by how accessible each area is from the house. Accessibility is therefore a key factor on the conception phase of permaculture designs. Space syntax analysis (Hillier and Hanson, 1984) was applied to explore accessibility relations in order to redesign the garden according to those zoning guidelines, which allows for objectively defining spatial delimitations in sites of different sizes. Visibility Graph Analysis helped to identify the most efficient spots for installing closed-circuit television cameras in order to achieve constant surveillance of the house surroundings. It was also applied to define dimension and placement of openings in the house so that the house dwellers could enjoy the best views of the garden. The study seeks to contribute towards the question of applying such analytical procedures for designing single-family housing units by discussing some of its potentials and limitations.

KEYWORDS
Sustainable Housing, Permaculture, Surveillance, Space Syntax

1. INTRODUCTION
Space syntax techniques were applied during the conception phase of a conversion in a single-family house in order to meet the clients’ needs for a more sustainable and safer environment. Two types of problems pointed by the dwellers were solved with the help of space syntax techniques: (1) the transformation of the garden for horticultural and contemplation purposes, considering accessibility and visibility properties and (2) the investigation of the visual relations of the house with its surroundings by means of Visibility Graph Analysis, Turner et al (2001) and Turner (2003), on plans and sections in order to identify blind spots and the most efficient points for installing closed circuit television cameras, CCTV. The applied procedures are described in this paper.

2. GARDEN DESIGN
The main purpose of the design was to adapt the garden for growing vegetables and visual contemplation. Visibility Graph Analysis helped to define openings in order to take advantage of the best views of the site from the house interiors and justified graph analysis helped to organize the productive elements according to permacultural zoning guidelines. The goal of
this topic is to explain how space syntax techniques were applied in the case of this garden design renovation.

Permaculture is “a system of agricultural and social design principles centred on simulating or directly utilizing the patterns and features observed in natural ecosystems” (Mollison, 1988). The main idea is to work with different types of natural elements towards a scheme that is able to produce most of its needs and return its surplus back to the system. Mollison (1988) proposes to organize these elements in the site by defining six abstract zones (from zero to five) around a house according to the frequency and the need to use them. The author does not prescribe metric distances between the zones as permaculture can be applied to an ample range of site dimensions – from a small urban site to a farm – and so the zones are usually intuitively designated by how accessible each area is from the house. In this study, graphic representations of the garden spatial system helped to prescribe the boundary of each zone, which allows for objectively defining these zones in sites of different sizes.

The spatial system of the garden was decomposed into nodes and lines so that each node represents either a convex space or a change of level in the site and each line a connection between these spaces. Because all interior spaces of the home are considered as zone zero according to the permacultural zoning guidelines, the house was considered as one convex space.

A justified graph was generated in which the root is the zone zero (Z0 in Figure 1) and each zone was defined according to its topological depth from the house. Figure 1 represents the conception process of the permacultural zones in the garden (”Z” stands for a defined zone and “C” for a circulation space). The permacultural design should help to meet the clients’ requirements for a productive garden.

Visual step depth representation was used to test different positions of openings overlaid on the landscape plans in order to choose the ones that visually integrate the house with the most interesting spots in the garden design. Figure 2 shows visual Step Depth from the three main rooms of the house and three possible locations for placing the openings in each room, in the middle (Op. 1), in the right corner (Op. 2) and in the left corner (Op. 3).
The graphs highlight the best option in order to achieve a better view of the garden from each room: option 3 for room 1, option 1 for room 2 and option 2 for room 3.

3. CONSTANT SURVEILLANCE

In order to meet the clients' needs for a safer home, one of the goals of the renovation is to offer constant surveillance – in this case, the ability to watch any public space close to the house limits from its interiors. Space syntax analysis helped to identify blind spots in the surroundings and to define the points where to install CCTV cameras making sure that all boundaries of the site are visible using a minimum amount of camera devices. The goal of this topic is to explain how space syntax techniques helped to design surveillance means in the house surroundings.

A diagram representing all isovists from the house interiors to the site surroundings helped to identify the current visual relations of the building to the street and thus highlight blind spots that prevent constant surveillance. The 2D analysis using Depthmap (Turner, 2001) was quite limited due to the great differences of level at the site. In an attempt to overcome this issue, the largest isovist that reaches the front facade was represented both in plan and section (Figure 3).
The diagrams in Figure 3 highlight: (1) the lack of visual relation from the interior of the house to the street, especially at the north-eastern facade, represented in the Floor Plan and (2) the blind spot caused by the boundary wall at the front facade represented in Section A. In order to solve these issues without loss of privacy, CCTV cameras were recommended to monitor the blind spots through.

Visibility Graph Analysis of the house surroundings helped to design a system that could monitor the maximum amount of blind spots using the minimum amount of camera devices. The system was able to cover almost all blind spots by locating a CCTV camera at the most integrated spot of the house surroundings, as represented by the VGA in Figure 3.
4. CONCLUSIONS

The paper addresses the use of space syntax as a tool for analyse spatial relations and explore different forms supporting the conception phase of architectural design. The techniques used here “objectify what is deeply subjective; namely, the way a person experiences space” (Arnold, 2011) in an attempt to provide means through which the designer may test different accessibility and visual configurations understanding how these relations can affect human experience of space.

Once used in permacultural design, the graphs allowed for the definition of zones that once were intuitively proposed by Mollison (1988). This approach eventually became a method to visualize these permacultural design guidelines. The VGA helped to test different designs and to choose the ones best suited to the needs of the residents. It also supported the identification of blind spots not hit by human vision and the choice of best points for installing the fewest number of CCTV camera devices using their maximum visual field in an attempt to increase the sense of security in the site.

Finally, the techniques were applied both for analysis and for conception of architectural form, reinforcing that space syntax can support generative design processes (Arnold, 2011) not exactly to transform this process into an exceptionally rational practice, but aiming to enrich the “constant negotiation” between creativity and reasoning that is an inevitable part of architecture (Arnold, 2011).
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ONE HOUSE, THREE GENERATIONS:
Exploring conversions in domestic space that tell about sociocultural changes over a century.

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ABSTRACT
This study seeks to further knowledge about Brazilian homes by addressing the spatial reorganisation of a vernacular residence, as it was adapted to changing lifestyles along a century and over three generations of dwellers from a same family. The house was built in the 1920s in a rural area in Northeast Brazil as the main residence in a farmstead – now no longer a productive unit. It is currently used as a residence by the second generation of landowners and as a holiday place by the family’s third generation and their children. Morphological aspects of geometrical (shape, size, position) and topological (accessibility, visibility) natures, as well as space labels and functions were analysed in diachronic perspective, in the light of narratives and views of some of the house’s dwellers about the successive conversions suffered by the spatial arrangement and how spaces were used then and now. Results point out that relations amongst inhabitants – family and servants – and between them and visitors were altered by subtle changes in those morphological aspects, following tendencies that predominated in Brazilian homes at certain times (some of them also elsewhere), and particular needs of the family. Among aspects turned mainstream at a certain epoch in our domestic architecture: (i) the space used for family meals has become highly accessible and visible in post-colonial society, signalling social openness and less reclusiveness of women, and (ii) the growing seclusion of bedrooms and number of shower/toilet (often en suite) facilities follow contemporary requisites of privacy and body care. The change from a farming support unit to a family residence in the 1980s required less complex, more practical service-related spaces whereas its increasing role as a holiday house, demanded the enlargement and higher visibility of gathering spaces, such as the verandas. It was, therefore, seen that within a minimally altered built shell (the container), the spatial structure (its content) was radically transformed to give expression and physical support to changing modes of life, and that such changes related, at once, to the ways Brazilian homes were – sensu lato – topologically reshaped in time, as well as to the specific needs of successive generations of householders in this case. This interplay of genotypical and phenotypical properties tells about Brazilian lifestyles in the context of middling socioeconomic groups, adding up to the corps of case studies that have been using configuration analysis to unveil the spatial soul of Brazilian homes.

KEYWORDS
Domestic Space, Vernacular Architecture, Spatial Configuration, Space Syntax
1. INTRODUCTION

Domestic space is not only a consequence of social changes, it is also a producer of social relations and can reveal possibilities of interaction amongst users. Dwellings may present the same appearance and have distinct spatial configurations, constituting different styles and modes of living. Conversions to readapt functions may show how the reorganization of domestic space relates to lifestyles that regulate everyday use of the dwelling and translate a cultural phenomenon.

This study seeks to further knowledge about Brazilian homes by addressing the spatial reorganisation of a vernacular residence, as it was adapted to changing lifestyles along a century and over three generations of dwellers from a same family. We can verify a process of transformation and adaptation of space to needs and modes of life through conversions, extensions and change of uses in some rooms.

2. DATASETS AND METHODS

Built in Brazilian northeast rural zone as a farmstead, the house examined in this study was initially a building in which residential use mixed with rural production functions. We considered the floor plans of 1920 (when the residence was built), 1980 (when it was refurbished to accommodate changing functions, and the addition of a third bathroom/toilet and a second kitchen) and nowadays (after the extension of a veranda and the addition of two en suite bathrooms). The study addresses two situations: the minimal living (interior spaces only) to simulate the family’s intimate way of life – and the minimal living plus the exterior – which better represents the spatial hierarchy concerning interaction among the communities that comprise the household – family, servants and visitors.

The method explores functional and morphological aspects (geometric and topological) in diachronic perspective in the light of the users’ narratives. In the geometrical analysis, we compare the room area in order to ascertain whereas certain uses demanded more space at each phase. Topological aspects are analysed through visibility and justified graphs. The space nodes correspond to different rooms within the house. Measures of integration and depth were calculated through the JASS software (BERGSTEN et al, 2003). Visibility analysis (processed through UCL Depthmap, TURNER; FRIEDRICH, 2011), reveals hierarchies of visual fields that might favour certain practices of social interaction and movement options.

3. RESULTS

Results point out that relations among inhabitants – family and servants – and between them and visitors were altered by subtle changes in those morphological aspects, following tendencies that predominated in Brazilian homes at certain times (some of them also elsewhere), and particular needs of the family.

In the justified graph analysis, the existence of rings within the building is associated to an easiness to circulate and to reorganize space (Cavalcanti e Trigueiro, 2001). An internal ring that passed through a bedroom – a common aspect of Brazilian pre-modernist domestic architecture – was eliminated in 1980 following increasing privacy demands. Furthermore, the existence of multiple rings connecting external areas – a resilient aspect of Brazilian homes that only recently tends to disappear following a widespread fear of insecurity – is related to the hierarchical rules of access and control involving the interface among dwellers besides the desirable openness to the outside space in a tropical climate. Contrarily, to the current trend, this openness increased in the studied case as time passed.

Currently, the internal space is mainly used to prepare food and sleep as residents and visitors spend most of their time at the verandas. According to Trigueiro (2015), the exterior is an important integrating element in vernacular Brazilian houses and, when considered in the analysis, tends to increase the system accessibility. The study case in question corroborates this, as the system was less integrated, and deeper (1.11), when considering the minimal living. When external space was added (through all entrances) the average integration value was enhanced...
even though the number of spaces in the system increased. In post-colonial Brazilian houses the space used for everyday meals, here labelled as "dining room", is recurrently the most integrated functional space. Our study case confirms this situation in all studied scenarios (Table 1). When only the minimal living was considered, the scale of most accessible spaces were: corridor, kitchen and master bedroom. When contemplating external spaces, the five most integrated spaces were the same for the 1920 and the 1980 representation: dining room, veranda, kitchen, corridor and exterior. As expected, bathrooms and bedrooms tend to be the most segregated spaces.

In the 1800s’ colonial houses, the front room, often referred to as the “visitors room” (here labelled as “living”) was related to the patriarch power to decide who was to be granted access to the house, and therefore, mainly used by him, unless when in the context of the closed family circle (Leitão, 2005). In our case, up to 1980, the living room was used only when there were distinguished guests. Indeed, its connection to the other rooms inside the house happened only through the master bedroom. According to interviews, even when the living room changed place (in 1980), it was never used as the family leisure and social area. These gatherings have always happened in the verandas.

The dwelling had four different entrances according to the 1920 plan, and three entrances from the 1980 configuration up to present days (Figure 2). Except for the kitchen entrance in 1920, all other entrances had transition spaces between interior and exterior, a common trend in Brazilian architecture. In the original house structure, there was a stronger distinction of routes as different people used diverse entries: the visitors through the living room, the servants through the kitchen and the family through the dining room, again a predominant feature in Brazilian houses. Since 1980, all entrances are used freely by family members, servants and visitors alike.

In the 1980 plan, a second kitchen (two spaces) was built aiming to facilitate domestic chores, thus adding 33.35m² (Figure 3) to the house. In 2016, the increase in area was mainly due to the verandas enlargement, which grew from 61.79m² to 100.09m², and signals the priority given to it by current residents. A former spare room was turned into the living room, which, therefore, gained area and the old living room became a bedroom (Table 2). Rooms that diminished in area were the larder (9.50 to 1.50m²) and the dining room/meals. The reduction of the larder is justified by an easiness to acquire provisions nowadays. In total, main changes in areas accounted for rooms for socialising (i.e. the veranda enlargement).

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1 Integration levels in this paper were computed by JASS and relate to RRA – real relative asymmetry (HILLIER&HANSON, 1984). The lower the value is more integrated.

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Figure 1 - Image of the house in the 1980’s and nowadays. Source: personal archive.
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Figure 2 - Floor plans and justified access graphs through the exterior.
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<table>
<thead>
<tr>
<th>TIME</th>
<th>ROOM’S INTEGRATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimal Living 1920</td>
<td>DR&gt;CO&gt;KI=MB&gt;BR=LA&gt;BR&gt;LI=BW</td>
</tr>
<tr>
<td>1980</td>
<td>DR&gt;CO&gt;KI&gt;MB=BR= BW&gt;LI&gt;BR&gt;LA= BW&gt;BR</td>
</tr>
<tr>
<td>2016</td>
<td>DR=CO&gt;KI&gt;MB= BR= LI &gt;BR&gt; BW= LA= BW= BR= BW</td>
</tr>
<tr>
<td>Exterior   1980</td>
<td>DR&gt;VE&gt;KI&gt;CO&gt;EX&gt;MB&gt;VE=BR=LA=BR=LI=BR= BW</td>
</tr>
<tr>
<td>2016</td>
<td>DR&gt;CO&gt;VE&gt;KI&gt;LI&gt;VE&gt;EX= BR=MB=VE&gt;SK&gt; VE=MB=VE= BW= SK=BR= BR</td>
</tr>
</tbody>
</table>

Key: Dining Room, Corridor, Kitchen, Veranda, Exterior, Master Bedroom, Bedroom, Bwc², Living, Spare Kitchen e Larder.

Table 1 - Sequence of most integrated spaces in all settings.

Table 2 - Altered metric areas for private sectors.

In the visibility graphs (Figure 5) warmer colours indicate locations with higher visibility and colder colours (e.g. blue) those with less visibility. In the studied case, high visibility coincides with rooms where there is, at present, more social interaction and movement of people at all times. Considering the minimal living only, there are no significant changes among the three situations; the dining room/meals always appears as the most visible space. When the exterior is considered in the current layout (2016), not surprisingly, the verandas become the most visually integrated space.
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Figure 4 - Altered metric areas for sectors.

Figure 5 – Visibility graphs at each epoch, considering minimal living (left) and adding the exterior (right).
4. CONCLUSIONS

This study demonstrates that within a minimally altered built shell (the container), the spatial structure (its content) was transformed to give expression and physical support to changing modes of life. Such alterations related, at once, to the ways Brazilian homes were - *sensu lato* - topologically reshaped in time, as well as to the specific needs of successive generations of householders in the studied case.

Among aspects turned mainstream at a certain epoch in our domestic architecture, the space used for family meals can be pointed out as becoming highly accessible and visible in post-colonial society (TRIGUEIRO, 2015 e BUZZAR, 2003), signalling social openness and less reclusiveness of women. On the other hand, as seen in the studied case, social openness plus individual privacy are well indicated by the enlargement and higher visibility of the verandas and the construction of *en suite* bathrooms. The change from a farming support unit to a family residence in the 1980s required less complex, more practical service-related spaces. This interplay of genotypical and phenotypical properties tells about Brazilian lifestyles in the context of middling socioeconomic groups, adding up to the corps of case studies that have been using configuration analysis to unveil the spatial soul of Brazilian homes.
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A SQUARE FOR PEOPLE

A visually communicative, configuration informed and social-oriented redevelopment project for Largo da Graça, Lisbon

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ABSTRACT

This paper describes an experimental project in which the urban designer uses Space Syntax and other analysis techniques coming from Public Life Studies and Building Thermal Physics, to inform the Design Decision-Making for the redevelopment of a public square. Largo da Graça in the historic centre of Lisbon was selected as a case study, suitable for testing many possible and different design changes when space syntax is embedded in the design decisions. The experiment generated a digital workflow with all the steps undertaken in solving design problems, a ‘design journal’ that includes efficiency targets (centrality, connectivity, enclosure, thermal comfort, social security, equality, and interaction) and a comparative test of the design proposals. The adopted design strategy, as well as the examples extracted from the workflow, could be used to illustrate a link between research and design, adequate for supporting and orientating the project and design of urban spaces.

KEYWORDS

Space Syntax, Urban Design, Design Research, Multidimensional Analysis, Data Visualization

1. INTRODUCTION

Space Syntax methodology can be a valuable support tool to design successful public spaces (Karimi, 2012). In fact, it has provided a valuable contribution in the design of many key public spaces, such as Trafalgar Square and Nottingham Old Market Square. The aim of this research is to provide simple examples about how Space Syntax together with Public Life and Environmental Studies can be successfully integrated within the design process so as tovaluably support the creation of efficient and social-oriented public spaces. To such purpose, a Multidimensional Analysis method to inform design decision-making is implemented in a relevant case study. The workflow is presented by giving some examples of the parameters, indices and multimodal ways of representing public open spaces, which have helped the design process, as well as examples on the possibilities of undertaking design changes when space syntax is part of decision-making. Specifically, it is discussed the example of the redevelopment project for a Portuguese historic square. Squares, in fact, offer rich possibilities of observing space appropriation processes, besides offering many sparks for architectural design.
2. THEORETICAL BACKGROUND

Within the system of the urban voids, historic squares maintain a privileged configuration and an exceptional character, concentrating both aspects of functional and representative order. Given their importance, many authors of urban morphology (Sitte, 1889, Lavedan, 1966, Krier, 1981) have sought to classify squares. Even the Space Syntax community, focusing on the syntactic quantifiable measures that expose the rules of the perceptive-cognitive apprehension of spaces, has gone providing a significant contribution to the study (Heitor et al., 1999; Can et al., 2013; Koohsari et al., 2014; Kubat et al., 2015). In particular, some authors have tried to identify the configurational conditions for squares to work as meeting and interaction spaces (e.g. Cutini, 2003; Guerreiro et al., 2014). Specifically, while retrieving a new index able to disclose the hierarchy of squares in cities (interaction index), Cutini refers to the studies of Sitte (1889), whereas Guerreiro studies the pedestrian network together with public life patterns, referring to the work of White (2001) and Ghel (2011). Their research results show that it should be possible to build new responsive, integrated and discursive knowledge on squares, as well as composite models of design evaluation, starting from the study of their spatial configuration. Additionally, urban design requires new effective responses and bottom-up approaches. Therefore, it seems a good strategy to adopt a multidimensional and interdisciplinary ‘learning by doing’ methodology of performance-oriented iterative analysis and design. In fact, this could help architects learn about the design problem, explore ideas and understand the possible effects of their proposals (Dursun, 2007).

3. METHOD

Architects learn about design problems through the conception and the critical evaluation of solutions, rather than through intentional and separate study of the problem itself (Lawson, 2003). Therefore, we can extract strategies by analysing sequences of design decisions and the different approaches:

- Approach to analysis: provides a description of strategies used to interpret public square’s space. They are concepts, attributes and scientific procedures;
- Approach to design: it provides a description of strategies used to undertake design actions, i.e. the various assumptions behind each decision illustrating how analyses are used as part of setting and assessing design aims.

3.1 APPROACH TO ANALYSIS

The distinctive features of a square are heterogeneous, and their origin twofold: global properties, referred to its relationships with the whole urban grid, and local properties, depending on the intrinsic morphologic features of its space. Therefore, a comprehensive analysis of a square requires a multidimensional and multi-scale approach (Lopes et al., 2015, Paio et al., 2016). It is consequently important to understand the global accessibility level of the square through segment analysis and derive radius n integration and choice maps (Hillier et Iida, 2005). Then, the analysis should be repeated at a local level, e.g. within a metric radius of 800 metres from the square, which corresponds to the distance a pedestrian travels in ten minutes, so at to finally provide a map of the local and global access points (Hillier, 2009). Furthermore, a 1 m² resolution VGA (Turner et al., 2001) highlights the local variations of attributes that influence interaction in squares, which are integration, connectivity and clustering, corresponding to the levels of centrality, capacity and enclosure of each spot in the square (Cutini, 2003). Finally, in order to generate aggregate models of agents’ movement in space, an agent analysis is processed (Penn et al., 2001). However, since building a reliable analysis model can be hardly straightforward, with risks of influencing the results, early empirical testing might be suitable for validating the analyses models and outputs (Asriana et al., 2016). Here, it may help counting, mapping and tracking pedestrian activity and using time-lapse photography, which are highly valuable techniques to add details to the analyses results as well. Furthermore, environmental and thermal comfort analyses may help to explain some observed anomalies and seasonal phenomena (Pezzica et al., 2016).
3.2 APPROACH TO DESIGN: THE CASE STUDY

The approach to design is implemented in the case study of Largo da Graça (Fig.1), a square located at the top of the slope where the homonym Convent lies, in the core of Graça neighbourhood, in Lisbon historic centre. Largo da Graça has a complex character, reflected by its roughly defined and highly fragmented boundary, its diversified topography and the presence of some impactful elements such as retaining walls, a big fountain and central green areas. Nonetheless, this place shows a latent potential for liveliness, that the redevelopment project aims at strengthening and increasing. The design is developed in three stages:

• The set up, which defines the starting point of the design problem based on the premises of problem framing and the general design concept;

• The iterative development, in which main design actions are undertaken, evaluated and acted upon with the help of the analyses and refined with the help of cross-comparisons of design alternatives;

• The performance test, in which the design proposal is tested against other successful examples, assessing the quality of the project.
Figure 1 - Square design and multidimensional analysis: 1. VGA control before and after (B/A); 2. VGA integration B/A; 3. Agent analysis B/A; 4. Grid and pattern superimposition; 5. Proposed project 3D view; 6. Thermal analysis and covered surface optimization; 7. Significant layers of the project (from left to right): streets, orography, greenery distribution, areas to walk and areas to stay, lightweight canopy covered area; 8. Interaction Index comparative analysis: famous Portuguese and Italian examples.
Figure 2 - Overlapping of significant layers. a. Volumes distribution; b. The designed topography; c. Axial integration; d. New greenery distribution; e. Program and functions.
The project originates from a superimposed hierarchical grid, created to structure and define the square’s spaces and built components, their function and spatial disposition. The design is parametric, thus increasing the control over the project and the possibilities of further investigations at various scales (Motta, 1999). The design strategy is built on the principle that only the presence of people coupled with weak or no barriers creates a public space (Ghel, 2011). Therefore, a serious deficiency of the square, highlighted by the VGA and agent analyses, is the virtual absence of movement across the heart of the square, caused by the existing topography and the current disposition of the retaining walls (Conroy-Dalton, 2003). This consideration leads to the development of a new proposal in which the morphology is designed so to invite people inside the square and to unify its space. The stairs accommodate stationary activities in areas with higher clustering coefficient values and suitable thermal comfort conditions (Fig. 2). The fountain is moved from the centre of the square into an area with a lower integration value, leaving the central space free. The lighting system is designed according to the natural movement patterns (Choi et al. 2006). The benches are placed where control is higher, that is near the corners. Pedestrians’ safety is increased by reducing road sections and by drawing wide sidewalks and zebras in two key spots, where the registered high level of informal crossings was suggested by the passage of two main axial integrators.

4. RESULTS AND CONCLUSIONS

To sum up, it is suggested that some structural difficulties in interpreting contemporary complex spaces can be better addressed by collecting contributions from several disciplines. The poster shows that it is possible to identify a limited number of significant variables (Integration index, Clustering coefficient, Neighbourhood size, Control, Interaction index, Gate count) suitable for describing the main features of public squares. The variables reduction customises the analysis and ultimately helps the designer to focus on the most significant properties, while simplifying the control over the project and its evaluation. Furthermore, it shows how it is possible to convey the main concepts of a configuration-informed design, through a few maps showing the effects that design actions will produce in the public realm. In this way, it seems possible to achieve highly informed design proposals (Fig. 3) for a “spatial retrofit” which takes into account notions of comfort, security, equality, use and appropriation.
REFERENCES


MUMMY, I NEED A WEE!
The Integration of Space Syntax, Internet of Things (IoT), and Self Tracking Technologies to Design for Pedestrians in Smart Cities

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ABSTRACT
City and town planners are accounting for Internet of Things (IoT) at different scales of applications. Planning for pedestrians has attracted practitioners and researchers overarching different domains and addressing various problems. This paper explores the re-use of self-tracking technology to have a human-centric planning for pedestrian whilst integrating this with the urban layer and agent-based modelling (ABM) technique. This study is a part of an on going research; it presents a part of its overall methodology to obtain interim findings. We focus on the comfort qualities the pedestrian demands in the walking pathway and in particular when they are walking with a child. An ABM is proposed to represent the phenomenon and analyse it. This study covers the development of the model, emphasizing how it would reflect the integration of the re-use of self-tracking technology and the syntactic measures to assist with planning for pedestrian in smart cities. The outcome of the research should interest city planners and make a concrete business case that would interest technology providers.

KEYWORDS
Agent-based modelling, Design For Pedestrian, Self-Tracking, Location-Allocation Problem, Spatiotemporal, Walkability

1. INTRODUCTION
Over the past few years, the definition of a smart city has evolved to mean many things to different people. Yet, one thing remains constant is the utilisation of information and communications technology (ICT) and the Internet to address cities challenges. Smart city concept is materialised as a problem-solving technological instrument to urban problems. The Internet of Things (IoT) is coming to a city near you, it is a crucial tool for digital citizens of the future (Walden, 2015; Kortuem et al., 2013). Cities stand to benefit the most from connecting people to big data. Cities are repositioning themselves to play a pivotal role in the development of humanity; however, because of the rapid population growth and the soaring urban expansion, cities are facing a variety of challenges related to urban life (e.g., urban planning, traffic management, urban safety, resource sharing, energy efficiency, and recreation). Letting down to cope with any of these aforesaid challenges may threaten the city’s prosperity and quality of life (Mitchell et al., 2013).

1.1 PEDESTRIAN WALKABILITY _ ACCESS TO SERVICES
Urban designers are interested in the spatial qualities of spaces that create pedestrian – friendly cities. Launching traffic calming schemes, refining the quality of pedestrian environment, and public realm are various initiatives to improve town centres viability (Begg, 2002). Planning-for-pedestrians is an evolving design problem as with IoT, living and mobility technologies,
more requirements arise. Pedestrian movement was categorised by Gehl, (1987) into three main types: *functional walking*, *social walking* and *optional walking*. This study focuses on the latter where pedestrian is out under favourable weather conditions to convenient public places. There are unmet ICT and spatial-planning design requirements in pedestrian environments (Guo. et al., 2013; Sisiopiku & Akin, 2003; Shriver, 1997). The design requirements become more crucial when young children are involved. Attention is always given to child-friendly design in functional urban spaces. Pedestrians need to be well informed about the routes prior to their walk. Open sources (OpenSource, 2016) are very limited to inform about the qualities of the routes and the facilities being offered (South, 2012). Expanding upon this case, when children are away-from-home and they announce that they need to go to the toilet, or if the parents notice that their body signals are indicating a need to go, it raises an urgent matter that needs to be solved. In this research we are focusing on young children and referring to this demand as Toddler Toilet Demand-ttd.

### 1.2 THE RESEARCH QUESTION

The research addresses the current common practice of pedestrians and interrogates the benefit of integrating IOT and spatial configurational models in smart cities design. The research question is: how can smart spatial planning techniques meet what the pedestrian demands in future cities?

### 2. BACKGROUND

Stonor et al. (2003) discussed 17 various factors of walkability (i.e. the time of the day, footpath dimensions, and qualities), and created a walkability index taking London as a case study. Pedestrian needs were identified by Alfonzo (2005) as in order to decide to walk or not to walk; the walk has to be feasible, safe, comfort, and pleasing within an accessible route or space. Mehta (2008) expanded the walkability models in Main Street to include the sensing of belonging, pleasure, comfort safety, accessibility, feasibility and usefulness as the walking needs, whilst categorising the street characteristics as physical, social and land use. To this end, we focus on the comfort qualities of the surroundings and in particular the pathway itself. Comfort is a positive emotional reaction to the walking environment, which is affected by various factors; thermal, visual, acoustic, smells, air pollution...etc. In particular, we focus on the comfort associated by accessing services, which are perceived as fundamentals; as well as, the size and location of pathway-facilities.

#### 2.1 SELF TRACKING

Many individuals use wearable devices, for tracking, quantifying, and documenting everyday life activities, gadgets, and self-tracking applications (Klauser & Albrechtslund, 2014). Self-tracking and social sensing devices gained attention from medical and public health professionals due to the potentials these devices have benefiting clinical decisions (Sharon, 2016). Among the most popular electronic gadget categories last year is the motion tracker, Fitbit (Mackinlay, 2013). Fitbit is used for physical fitness purposes; however, the data gathered can be re-used in a different analytics context. While the majority of activity trackers are recommended for adults and kids (+13), the same device can be attached to a toddler to track a certain behaviour.

#### 2.2 THE URBAN CONTEXT

We take Bishop’s Stortford as the case study to analyse the pedestrian demand in the main pedestrian corridor of the city, see fig. 1. Some shots are taken to show main segments. This study is taking the inner urban core of the town, the area around South and North streets (BSTC, 2015). Many studies have deployed configurational models to predict pedestrian movement (Lerman et al., 2014); such models are based on the topological features of the space which are deployed for both vehicles and pedestrian (Hillier et al., 1993). Via axial map (62 axial lines) and the connectivity graph, see fig. 1, while taking South Street (street 1), as the graph root. Integration values were calculated using Depthmap (Turner, 2004), see fig. 3
2. DATASETS AND METHODS

The study explores the potential re-use of self-tracking technique to predict the pedestrian demand in outdoor urban spaces. It integrates network’s spatial attributes deploying agent-based modelling (ABM) approach. Integrated ABMs and space syntax have been used by (Shelton, Pereira et al., 2012) and (Jiang & Caramunt, 2002) in the context of pedestrian movement. Studies proved successful in predicting pedestrian movement and evacuation in the case of emergencies. This study deploys the same method addressing the planning for pedestrian. With a human-centric approach, it proposes a pedestrian planning model, which amalgamates integration values and ABM technique.

2.1 THE STUDY

In August 2015, a pilot study (n=2) was conducted. The recruitment of participants was done via word-of-mouth and posting in town centre nurseries that we are looking for volunteers to have the device attached to their toddler/ young child for one week. In September, a device (Fitbit- Zip model) was given to two families who have 2-year-old healthy toddlers. The whole trial was explained to them, and upon their consent, we asked the parents to ensure that the device is attached to the toddler whenever they are going to a walk in the city centre, and once the toddler demands a toilet or to rest, they take a record of the number of steps being made (reading the count, stating the location, and document it on what we called it ‘My ttd Monitor’. The documentation is done using a smartphone. A parent who is taking a child for a walk, will be having a stroller, diaper bag, toys, water/ juice and snacks, and potentially a handbag. We realised that on-the-go documentation on a piece of paper, is not handy and it will be inconvenient. So we asked the parents to audio record the ttd event and we transcribe it, see Fig. 2. There was no minimum number of walks, but we explained to them that the more they record, the clearer and reliable the outcomes would be. Each of the toddlers had an account with their names (Fitbit profile), through which we accessed their data log and retrieved the 7-day record. Devices were collected alongside the diaries, My ttd Monitor, from the parents on the 8th day.

2.2 THE MODEL DEVELOPMENT

The data collected was analysed and correlated to the urban area’s spatial attributes. An ABM was designed to depict the ttd behaviour (normal distribution of the data collected) deploying a step-based-demand agent architecture. In the simulation environment, there are two main layers: 1. Urban layer is the pedestrian pathways and 2. Behavioural layer is the spatial values and movement prediction technique.
3. RESULTS

A log of the seven-day tracking was retrieved from the two gadgets and the audio recordings and visualised in the urban context. Figure 2 illustrates a sample of three-day visualisation showing: the starting points, the route taken (distance and time), and the ttd details.

We observed the fit-for-purpose of using tracking devices for planning for pedestrian as: 1. the toddler does not understand what this device is for, hence the behaviour is not affected (no biasness), 2. the device does not count the steps if the baby is on the buggy, bus, or carried by an adult (accuracy), and 3. potential to use the retrieved data for planning purposes of other facilities (e.g. public seats' location). For instance, 1 kilometre equals to 5,000 toddler's steps. Fit I toddler after 100 steps (0.2km), was tired and sat on the ground (as noted by the parent in the My ttd Monitor).

3.1 THE MODEL

Each toddler was presented as an anonymous agent (agent a, b, n). The agent randomly enters the urban network (various entry points). The ttd measure is a function of (the amount of liquids the toddler had, last time the toddler used the toilet, the activity, the distance walked, and time spent before reaching the Main Street). These elements form the initial state (InValue_ttd) which in order to be simulated, each agent is assigned to InValue_ttd on a random distribution basis.
4. CONCLUSIONS

The proposed approach depicted the pedestrian demand in Main Street area via integrating IoT, and spatial and behavioural layers of the urban space. This is a part of ongoing research; the interim outcomes reveal potentials of a smart integrated planning tool. The study proposed an innovative idea to improve the comfort of walkability via the re-use of self-tracking collected data to assess and predict the candidate locations of pedestrians’ facilities especially for adults with young children. The use of tracking devices managed to inform the design-for-pedestrian with individual demands and provide smart human-centric solutions. The deployment of ABM managed to denote the pedestrians and their various demands throughout their walk paths. It provided a framework within which an alternative approach to self-tracking for pedestrian planning can be developed. The next step is to increase the sample size and to expand the urban area. In addition, a wearable camera, same notion of the wearable designed by Mehta et al. (2016) is to complement the tracking device, which may refer to as the (ttd Kit) to capture the surroundings and the facial impressions.
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ROAD DUPLICATION IMPACT IN URBAN AREAS TOWARDS SPACE SYNTAX ANALYSIS

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ABSTRACT
The proposed study discusses the application of Space Syntax Theory in road infrastructure and urban circulation infrastructure integrated planning. The structure of the urban environment provides an endless range of readings systemic descriptions and analysis. Among those, the ones provided by Space Syntax Theory and methods display robust results that comprise significant relationships between pedestrian and vehicular movement depicted from spatial configurations, what recommends its application in research problems that target these phenomena. In its turn, the interaction between road and urban networks is undeniable. Historically, road systems are powerful attractors that organize spatially urban settlements the occupancy population centre generating conurbations. However, paradoxically, at the same time that cities and roads are inextricably linked, this relationship has a conflictive nature with negative implications for both systems. In this paper, we intend to focus on spatial discontinuities imposed by roads stretches on intersections with urban grids that give emergency to social phenomena referred in literature as “community severance”. This notion applied in situations where regional transport infrastructure or motorized traffic acts as physical or psychological barriers segregating urban areas. In this context, our aim is to assess “community severance” impacts related to road crossings duplication in urban spatial configurations. The analysis of such impacts on urban accessibility and segregation patterns between settlements areas rely on space syntax literature about the theme and its potential application in transport studies. The methodological test was performed on an empirical case - the district town of Anhanduí, located in Brazil Midwest Region state of Mato Grosso do Sul that is crossed by BR-163 highway. The results confirm the hypothesis that urban crossings duplication, in the way they are usually designed in Brazil, induces “community severance” processes with negative impacts on city life and functional centralities, generating urban discontinuities which tend to deepen socio-spatial segregation processes and modify urban dynamics. This research intends to present Space Syntax methods and tools within transportation infrastructure technicians and policy makers, and raises their awareness to negative impacts of road crossings on urban territories.

KEYWORDS
Space Syntax, Syntactical Measures, Urban Highways Crossings, Community Severance.
1. INTRODUCTION

The close link between cities and roads is undeniable. Historically, road pathways attracted people, and organized settlements and their surrounding territories, informing tendencies for urban expansions can be said that cities are composed, basically, of the flows of people and goods and land use. In this sense, Panerai (2006, p. 18) states that “The strength of the road/city relationship is such that certain cities seem to be only a succession of roads around which the city is organized”. According to road engineering terminology, the segments of roads that cross these urbanized areas are named as "Urban Crossings". However, paradoxically, cities and roads are closely linked, but from such relationship cause a series of conflicts and negative implications for both networks: urban and road ones. Regarding the impacts generated by roads on cities, the ones that should be highlighted are environmental, visual and noise pollution; changes in land use and fringe occupation; and urban displacement issues due to spatial and urban grid discontinuities. In this sense, it is appropriate to cite Secchi (1989, p. 553) for whom “the road is now the crucial space for reflecting on the territory and the city, since it becomes a place of maximum concentration of noise, air and visual pollution, incongruously fragmenting the urban space and the territory, thus dispersing origins, destinies and movements”.

In this paper, we propose to describe and analyse city territory fragmentation caused by the barrier effect, a consequence of highway stretches crossing the urban grid. The usual solution for urban crossings would be implementing road detours; however, nowadays there are dissonant voices questioning the cost-benefit of such strategies that brings socio-environmental restrictions. Impacts on urban fabric accessibility patterns increase exponentially when highway lanes are duplicated with physical barriers between them. For safety reasons, highways technical regulations prevail over urban ones, imposing access control to its bordering land plots, through physical obstacles (guard-rail, concrete barriers, etc.), that reduce drastically connections between parts of the urban grid. Restrictions to pedestrian movement range restricting or confining such flows to a few specific points, where it remains possible movement across the road system. This kind of crossing is not levelled, but usually done above or below the road level through viaducts, underpasses and footbridge (Figures 1 and 2).

Figure 1 - Example of crossing urban road with simple lanes.

1 Along the same lines, at the beginning of the last century, Marcel Pöete wrote that the two elements that are the basis for the formation and development of cities are the location and the geographical frame, considering that the location receives the city, but the road gives it life. POËTE, Marcel. Introduction à l’urbanisme: l’évolution des villes, la leçon de l’antiquité. Boivin, 1929.
In this context, becomes relevant the concept of urban resilience, in the words of Cutini (2013, p. 102.1) is the "(...) the capacity of an urban system, thanks to the features of its spatial elements, to take abruptly imposed transformations, without significantly changing their mutual relations (...)". This design meets the purpose of this study, given that the doubling of urban crossing promotes an abrupt change in the urban fabric. To operationalize the evaluation of urban resilience, Cutini (2013) proposes the use of certain configurational measures.

Therefore, in order to assess the impact of the highway duplication on the urban environment around, we propose a study applying the theory and methods of Space Syntax. Thus, this study aims to analyse the effects of the implementation of urban crossings duplication in the spatial configuration, gauging the level of urban resilience to such intervention, which effects on urban grid are simulated, modelled and through syntactic measurements.

2. THEORETICAL FRAMEWORK

2.1 URBAN HIGHWAYS CROSSINGS

In this study, we use the concept of urban highways crossings presented by Amin (2012, p. 35): "Urban crossings are segments of roads that run across urban areas. They are characterized by population concentrations in their adjacent areas and the need to fulfil and reconcile the traffic demand of two different types of users: long-distance and local."

Regarding their functions, urban crossings have negative impacts on both highways’ and city’s environment. Sharing the highway with local traffic interferes traffic flow and increases conflicts and accidents, which directly impact the mobility of vehicles in long-distance intercity journeys. In addition, highways with the access restrictions hinder the movement and connection between one side and the other of the highway, negatively impacting the accessibility of intra-urban displacements.

At this point, interventions on highways near urban areas have an element that corroborates the lack of harmony with their surroundings by imposing legal, administrative and design specificities that the consequent contribute to urban grid fragmentation, along with autonomous governance and planning responsibility unrelated to municipality institutions and legislation. Thus, the design of a new highway (or even an intervention for increasing its flow capacity) is federal or state department attribution, which policies may conflict with urban and territorial planning and transit jurisdictions of the city.
The transportation engineer has a key role in such context, since this technician goal is to guarantee long distance traffic fluidity, and, in most cases, they act similarly in highway projects for rural and urbanized regions, disregarding the peculiarities of the latter. Following this idea, Marshall (2005) believes the focus on traffic summarizes the planning process to mathematical calculations for optimizing a limited number of variables and subordinating all other elements.

2.2 COMMUNITY SEVERANCE AND URBAN SEGREGATION

Mouette and Waismann (2004, p.33) defined the road barrier effect as follows: "[...] to denote the restrictions or inhibitions caused by interurban traffic and roads on urban mobility that generating an impediment to free pedestrian movement between the two sides of the road." Internationally, the term community severance indicates this phenomenon, which, as Ancien et al. (2016, p. 293), "[...]describes the effects of transport infrastructure or motorised traffic as a physical or psychological barrier separating one built-up area from another built-up area or open space."

Thus, when a highway is duplicated, it must be more than one lane, with a separation between them due to the presence of physical obstacles. In this sense, Ulysseá Neto and Dias (2003) conclude that are no longer allowing indiscriminate crossings, because this type of longitudinal blocking often causes the interruption of existing streets, which forces people to travel much longer distances than those they would usually travel before the intervention.

Mouette's (1998) affirm that the road barrier effect results in restrictions or inhibitions to the free movement of pedestrians caused by two obstacles: physical or vehicular traffic. Therefore, the population is forced to make detours or deviations that are impedance to movement, increasing daily displacements time or distances, what tends to reduce or even suppress journeys across highways.

The Brazilian National Department of Transport Infrastructure – DNIT, (an executive stance under the Ministry of Transport), admits publicly that “The existence or insertion of a highway in an urban area establishes a conflict, road space vs. urban space, with serious negative impacts for both. (...) The most important negative impacts detected in these cases are: (...) b) urban segregation/alteration of accessibility conditions” (DNIT, 2005, p. 41).

According to Villaça (2001, p.142), “segregation is a process where different classes or social strata focus more and more on different areas or neighbourhoods of the city.” Obviously referring to residential segregation phenomena from homogeneous socioeconomic foreground. Mouette (1998, p.40) relates population segregation to road barriers effect, since it “can segregate part of the population, in detriment of another share, by preventing the former from reaching a certain area, thus separating and isolating it from places and people.”

At this point, we highlight studies, such as Vaughan’s (2007), which demonstrate the importance of addressing socioeconomic conditions on urban design, consistently verifying the correspondence between poverty and spatial segregation.

2.3 URBAN RESILIENCE

Regarding the urban resilience, which is the study subject, we reiterate the concept presented by Cutini (2013, p. 102.1), for whom urban resilience is the "(…) capacity of an urban system, thanks to the features of its spatial elements, to take abruptly imposed transformations, without significantly changing their mutual relations (…)". Following in the same direction, Rigatti (2016, p. 3) says that "(…) resilient urban systems are able to withstand transformations in their morphological characteristics without modifying their underlying structure, that is, the city is able to function and adapt to changes."

The great majority of works dealing with urban resilience relate to the capacity of cities to withstand abrupt changes in their structure related to natural events such as earthquakes and floods. Regarding the transformations caused by urban infrastructure works, the work of Professor Décio Rigatti (2016) must be mentioned; he addressed the resilience of the urban structure of Porto Alegre resulting from the works for the 2014 World Cup.
2.4 SPACE SYNTAX

The use of Space Syntax appliance to analyse urban crossings related phenomena is justified by Hillier et al. (1993), who state that urban road network configuration, the largest spatial pattern in the city - is determinant for movement flows and, therefore, urban grid spatial patterns relate intrinsically to co-presence in spaces, with enormous consequences for both the land use and functions of cities.

Hillier and Hanson (1984) understand that the system of open public spaces in an urban system is constituted by elements that can be individualized and identified. Thus, they start from the premise that this system can be decomposed in one or two dimensions represented as a map of axial lines. The linear features of the axial map represents better the transport flows and pedestrian movement interactions we intend to analyse in this paper. According to Holanda (2002), the axial map is the linear representation of space, allowing the syntactic description of the configuration and the clear visualization of topological distances in the urban network. This type of representation is based on the axial lines that would be the longest lines of visibility and continuous movement in the system.

In axial analysis, spatial configuration features (morphological properties) are quantified by extracting syntactic measures. In the words of Rigatti (1997, p. 176), "syntactic measures are, then, configurational properties transformed into a measured pattern, enabling analyses and comparisons".

At the beginning of this century, Turner (2001) proposed a methodological improvement to describe, analyse and represent movement potentials and flow probabilities within urban grids so called Angular Segment Analysis. According to Zampieri (2012, p.41), this analysis "is a tool that allows thinking of axial lines according to the deflection of each route. This process segments the axial lines at their intersections to others, so weights can be assigned, depending on the angle at which the segments are connected." Thus, in this type of analysis, in addition to the topological structure depicted in axial analysis, the connection between axial lines is pondered by its angulations what ponders the notion of topological distance (depthness) with that of perceived spatial and visual continuity. Another thing that makes the angular segment analysis different is that it splits the axial line at the intersection with other axes, so it is possible to correlate each segment to movement potential and activities location, what is most relevant for local scale analyses, as proposed in this article. In this sense, Braga (2013, p.270) concludes that this analysis "allowed the peculiarities of uses and social appropriation in the stretches of an axial line to be understood in a more objective way, in a reduced scale, so the dispersion of urban functions could be analysed not from potentials of movement, but from the probability of flows along segments." Following the work of Hillier and Iida (2005), the high correlation index between the Angular Segment Analysis and pedestrian or vehicular flows are foremost important to build our case.

Thus, considering the particularities of the proposed research, and considering that it seeks to evaluated the urban resilience level, we use the lessons of Cutini (2013) and Rigatti (2016) with the following axial syntactic measures:

- Mean connectivity value;
- Choice;
- Sinergy.

In addition, as a research deals with the verification of flow trends, we chose to use the segmented map, since it transforms the axial map lines into segments, allowing the assessment of each segment of the axis. The following angular measures are used: integration and choice.

The measure of integration represents the potential to "go to", that is, how easy it is to go from one point to another. According to Oliveira et al. (2015, p. 162), "it is a measure of the degree of centrality, relating to the movement of destiny, [...] [it has] the ability to identify significant places from the point of view of the functionality of urban agglomerates. Integration usually emphasizes spaces in the city commonly known as 'main streets', where a large part of non-daily commerce is located, often associated with the concept of (functional) urban centre.”
For Turner (2007, p. 540), the measure of choice based on that of betweenness centrality in network theory consists in “for all pairs of possible origins and destination locations, shortest path routes from one to another are constructed.” So, for each time a node is traversed in an origin-destination path, the choice-value increases one point.

3. THE STUDY EMPIRICAL CASE AND ITS DATASETS

The District of Anhanduí, located in the city of Campo Grande, capital of the state of Mato Grosso do Sul, Brazil, is our case study. The choice of this location is mainly due to two factors: the situation in which BR-163 highway crosses the entire urban perimeter of the district; and the forecast of duplication of the highway.

The occupation of Anhanduí began in the 1950s, but the current configuration corresponds to a project of subdivision of land approved in the mid-60s, which planned the execution of 2,800 plots of land. The original plan had a city square, and around it would be the city hall, church, forum and post office, creating a kind of civic centre. It is observed that the current urban fabric of the District of Anhanduí is characterized by an orthogonal grid layout with chessboard format, with connections in “X”, forming a non-hierarchical system.

According to census data (IBGE, 2010), the district has a total population of 4,267 inhabitants, with 2,040 people living in the urban area and 2,227 in the rural area. The district main economic activities are agriculture and informal commerce, along the BR-163 Highway, where local products, mainly handmade objects, homemade sweets, cheeses and pepper are sold directly by locals to travellers. Formal commerce and services are located along the highway.
BR-163 is a highway that connects Brazil from South to North crossing the Centre-West of the country, comprising the entire state of Mato Grosso do Sul, and constitutes the main logistics corridor of this State, transporting agricultural goods to the ports of Paraná and Santa Catarina.

4. METHODOS AND DATABASES

A set of *orthophotos* of the District was obtained what enabled the urban grid decomposition into an axial map (AutoCAD 2017). At this point, it is important to note that this paper focuses on non-motorized forms of transportation, and, therefore, all permeability’s urban public space was considered included elements such as walkways and passageways throughout which pedestrians and cyclists can move. On the other hand, when physical obstacles were identified, such as road elements that make it impossible for pedestrians and cyclists to move freely, especially concrete barriers and metal fences, the axial lines were interrupted. After that, the functional design for the duplication of BR-163 Highway was obtained and the design changes were added to the axial map in order to express the further changes to spatial continuity due to road lanes duplication. The changes consist basically of a barrier between the two lanes of the highway (which sections, in the model, the transversal routes), the inclusion of two footbridges and an underground, and two viaducts located at both ends of the urban settlement.

After the linear representation of the map the next methodological step is the process of calculating the models through a specific software. The procedures for obtaining measurements are identical, in the original situation and in the projected situation.

This research uses the angular analysis of the segment maps. Thus, a new map is created, with the syntactic angular measures in. Different theme maps are generated for each syntactic measure and, in addition, a text file with all the numeric data of the maps.
Finally, the variables from segmented analysis are assessed and compared in the two ways: in roads after and before the duplication with obstruction to movement in urban crossing. This analysis will indicate urban configuration changes due to the road duplication in urban crossing. In addition, the values of the variables of the entire study system are compared with others cities of Brazil and the world.

Therefore, two thematic maps were created for each measure, related with these two analyses, that is, to the period before and after the duplication.

5. RESULTS

5.1 ORIGINAL SITUATION

Preliminarily, it is observed that the current urban fabric of the District of Anhanduí is characterized by an orthogonal grid layout with chessboard format, with connections in "X", forming a non-hierarchical system, which model refers to the correspondence between global and local morphological properties.

To examine the level of urban resilience, the axial measurements “connectivity”, “choice” and “synergy” were measured, according to values below:

<table>
<thead>
<tr>
<th>Mean connectivity value</th>
<th>Choice max /k</th>
<th>Int. R₃ x Int. Rₙ</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.09</td>
<td>0.4236</td>
<td>0.9631</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 - Values regarding the urban resilience index in the original situation

The most connected lines stand out for their color, which varies from red (more connections) to dark blue (fewer connections). Regarding the average connectivity, a value of 6.09 connections per line was verified, which can be considered a very high value. This situation is characteristic of regular and orthogonal mesh cores. According to Medeiros (2006, p. 357), “(...) the orthogonal grid optimizes the number of connections due to X-crossings that reinforce the possibility of lines crossing most systems.”
Medeiros (2006) also affirm that the average connectivity of Brazilian cities is 3.9, that is, Anhanduí, according to the information above, has a much higher average connectivity when compared to other Brazilian cities. In addition, in a worldwide comparison, the highest results of this variable are found in Latin American cities (5.7), which, despite being a value close to that found in Anhanduí, still is lower.

In addition, the map shows that the 3 most connected lines refer to the highway and its side streets.

The index choice proposed by Cutini (2013) varies from 0 to 1 and corresponds to the following expression:

\[ v = \frac{\text{choice max}}{k} \]

Where \( k = \frac{n^2 - 3}{2} n + 1 \), with \( n \) = number of lines in the axial map.

Increasing the index “choice”, the level of resilience of the urban system decreases. This is justified by the fact that it is plausible to assume that systems with a diffuse presence of shorter paths across the network have a higher level of resilience. In a single-crossing situation, the index found corresponds to 0.4236.

Synergy corresponds to the correlation between global and local integration of a system. The Depthmap software allows the direct calculation of the “R²” index of this variable. The value found is 0.9631, which is a very high correlation. This high correlation is explained by two situations: first, according to Medeiros (2006), “to synergy, the larger the system, the smaller the value”; so, for a small system, as is the case in this study, the synergy value will be higher. Second, the regular orthogonal mesh results in a high convergence of global and local integration scales.

An angular analysis is used to assess the fragmentation of the urban system and the potential of flows in the segments. Segment maps will be used to achieve this. In this method, the axes are “broken”, which results in an increase in the total number of axial lines, reaching 390 segments.

<table>
<thead>
<tr>
<th></th>
<th>minimum</th>
<th>average</th>
<th>maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integration Rn</td>
<td>4,491</td>
<td>209,627</td>
<td>279,071</td>
</tr>
<tr>
<td>Choice</td>
<td>0</td>
<td>2979,420</td>
<td>11926,000</td>
</tr>
</tbody>
</table>

Table 2 - Values referring to the measures of integration and choice, in the original situation, using the segment map.
It is possible to observe that the segments with the highest integration values diffuse parallel the axis of the BR-163 Highway and its side streets, covering the entire extent of the urban sprawl. However, it is also possible to verify that the network has distributive integration features typical of shallow system that concentrates integration along the longest and most connected lines and is subdued to border effects. In addition, it is possible to affirm that there is no significant difference between the values found on one side and another of the highway; continuity between segments establishes the spatial pattern.

As a role, it is possible to say that the lines with higher integration measure are those that have, potentially, higher movement potential. It was inferred that easier to reach segments from any other point within the system tends to concentrate economic activities. In a brief comparison between the integration map and the current land use, it is possible to verify that there is some correspondence between commerce location and integration measures.

Angular choice measure (n) relates to urban navigation through the urban grid, depicting the shortest routes crossing the system. For Turner (2007, p. 6) “Betweenness, or choice as it is called in the space syntax community, is calculated by generating shortest paths between all segments within the system”. According to Ugalde (2013, p.194), choice is “the syntactic measure with the greatest ability to capture movement paths in spatial configurations.” In Figure 6.B it can be observed that, in general, the segments with higher values for this measure correspond to places where there are more commercial uses, especially, it depicts the informal commerce concentration (Figure 4).

It is worth noting that the civic centre location supposed to exist in the original project does not currently have the characteristics of centrality, the expected outcome of which would be a symbolic centre. The commercial establishments, as already shown, are clustered along BR-163 Highway and its adjacent roads, where the highest indexes were found for the measures of integration and choice, therefore, concentrated where movement potentials and flow probabilities area higher.

5.2 PROJECTED SITUATION WITH THE DUPLICATION

With the duplication project and the construction of new devices, as well as the sectioning of the transverse routes to the highway, there will be an increase in the number of existing axial lines. In order to identify changes due to interventions on the highway, the actual situation map was modified, including projected elements prescribed for road lanes duplication: viaducts, walkways and the underground passage. The modelling considered unlinks, where segments are superposed but have no connectivity. The pattern of cross-sections in “X” persists, but the transversal routes overpassing the highway were suppressed by blockages between the duplicated lanes. Thus, cross-sections in “T” appear along the side streets of the highway modifying continuity patterns between both sides of the lane.

The table below shows the measurements verified from the simulation of the space system, with the duplication project already inserted.

<table>
<thead>
<tr>
<th>Mean connectivity value</th>
<th>Choice max /k</th>
<th>Int. R₃ x Int. Rₙ</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.09</td>
<td>0.5284</td>
<td>0.5849</td>
<td></td>
</tr>
</tbody>
</table>

Table 3 - Values referring to the urban resilience index in the projected situation
As to the mean connectivity, there is a decrease of more than 30% in its value, making it 4.09 connections per line, which reflects a lower internal articulation of the grid. This is explained by the fact that the transverse axis is cut off from the road. This number of mean connectivity is slightly higher than the average of Brazilian cities (3.9). In a brief analysis on the map, it should be noted that the highway (and its side streets), which, in the original situation, are the ones with the greatest number of connections to other roads, now, with the changes caused by the duplication project, are not anymore.

In the assessment of the index “choice”, the situation simulated with the duplication project caused an increase in this index, reaching the value corresponding to 0.5102. This difference is perceptible by analyzing the maps. In this second situation, it is possible to verify a smaller amount of shorter paths in the network (greater presence of lines of strong blue color).

The value found in the synergy index, with the duplication project, drops to 0.5849, which corresponds to a decrease of approximately 40%. This decrease in values reflects a separation between integrations, globally and locally. In addition, it was verified that the size of the system is not the most determining factor for this measurement.

In order to perform the comparative analysis with the results verified in the original situation, it is necessary to draw up the segment maps already with the lines referring to the duplication project, in order to ascertain the measures of global integration and choice.

<table>
<thead>
<tr>
<th></th>
<th>minimum</th>
<th>average</th>
<th>maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integration Rn</td>
<td>2.5</td>
<td>116,662</td>
<td>160,554</td>
</tr>
<tr>
<td>Choice</td>
<td>0</td>
<td>2970.81</td>
<td>39860</td>
</tr>
</tbody>
</table>

Table 4 - Values referring to the measures of integration and choice, in the projected situation, using the segment map.
The angular Integration measure including the designed highway duplication is significantly revealing. The first phenomenon that draws attention is the clear distinction between the patterns found between one side of the highway and the other. It is important to note that the highway, which has the most integrated element, loses higher level of integration, becoming a kind of “barrier” dividing the District territory. A plausible conclusion is that this can stimulate a process of spatial and social segregation, or community severance. In addition, it is observed that the average values of the integration measure decrease considerably, so that it can be stated that urban accessibility decreases. In addition, it is expected that, as time passes, new functional centralities will appear along most connected axes transversal to the highway. A new configuration will emerge in which the impact of discontinuities imposed by changes on the road system upon the urban system will transform commerce which today revolves around interregional flows.

As regarding the angular choice measure, due to the barrier imposed by the duplication of the highway, the results were quite different from the current situation. If before there was a concentration of the higher flow probability around the centre of the system corresponding to the main routes, now there is a displacement to one of the extremities next to a U-turn. This fact demonstrates that the previously verified pattern, common to orthogonal grid settlements, was significantly altered, and the physical barrier embodied in the duplication of the highway will significantly the decisions about route choices used for intra-urban displacement.

6. FINAL CONSIDERATIONS

Firstly, this study is the initial part of a research project that is still in progress, and, therefore, it needs further development. Urban interventions alter the spatial characteristics of cities, bringing along social consequences. In the case, we verified that the duplication of BR-163 Highway, which crosses the urban sprawl of the District of Anhanduí, alter profoundly the spatial configuration of this location.

Following the Spatial Syntax approach, we found significant changes in development tendencies due to changes on the road infrastructure. The results confirm the assertion that the duplication of an urban highway, in the manner in which it is commonly done, increases the negative impacts derived from its barrier effect, especially those referring to discontinuity and fragmentation of urban space, which tend to worsen processes of social segregation.

Finally, the findings from the segmented maps enable the visualization of the flow and movement relations, so that such technique, with the necessary adjustments and furthering, can be used in a way that helps the discussion and the studies of interventions in urban highways.
Concepts of urban resilience, usually applied in situations of natural disasters (earthquakes, floods, etc.), can also be applied in situations of significant road interventions and can show the behavior of the urban structure.

The most important is that the symbiosis between the road system and the urban settlement development, specially its functional centrality based on the commerce of local products and services directed to interurban traffic is due to fade, compromising the very existence of this small town. Several small towns that emerge in rural areas along regional roads are sensible to changes in urban crossings. Sometimes the mere existence of such crossings acts as powerful attractors to urban activities such as formal and informal roadside commerce. Inter-urban and intra-urban traffic segregation enhances the efficiency in cargo flows and urban community security, nevertheless, such design strategies must consider the impact on the spatial life of small towns, because sometimes it can promotes severe changes in their dynamics and social organization.
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ABSTRACT
Significant progress has been made in order to develop methodologies aiming at measuring urban sprawl. However, most of the current methodologies put great emphasis on density and urban form measurement, while accessibility receives little attention. Methodologies commonly employed to measure sprawl do not grasp details of intra-urban levels, including street network configuration and accurate location of urban activities, such as residential and job location. Hence, accessibility remains almost unaddressed in urban sprawl measurement studies. Measuring accessibility is important because it enables us to tackle the most obvious negative effects of urban sprawl, such as the increase in commuting distances. In this paper we propose an urban sprawl indicator, which is based on weighted accessibility measure. It attempts to measure spatial mismatch between residential and employment location. This paper aims at bringing urban sprawl measurement to a network and configurational perspective, which is helpful to measure accessibility. For this purpose, we describe the urban system as a graph where nodes represent small portions of urban built forms and lines represent the street segments connecting them. The method was applied to Torres, a small town in Brazil, where some hypothetical scenarios were carried out in order to compare the results. The results indicate that the proposed method has potential to be used in comparative studies about urban sprawl, since it enables us to grasp different mismatching degrees between residential and job location. We conclude that commuting distances are influenced not only by spatial mismatch between activities but also by its accessibility in relation to the whole system.

KEYWORDS
Urban sprawl measurement, graph-based approach, spatial configuration, accessibility measure, urban performance indicator

1. INTRODUCTION
Urban sprawl has been often characterised as low-density and monofunctional urban development. Moreover, it has been often related to negative effects, such as increasing commuting distances, intensive use of individual vehicles, and greater land consumption, albeit this kind of correlation is yet to be proven with more empirical research. Over the past few decades, there has been increasing concern about this phenomenon and its impacts. Currently, there is general agreement that it should be monitored in order to better guide urban development policies.
Recently, several researchers have developed quantitative indicators and indexes to compare the sprawl degrees of cities or to monitor the phenomenon in a single city over the time. Despite the great effort that has been made, much of the existing work has excessively focused on density patterns and general urban form that characterises urban sprawl. Meanwhile, aspects such as accessibility and details in intra-urban scale – streets network configuration and activities distribution – have received less attention. Such aspects are precisely the ones that should be more explored in quantitative work because they are strongly related with sprawl effects and raise a more accurate debate on urban performance. We have to focus on the fact that what makes sprawl undesirable is its negative effects and not its urban form. Actually, the correlations between urban morphology and urban real effects are still yet to be proven, and, because of this, we urgently need to improve our methods to reach urban performance.

The key argument in this article is that we need to develop urban sprawl measurement tools towards indicators that are more strongly related to impacts, such as accessibility. In this paper, we make an effort to bring the discussion on urban sprawl measurement into a configurational approach. Little attention has been given to particularities of intra-urban scale in sprawl literature. Nevertheless, highly developed methods can be found in urban configurational studies. Therefore, we suggest an accessibility-based indicator, which is derived from a configurational and systemic approach. Such methodology is capable of providing a better description system of morphological and configurational properties of the urban spatial structure. A more accurate description, in turn, enables more accurate and sophisticated strategies to measure sprawl.

Another important point to consider is that most of the current methods for measuring sprawl use aggregated data that poorly captures configurational and fine-grained issues. Fortunately, it is becoming increasingly easier to find refined urban data and computational tools that perform measures in intra-urban level, so it is worth making use of this.

Next section provides a brief review of some urban sprawl measures research recently developed. In particular, we attempt to verify how accessibility has been approached in those studies and its main shortcomings. The third section presents our proposal of a new urban sprawl indicator, which is based on a weighted accessibility measure. This section also provides background on urban configurational studies and a pilot study. The fifth section presents a case study where the proposed method was applied. Finally, the last section provides final consideration.

2. URBAN SPRAWL MEASUREMENT

The first challenge one faces when dealing with urban sprawl measurement is its unclear conceptual definition. Sprawl has become an umbrella term covering many forms of development (Longley, Batty and Chin, 2002). Although there is no consensus on a definition for urban sprawl it is widely accepted that it refers to low-density development and to high reliance on the automobile, because people live too far from workplaces, study places and shopping places (Jaret et al., 2005).

In the last few decades, sprawl has been conceptualised as a matter of degree, not an absolute form (Chin, 2002), as well as a multidimensional phenomenon that requires a different set of measures for each dimension. Several scholars (Galster et al., 2001; Ewing, Pendall and Chen, 2002; Ewin and Hamidi, 2014; Bertaud and Malpezzi, 2003; Ribeiro and Holanda, 2006; Torrens and Alberti, 2000; Torrens, 2008; Frenkel and Ashkenazi, 2008) have developed quantitative indexes for measuring sprawl degree and comparing cities. Such methods play an important role in sprawl debate due to the promotion of a more rigorous definition of the phenomenon. In this section, we highlight some relevant aspects of those methodologies for measuring sprawl, in particular, some gaps concerning accessibility assessment.

2.1 LITERATURE REVIEW

Galster et al. (2001) defined sprawl as a condition that is represented by low values on one of the eight dimensions of the phenomenon: density, continuity, concentration, clustering, nuclearity, mixed uses, proximity. The researchers developed operational measures for each dimension.
According to Jaret et al. (2005), this work is a conceptual and methodological breakthrough in urban sprawl measurement.

Ewing, Pendall and Chen (2002) focus on sprawl impacts rather than sprawl characteristics and urban form. The authors propose a composite index based on the four main factors that are measurable: a) density; b) mix of homes, jobs and services; c) strength of activity centres and downtowns; and d) accessibility of the street network. They apply those measures to 83 metropolitan areas in the United States and relate them to quality of life indicators, such as time of commuting, air pollution and traffic jam. Later, the research was updated with more recent data (Ewing and Hamidi, 2014). Their accessibility measures are related only to block size, overlooking configurational issues.

Bertaud and Malpezzi (2003) focus on spatial distribution of the population. They examine density gradients and propose an alternative measure of urban dispersion by synthesising densities and distances to the downtown into a single index. Both methods are related to distance between population and CDB (Central Business District). The measurement methods are applied to almost 50 cities all over the world. It was one of the first efforts to study urban form systematically around the world. Later, Ribeiro and Holanda (2006) have included seven Brazilian cities to the sample. The method proposed by Bertaud and Malpezzi (2003) is interesting because it faces the problem of accessibility between the population and the CDB, where the job opportunities are located. The problem is that it assumes that all the employments are in the CDB, which means a monocentric pattern is assumed. However, as cities expand, they tend to assume a polycentric pattern (Longley, Batty and Chin, 2002; Louf and Barthelemy, 2013) and the employments are most likely to be dispersed (Song, 1994). Accordingly, population distribution can be better explained by a model that accounts for distance to all employment rather than just to employment in CDB (Song, 1994; Anas, Arnott and Small 1998).

Frenkel and Ashkenazi (2008) make use of measures from different disciplines to carry out a study about sprawl in seventy-eight urban settlements in Israel. The thirteen chosen variables are related to three dimensions of urban sprawl: density, scatter, and mixture of land uses. The measures were weighted into one integrated sprawl index in order to compare cities. The authors attempt to measure urban sprawl from a multidimensional perspective. However, they leave out accessibility, which is an important dimension of the phenomenon.

Unlike the authors mentioned above, who analyse a great number of cities, Torrens (2008) focus on only one city: Austin. The study embraces forty-two measures, which attempts to embrace the full range of sprawl characteristics: urban growth, density, social, activity-space, fragmentation, decentralisation, and accessibility. One of the main contributions of this study is to achieve multiple scales, including the intra-urban level. The author examines accessibility patterns: to the CDB, to major employers, to schools, to other educational opportunities, and to locally unwanted land-uses.

2.2 CRITICAL ANALYSIS

Most of the studies mentioned above consider multiple dimension of sprawl, including density, general urban form, mix of uses and accessibility. Here we highlight the main shortcomings:

- Density and urban form overemphasised, effects overlooked
- Little attention has been paid to intra-urban scale. The research we have analysed deals almost exclusively with aggregated data, usually in the metropolitan scale. Torrens (2008) is an exception.
- The urban form is assumed to be monocentric in almost all of the related studies. However, many authors agree that the real nature of cities is more polycentric instead of monocentric (Song, 1994; Longley, Batty and Chin, 2002; Louf and Barthelemy, 2013).
- Measures are not systemic and do not consider spatial relationship among activities
- Accessibility poorly explored.
As we could see, density is the most studied dimension of sprawl. Measuring and modelling the spatial distribution of residential density has been attempted in several ways. However, according to Ewing, Pendall and Chen (2002) density should not be overemphasised. Researchers should pay more attention on how urban sprawl affects the urban environment.

Accessibility, in turn, is a key point in urban performance debate since it is strongly related to efficiency, equity and sustainability (Bertuglia, 1994; Netto and Krafta, 2009). Low accessibility can be considered one of the most undesirable aspects of urban sprawl, since residential areas may be too far from jobs and services (Ewing, 1997). Consequently, it can lead to more fuel consumption and automobile dependence. Despite all the possible bad impact in urban performance, accessibility has received little attention in sprawl measurement studies. Although accessibility is regarded as an important dimension of sprawl it is not always included in an operational way.

The literature review lead us to the conclusion that one of the main shortcomings of current methodologies is that urban morphology in intra-urban level is poorly described. As we will see in Section 3, a network perspective can contribute with a more precise description of the activities distribution and their spatial relationship, leading us to operationalize accessibility.

3. BRINGING SPRAWL MEASUREMENT INTO A NETWORK PERSPECTIVE

Urban sprawl exhibits poor accessibility, first because residents are often distant from urban opportunities, such as work, shopping, and entertainment. Second, because opportunities are themselves far from each other (Torrens and Alberti, 2000). On that account, measuring spatial mismatch among urban functions seems to be a good urban sprawl indicator. However, we need to handle with urban spatial features in intra-urban scale to give a step further in the direction of impacts assessment. The main features to accurately assess accessibility are the street network and the spatial distribution of residential and non-residential areas.

A traditional approach would define a unit of study, such as neighbourhoods or census tracts, and compare number of households and employments, or measure distance from residential areas to the CDB. Much of the sprawl measurement literature is based on such type of analysis. The main assumption in this type of study is that each unit is independent of the others. In such approach, accessibility would be assessed by measuring distances in straight-line from each unit of study to a monocentric downtown area.

However, we already have more sophisticated methods to measure accessibility, under a configurational and systemic approach. Besides, we already have methods to represent cities in a more detailed way, describing street network and activities distribution. Urban spatial configurational studies have tackled the intra-urban scale by using a detailed description of urban configurations. Such approach regards cities as networks of public spaces (Hillier and Hanson, 1984) and urban built forms, which host urban activities (Krafta, 1994). In the network analytic framework, the basic unit is a pair of units tied by some kind of relationship. This way, one can measure the interaction between all possible pairs of units.

Several graph-based methods for describing the urban spatial system and for operationalising measures have been suggested in the literature (Hillier and Hanson, 1984; Krüger, 1990; Krafta, 1994; Batty, 2004; Porta, Crucitti and Latora, 2006, Figueiredo, 2015). However, sprawl literature has rarely incorporated this kind of study.

In this article, we tackle urban sprawl measurement from a network perspective. We attempt to develop a measure from a systemic and configurational point of view because it seems to be most appropriate to describe and assess accessibility accurately.

4. URBAN SPRAWL INDICATOR BASED ON WEIGHTED ACCESSIBILITY

This section presents an attempt to deal with accessibility in an operational way. The first step was to figure out a good description system, then the calculation method. Finally, a pilot study is also provided.
4.1 DESCRIPTIVE SYSTEM

A graph-based methodology is proposed to describe the urban spatial structure because it enables disaggregation of urban system in small portions. Although urban sprawl is generally characterised in metropolitan scale, we argue that urban sprawl must be assessed also by its characteristics in intra-urban level. Details such as street network configuration and jobs and household locations can be considered as important as general urban form and general population distribution. Scholars have developed several descriptive systems which are graph-based. Figure 1 summarises the main ways in which streets network can be represented as maps and their corresponding graphs.

Krafta (1994) proposes an urban graph which describes public open space and built forms. This way, elementary portions of space are represented by dots, and the connectivity among them is represented by lines. Urban built forms are, actually, small portions of the city and can host attributes of residential use, non-residential use or both.

The descriptive system we adopt is an urban graph which is very similar to the schema “c” showed in Figure 1. However, instead of mere junctions, the nodes describe small portions of the city containing urban built forms, following the descriptive system suggested by Krafta (1994). Each node contains a set of urban built forms so that nodes can be loaded with attributes about the number of households or quantity of jobs, for instance. One advantage of this description system is that it enables us to have an accurate description of the distribution of urban activities and how they connect to each other.

Besides accurately describing urban activities location, the main advantage of this description system is that it enables to measure network distances between activities since Euclidean distances are preserved in the graph representation. It can be regarded as a primal approach (Batty, 2004; Porta, Crucitti and Latora, 2006), which means that distances in the map are the same as in the graph. Graph-based measures are often based on topological distances, but to deal with sprawl measurement it seems to be better using Euclidean distances. Another possible way to measure distances could be by temporal distance, or in other words, commuting time. In this paper, we assume that the proposed measurement method do not consider any transportation facilities, which in turn could change considerably the commuting time. The model considers only the configuration of the streets network and the distribution of activities.

Therefore, the descriptive system adopted depicts the city as a system. Links between activities are highlighted, making it possible to develop a systemic indicator based on graph-based measures.
4.2 ACCESSIBILITY MEASURE

A common way to measure accessibility is to produce a composite index of accessibility from one place to all others (Batty, 2009). Since accessibility implies in some measure of proximity (Ingram, 1971), and proximity can be measured by distances, a sum of distances can be used to measure accessibility. Torrens and Alberti (2000) argue that a gravity-based measure is one of the possible methods that can be used to assess accessibility in sprawl measurement context.

In this paper, we adopt a method based on gravitational models (Haynes and Fotheringham, 1984; Torrens and Alberti, 2000). In such approach, we have the following components: the capability of a point in generating trips; the attractiveness of a destination; the cost or distance among all pairs of origin and destination; and some mechanism of weighting to discourage long trips. We attempt to adjust this classical measure to the sprawl measuring concerns. Therefore, we consider the capability of generating trips as the number of households and the attractiveness of a destination as the number of workplaces. Distances are measured by metric network distances of the shortest path among the urban activities. We do not consider any mechanism to discourage long trips because the intention is exactly to assess the increasing distances between activities.

Hence, the proposed measure of weighted accessibility ($A_{ij}$) in a given point is a sum of distances ($d_{ij}$) weighted by origin ($O_i$) and destination ($D_j$) attributes.

$$A_i = \sum_{j=1}^{n} \left( d_{ij} O_i D_j \right)$$

Equation 1 - Weighted Accessibility measure for each node

The algorithm does not consider distances from one point to all others. It computes only distances between pairs of nodes that contain complementary activities, like households and workplaces. To use the gravitational model language we will call the households as origin points and the workplaces as destination points. The algorithm identifies all the origin-destination pairs of nodes before starting the calculation. The first step to measure the weighted accessibility of a given point is to detect all the nodes which contain destination attributes. The second step is to measure the distance of the minimal path between each origin-destination pair and multiply it by the attributes of the origin point and of the destination point. Then, sum up all.

This measure can be read as the potential that each point has to cause undesirable consequences to the city. The results are computed for each node, so it can be used as a local indicator of the potential that each part of the city has to cause undesirable effects related to increasing distances. For example, if you build a huge residential area far from all the urban facilities and jobs, it will have undesirable effects powered by the number of people living there, increasing vehicular dependence and fuel consumption.

Nevertheless, our focus in this paper is to propose an urban sprawl indicator aggregated for a whole region. The purpose of this indicator is to compare different urban settlements from the point of view of spatial mismatching between residences and employments location. The proposed indicator basically consists of a weighted average of all values obtained for weighted accessibility measurements in a particular urban graph. Since cities are very different in size and in their urban configuration characteristics, such indicator should capture all those aspects. Even tough it is an aggregated indicator it can still be regarded as a systemic measure since it is obtained from a graph-based measure. In other words, it considers the spatial connection among different parts of the city.

The Sprawl Indicator ($I_{sprawl}$), showed in Equation 2, is the sum of weighted accessibility of each node divided by the total number of origin attributes ($O_{total}$) and the total number of destination attributes ($D_{total}$). The higher the value found for the Sprawl Indicator the higher the distances between households and employments.

$$I_{sprawl} = \frac{\sum_{i=1}^{n} A_i}{O_{total} + D_{total}}$$
4.3 PILOT STUDY

The Sprawl Indicator was applied to some sets of theoretical models that represent different urban configuration patterns, concerning street network and spatial distribution of employment and residences (Figure 1). This pilot study aimed at verifying the responsiveness of the indicator for different urban patterns. Each set of urban models isolates one important aspect that the indicator should embrace. The results for the proposed urban sprawl indicator, showed in Figure 2, were consistent with what was expected from both visual and statistical analysis (ANOVA).

The first set of examples describes different street network configuration, with different connectivity degrees. We can see that the urban configuration of street network really interferes in the result, since it presents significant difference in the results. The exception is when we compare 1c and 1d (p=0.996) and 1d and 1e (p=0.255), which are actually very similar to one another. We can also notice that the most fragmented example (1e) presented the higher sprawl indicator, while the most connected (1a) presented the lowest value. In this set, since origin and destination are not weighted, distances were computed from each node to all others.

The second set describes different patterns of employment location, ranging from monocentric to polycentric patterns. Again we can see significant differences (p=0.000) in the results, with some few exceptions. More dispersed patterns of employment location resulted in higher scores for the urban sprawl indicator.

Finally, in the third set, we actually have two subsets that describe different distribution of residences, comprising different households and jobs mismatching patterns. Statistical testing (Factorial ANOVA) showed that both factors – jobs location and housing location – that interfere in the result are independent. Then we could realise that, regardless the pattern of residence location, if workplaces are concentrated in the geographic centre of the system the values for the indicator tend to be lower. Likewise, if the residences are located closer to the geographic centre the values tend to be lower because this way distances are shortened. Another interesting finding is that when the workplaces are completely mismatched from residences, it does not matter if the residences are concentrated, like in 3b and 3e, or if they are split, like 3c and 3f, because there is no significant distance between 3b and 3c and between 3e and 3f (p=0.812).

Since the results of the pilot study were satisfactory and showed to be trustful to capture different urban configuration characteristics, next section presents an attempt to establish a method to use the proposed indicator with empirical data.
Figure 2 - Pilot study. Different examples of urban configurations and their respective results for the urban sprawl indicator. It is important to highlight that higher values represent the most sprawled examples.
5. CASE STUDY

The study area was the municipality of Torres, in the south of Brazil. It was chosen because of the availability of data. Since 96% of the population is urban, the rural part was excluded from this study. Torres presents one main centre and a few sub-centres. Most of them are near the most important roads, which have attracted new urban settlements since they were reconstructed.

The first step was to construct the urban graph that describes the urban system of Torres. The nodes correspond to the street junctions, however, we assume that they describe small portions of the city containing a sample of urban built forms, which can have attributes about its number of households, its number of workplaces, or both. The lines describe the street network that connects the urban built forms.

Nodes were loaded with attributes of households and workplaces, which can also be read as origin and destination points, respectively. The number of households was obtained from Census 2010. Since we did not have the exact location of workplaces in Torres, we used the commercial places obtained from a mapping done by the city hall. Commercial places were used as a proxy for the number of workplaces, although it is surely a simplification of all possible workplaces in the city. Not all the nodes were loaded with workplaces, but all of them have households. Figure 3 shows the overall distribution of activities loaded in the graph.

Since historical data series from Torres were not available, we adopted some hypothetical scenarios for households and workplaces distribution. Therefore, three different spatial patterns of workplaces distribution were used, as well as two different spatial patterns of household distribution.

Figure 4 presents the scenarios used for commerce distribution. Scenario 1 describes empirical data, which resembles the real distribution pattern of commerce facilities. Scenarios 2 and 3 are hypothetical and describe a monocentric pattern and a more dispersed spatial distribution pattern of facilities, respectively.
Figure 4 - Spatial distribution pattern of workplaces.

Figure 5 shows the scenarios used for housing distribution. Scenario A describes empirical data, while Scenario B describes a simulation of a more dispersed pattern, in which denser sub-centres were settled far from downtown.

Figure 5 - Spatial distribution pattern of households.
Those patterns were combined into six different scenarios of activities distribution and Table 1 shows the results for the urban sprawl indicator ($I_{sprawl}$).

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Distribution of households</th>
<th>Distribution of workplaces</th>
<th>$I_{sprawl}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Scenario A</td>
<td>Scenario 1</td>
<td>3.869</td>
</tr>
<tr>
<td>A2</td>
<td>Scenario A</td>
<td>Scenario 2</td>
<td>3.181</td>
</tr>
<tr>
<td>A3</td>
<td>Scenario A</td>
<td>Scenario 3</td>
<td>5.331</td>
</tr>
<tr>
<td>B1</td>
<td>Scenario B</td>
<td>Scenario 1</td>
<td>6.144</td>
</tr>
<tr>
<td>B2</td>
<td>Scenario B</td>
<td>Scenario 2</td>
<td>5.850</td>
</tr>
<tr>
<td>B3</td>
<td>Scenario B</td>
<td>Scenario 3</td>
<td>6.810</td>
</tr>
</tbody>
</table>

Table 1 - Final ranking for urban sprawl indicator.

Before discussing the results it is important to highlight that three levels of analysis can be conducted with this model. The first one is calculating accessibility of each node, without any weighting system. The second one is calculating the accessibility of each residence place to every workplace. The result can be read as a local indicator that shows how far each point is from workplaces. This way, only nodes with destination activities – workplaces – are weighted. The third one is the urban sprawl indicator, an aggregated indicator for the whole urban system. Here, origin and destination points are weighted. Therefore, the indicator shows the spatial mismatch between residences and jobs.

The variables that interfere in the result – distribution of household and workplaces – are independent. The statistical analysis (Factorial ANOVA) reveals that there is a significant difference between the results. It also showed that both aspects (distribution of households and workplaces) are independent. The post-hoc test shows that the most dispersed pattern of workplaces (Scenario 3) tends to increase distances, regardless the housing distribution pattern of households. The same occurs with households.

The results also showed that the more concentrated the workplaces are in highly accessible places, the less sprawled the system is. This finding should be more deeply investigated since it seems to reveal that decentralising jobs may not be a powerful urban policy.

6. FINAL CONSIDERATIONS

Previous studies about urban sprawl measurement have explored mainly indicators based on density and general urban form. Nevertheless, none of the measures developed up to now has focused on accessibility and intra-urban details. Aiming to fill this gap, this study presented an alternative accessibility-based indicator. The main advantage over the current methodologies proposed in sprawl studies is its stronger relationship with sprawl impacts. As already claimed, density and urban form’s measures have limited power to direct urban policies. We need to improve methods for intra-urban level analysis to tackle urban performance issues.

Besides verifying accessibility to employment opportunities and spatial mismatch between urban activities, this study demonstrated that the proposed indicator could also capture how far activities are from the most accessible places – considering here accessibility from each place with all other ones.

Empirical research should be extended to reveal the capability of the indicator, based on weighted accessibility measures as a decision-support tool. The indicator could be compared...
with real traffic, pollution and fuel consumption data to produce real urban performance indicators.

Further work could also join the accessibility-based indicator with other types of sprawl measurement indicators to improve a multidimensional approach. Outside the sprawl measurement context, the methodology could also be applied to specific origin and destination input, such as poor household location, employment opportunities, and more.
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PLACES OF WORSHIP
Space and religion in Lisbon suburban configurations

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ABSTRACT
The emergence of new religious movements is a global phenomenon. Although becoming subject of inquiry by recent academic works concerned with new spiritual content and practices, the places of worship persist an overlooked subject. The aim of this research is to understand the implications of spatiality in the constitution of the new places of worship within Lisbon suburbs after the 1970’s. It analyses the relationship between place centralities and new spatial cultures and urbanities in suburban landscapes. It also analyses change and persistence of traditional pattern of sacred spaces. To pursue these aims space syntax methodology was used in order to analyse street networks configuration to understand location of places of worship. The main technic was segment analysis. The syntactic measures were calculated to understand the relationship between global and local structures and read the city as a whole (urban and suburban). Using GIS software, places of worship were mapped within Lisbon region according to different religions. The patterns of distribution are then compared with the syntactic measures. The results have confirmed the hypothesis of space dematerialization and placelessness which characterizes the new religious movements. The pattern of distribution of places of worship (factories, warehouses, shops, cinemas, etc.) in Lisbon region follow places of good accessibility (global and local). The value of space remains not in its symbology but in its accessibility and functionality.

KEYWORDS
Houses of worship, religious movements, spatial patterns, spatial cultures

1. INTRODUCTION
The emergence of new religious movements is a global phenomenon. Although becoming subject of inquiry by recent academic works concerned with new spiritual content and practices, the places of worship persist an overlooked subject.

Religion leaves an imprint on landscape, through culture and lifestyle. Many rituals leave their mark on the physical appearance of an area. Traditional religious structures - such as places of worship, and other sacred sites - dominate many landscapes (Park, 2004:2). Seeking for good
accessibility, large infrastructures and dense populated areas, new religious movements, seem not to follow this principle. As we can see in the following propaganda by Igreja Evangélica Acção Bíblica, believers are well aware of this non-spatial idea of religion: “The church is not this space, these walls, this furniture, these equipment, this decoration. The church is the people who are already here and those who will be reached by God with our collaboration”.

According to Yi Fu Tuan “the religious person is one who seeks coherence and meaning in his world, and a religious culture is one that has a clearly structured world view (1976, p.271-2). Religious observance - church attendance, and so on - affect the time management, spatial movements and behaviour of believers. However, the territorial imprint of these new religious movements, do not create spatial cultures that promote local identity and community. What is the place of religion today? How much does organized religion matter in terms of its physical environment? What is the role of religion in defining spatial cultures? What is the persistence of the traditional pattern of sacred space?

In this paper we will look at the distribution and dynamics of religion in AML, consider what factors might account for the observed patterns, and look in detail at the processes of change. We are not concerned so much with religion per se, but with the many different ways in which religion is expressed in space. It sees religion as a human activity, and explores its social and spatial patterns.

This study is part of an ongoing research in CRIA – Centre for Research in Anthropology, at ISCTE IUL, which analyse the contemporary landscape of religious in AML after the 1970’s. Such region includes most religious and ethnic groups found through the world and is part of the international debate on urban informality of European southern countries - related to realms of the planning, construction and governance of the built environment. In this paper we explore the distribution of places of worship of Igreja Universal do Reino de Deus (IURD), a recent religious movement in expansion and compared it with the traditional religious Catholic Church.

In this paper we put particular emphasis on the study of street networks configuration as a major factor for placement of places of worship within AML. It analyses the relationship with the place centralities and how they help to form new spatial cultures and urbanities in suburban landscapes. It also analyses change and persistence of traditional pattern of sacred spaces.

2. BACKGROUND

Mapping space and religion in the context of contemporary metropolis is not an usual thematic across disciplinary research despite some relevant studies have been emerged recently in different fields.

The human geographer Yi-Fu Tuan, in is book “Religion: From Place to Placelessness” (2009) poses the question of what does it mean to be religious in the modern world and argues that religion experience moves toward universalism and placelessness.

Zelinsky and Matthews in the book “The Place of Religion in Chicago” (2011) provide a detailed, systematic geographical study of the religious landscape within a metropolitan area - Chicago. They have scoured the city to document and investigate the locations and traits of the various houses of worship (roughly 4,900) classifying them along various lines: denominational affiliation, size - prominence, architectural style, conditional of building, racial-ethnic composition date of erection, and character of the immediate environments. The authors aspire to fully and accurately describe the current material manifestations of organized religion within Chicago, the physical and locational attributes of houses of worship and there temporal and spatial arrangement.

According to Bret Carrol (2015) spatial analysis as moved to a central position in American religious landscape. Religious practice involved fundamental spatial distinctions between sacred and profane, inside and outside, centre and periphery, and up and down that provided believers with a sense of social, geographic, and cosmic orientation. Attention to the spatial
dimensions of religious practice generated fruitful research and new concepts of space on and new studies of churches and other built environments.

In the context of space syntax literature, Kershen and Vaughan (2013) explore the relationship between patterns of immigrant settlements and religious practices in the east end of London, over the last 350 years. They found that places of worship provided a spatial locus for communal solidarity not just for religion but also for the emergence of spatial cultures. Although the analysis of urban space and religious practices has not deserved special attention in space syntax literature the theory and method holds a special position in the context of the spatial humanities - a new interdisciplinary field resulting from the recent interest in space, also known by “spatial turn” (Bodenhamer et al, 2010). With a set of analytical methodologies for representing and studying the morphology of human-made spatial systems though quantitative and well defined analytical procedures it can help to understand the importance of religion dimension of urban life.

In Portugal such studies are almost inexistent despite the emergence of new religious movement within the metropolitan areas. Particularly interesting is the case of IURD, a religious movement which was born in Brazil in the 1970’s. The movement is characterized by an expressive increase of its faithful in this country. According to the IBGE Census, the number of IURD believers increased from 269 thousand in 1991 to 2.1 million in the year 2000 (Lima, 2007). In Portugal there is no specific data about the number of practitioners. However, by searching the term IURD in Google Trends - a real-time online search data to help you gauge consumer search behaviours over time, one can understand the importance of this religion in Portugal and particularly within metropolitan areas. Setubal, Lisbon and Porto are the regions which concentrate the main interest (Figure 1 - bottom).

Particularly interesting is also the pattern of distribution within the world. According to the most popular online search terms in the past 5 years, Portugal ranks 4th in the world regions interested in this religion. The first three are, Mozambique, Angola and Brazil (Figure 1 – above). Such aspect confirms the importance of Portuguese language in the dissemination of this religious movement around the world (Rodrigues and Silva, 2014).
3. ONGOING WORK AND OUTLOOK

Mapping has become one of the key tools by which arts and humanities researchers have collaborated and innovated, and by which they have interacted with the social sciences. Mapping has also become increasingly informative and rewarding methodologically. “This renewal of interest stems in large measure from the ubiquity of Geographic Information System (GIS) in contemporary society” (Bodenhamer et al. 2010).

Following this approach and after identified the two main religious movements in the AML, IURD and Catholic places, we used GIS software to analyse distribution patterns and dynamics. A total of 306 places of worship (50 IURD places and 256 Catholic churches) were mapped within the metropolitan area. The data was collected online from IURD (www.universal.org), Patriarcado de Lisboa (www.patriarcado-lisboa.pt) and Diocese de Setúbal (www.diocese-setubal.pt) (Figure 2).

![Figure 2 - Places of worship over a map of transportation (OSM) showing railway and train stations across AML (Lisbon Metropolitan Area)](image)

In order to compared the spatial patterns of distribution of the new religious movements (IURD) with the accessibility patterns we elaborate a space syntax analysis of AML.

Space syntax (Hillier and Hanson, 1984; Hillier, 1996) is a way of researching cities to understand how social and economic process shape space over time. Through its set of methods and tools for analysing patterns of space, certain spatial structures are unrevealed and related to the way people use space.

Applying these set of methods and techniques and using DepthmapX, Space Syntax Toolkit and Qgis free software, the spatial structure of de AML was modelled as a network of street segments based on the axial map developed by Teresa Heitor and João Pinelo (2005).
the sort of variables that can be calculated we analyse in detail the measures of ‘integration’ (NAIN) and ‘choice’ (NACH). Integration measures the distance from each spatial element to all others in a system and Choice measures the potential movement that passes through each spatial element on shortest or simplest trips between all pairs of spatial elements in the system (both up to a certain radius and given a definition of distance), (Hillier et al, 2012:155-156). Other definitions for integration and choice are that they represent, respectively, the to-movement and the through-movement potentials of a space. One of the great advantages of space syntax is that it analysis space at the micro and macro scale of the city at once. Thus, it will be possible to make comparisons across radii where a crucial factor is that different radii will define systems of different sizes where different patterns and scales of to-movement and through-movement are found (Figure 3).

4. PRELIMINARY RESULTS

The results of space syntax analysis were then compared with the patterns of distribution of places of worship. NACH 5000 m is the radius which best fit the location of IURD places (Figure 3). Global and local accessibilities seem to be important simultaneously. The spatial pattern of IURD places seems to capture with certain accuracy the main flows of contemporary development of Lisbon suburban axis: Amadora-Sintra; Odivelas-Loures-Malveira; Sacavém-Vila Franca Xira; Arco Ribeirinho Sul and Almada-Quinta do Conde-Setúbal, which correspond to the main populated areas. Occupying pre-existent infrastructures (factories, warehouses, shops, cinemas, etc.) reveals also the importance of transportation and the location of railway stations across AML (Figure 2).

The aim is to investigate further correlations between the collected data of places of worship and space syntax parameters. The treatment of statistical data and the use of ethnographic methods will help to understand the existing communities and spatial cultures. Future steps
will include also the analysis of visual prominence, date of construction, denomination, ethnic affiliation and architectural style(s) of the houses of worship.

We hope this research forms a contribution to our understanding of an overlooked element of the Portuguese urban scene: the religious landscape of the contemporary metropolitan areas. It seeks to contribute to the study of religion in Portugal - such an in-depth examination of a suburban area religious geography is original and a welcome addition to the space syntax literature.

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#189
REASONING WITH SPATIAL LOGICS
A prototype iconographic tool for deliberation in urban domains

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ABSTRACT
In this paper we report on some recent, exploratory research into development of a graphic tool for reasoning about urban community formations, as part of a wider UCL project ‘Visualizing Community Inequalities’, (supported by the Leverhulme Trust). This paper focuses on one section of the research relating to the challenge of integrating diverse and complex data derived from urban community settings. To address this challenge, we have drawn on insights from social and spatial analytical literature, including notions of class categorizations and spatial patterning and ordering. We sought to test how working with a set of visual, intuitive and interactive tools may help urban practitioners to reason about community formations, and to construct iconographic ‘concept graphs’ to represent their knowledge. To this end we led a participatory workshop, in which participants engaged with research data and explored some ways in which concept graphs might incorporate conceptual and spatial categories to build urban domain knowledge representations (KR). We do not offer firm conclusions in this paper, but outline a broad theoretical background to our approach, some of the basic methods we explored and employed, and suggest further avenues for research in KR for urban practice.

KEYWORDS
Urban practice, design knowledge, spatial logics, knowledge representation, graphic tools

1. INTRODUCTION
Urban ‘design knowledge’ can been seen as combining frames of rational problem-solving and of reflective practice (Doorst and Dijkhuis, 1995). The notion of the ‘rational’ frame suggests that the designer forms an informational process within an objective reality and seeks optimal results from poorly structured problems. The notion of the ‘reflective’ frame suggests that the designer constructs the ‘problem situation’ through creative practice.

Design knowledge requires practitioners to think of urban spaces in terms of their spatial and conceptual associations or implications, or rather their ‘spatiality’ and ‘trans-spatiality’ (Hillier and Hanson, 1984: 40-42; Sailer and Penn, 2009). Practitioners categorize urban spaces by combining representations of artifacts through associations and implications (cf. Lefebvre, 1993: 294-297), within the limits of spatial and temporal logics (ibid: 195-196). From these experiences and logics they extend ‘image schemata’ to represent their spatial cognitive and historical knowledge (MacEachren, 2004, 185-190).
To support their design knowledge, urban practitioners also make use of visual and spatial metaphors such as circles, triangles, planes, globes and scales. However, these metaphors may serve to enframe practical thinking (cf. Ingold, 2000: 209-218), and serve to conceal knowledge from discourse (Hommels, 2010). As such, our challenge is to ‘unfold’ knowledge (cf Ingold, 2000: 189-208; 2011, 229-243), to represent the environment intelligibly (Hillier, 2007, p.67-68), and to avoid abstract schema (Lefebvre, 1991: 301-302).

2. REPRESENTING SPATIAL LOGICS

Spatial logics of urban configurations have been described in various urban domain contexts. For example, urban spaces have been shown to bear patterning based on metric and topological distancing (Hillier, 1999; Hillier et al, 2010; Hillier and Vaughan, 2007). In another field, the Region Connection Calculus (RCC8) extends from basic relations of connection, intersection and contact (Randall et al 1992), to describe part-component and connective relationships (Berta et al, 2016). Elsewhere, Lakoff (1987) has offered several image schemata that relate to spatial relationships within urban domains (see Figure 1).

![Figure 1 - A combination of spatial logic icons, derived variously from the RCC8 language and from Lakoff (1987)](image)

Working with concept graphs allows us to model semantically rich domains that can include sets of beliefs, desires and intentions among community participants in a consistent and traceable way (Sowa, 2008; Kavouras and Kokla, 2007). Concept graphs based on simple logical constructions of domain knowledge may provide intuitive and portable schema for KR. As such they would constitute a toolkit for testing ‘true’ or ‘false’ entities – including facts, goals, implicit or explicit rules, their attributes, conditions and relationships (Chein and Mugnier, 2009, p.22).

Concept graphs can represent entities and relationships using generalized or categorical concept nodes and relation nodes. Every concept has an abstracted type, which can be either specified or non-specified. Concept graphs can be used to configure and test assertions by ‘projecting’ or ‘simplifying’ sets of abstract concepts into specific instances (and vice versa). Conceptual graphs represent this schematization using arcs (or edges) that connect concepts to relations, for example:

```
[Concept_1]  ->  (relation)  ->  [Concept_2]
```
Concept and relation types are arranged hierarchically based on a generalization order; this means that one type can subsume another. Graphs can be projected in the sense that their nodes can be changed into specific sub-types or general super-types and then tested for logical composition. Projection also supports graph unification whereby sets of nodes between graphs are generalized (preserving their arguments and values), and then compared with similar graphs to identify their similarities (isomorphisms).

The linear form graph, below, demonstrates how a generalized graph projects into specialized graphs. This shows how agents interact with entities (and their themes), and also their position within the conceptual hierarchy: {*} demarcates the top super-type and *x the bottom sub-type (being the specific instance), while ?x can demarcate uncertainty:

**Generalization:**
\[
[\text{Identity}:\text{Name}{*}] \leftarrow (\text{Agnt}) \rightarrow [\text{Activity}] \rightarrow (\text{Thme})
\]
\[
\rightarrow [\text{Space}:\text{Characteristic}]
\]

**Projections:**
\[
[\text{Girl}:\text{Alice} \; *x] \leftarrow (\text{Agnt}) \rightarrow [\text{Sleep} \; *x] \rightarrow (\text{Thme}) \rightarrow
\]
\[
[\text{Hole}:\text{Deep}:\text{Curious} \; *x]
\]
\[
[\text{Animal}:\text{Rabbit} \; *x] \leftarrow (\text{Agnt}) \rightarrow [\text{Running} \; ?x] \rightarrow (\text{Thme})
\]
\[
\rightarrow [\text{Door}:\text{Small} \; *x]
\]

Using these and other logic tools, conceptual graphs allow high-level generalizations to be agreed among a community of domain practitioners, and specialized with more specific or concrete instances of those general categories. Conceptual graphs may be constructed through a top-down (general-to-specific) or bottom-up (specific-to-general) process. A ‘middle-out’ extension to this well-established graph process has been developed by Berta et al (2016) in the field of ‘urban ontologies’. To paraphrase their approach, the specifications of relational concepts (ontologies) are extrapolated through domain practices. The extrapolation process is limited selectively according to the **scale of representation**, the **historical significance** and the **‘relational functionality’** (in terms of logical composition) of the urban elements under analysis. The ontologies are shared as a compositional template, which includes spatial and functional classes, spatial data properties and their logical relationships from a given set of domain phenomena.

### 2.1 PROOF OF CONCEPT

To test the practicable viability of incorporating spatial logics into conceptual iconographic schema we conducted a prototyping workshop involving a group of planning and design urban practitioners. The participants were invited to engage with mapped data visualizations produced from an earlier community data gathering exercise, in which the community participants had ‘mapped’ significant features of their local environments (O’Brien et al, 2016). These maps where digitized with a GIS and the points data were manipulated to produce a range of visualizations, including the example in Figure 2.
Figure 2 - A visualization of urban community data from the 'VCI' project at UCL, representing the 'significance' of local features weighted by node size.

The practitioners were then presented with a set of graphic icons that represented the range of structures, scales and other features selected by the community participants. The practitioners were also presented with graphic representations of spatial logics (Figure 1) to describe ways in which these structures and scales might be arranged. The participants were invited to build a basic (roughly defined) concept graph to describe any discernable patterns pertaining to community formations within the mapped data. Figure 2 presents one example of the concept graphs produced by the practitioner participants.
The participant's concept graph shown in Figure 3 represents a possible journey from home (left) to a supermarket (right), which crosses busy roads carrying local (pedestrian/velomobile), city-wide (light/heavy automative), and regional (heavy automative/transit) traffic. The journey has a negative dimension involving a road junction (e.g. for hindering pedestrian access). The supermarket contains a café as a positive dimension (e.g. for social life), represented here using an RCC8 icon for ‘tangential proper part’ (TPP). From this illustration we may construct a concept graph:

**Generalization:**

\[
\text{Origin:Name} \leftarrow (\text{Agnts}) \rightarrow \text{Activity} \rightarrow (\text{Thme}) \rightarrow \\
\text{Urban entity:Type} \rightarrow \text{Movement:Scales} \rightarrow (\text{Thme}) \rightarrow \\
\text{Urban entity:Type} \rightarrow \text{Logic relation:RCC8} \rightarrow \\
\text{Destination:name}
\]

**Projections:**

\[
\text{Home-shop} \leftarrow (\text{Parent+child}) \rightarrow \text{Cross road} \rightarrow (\text{Neg}) \rightarrow \\
\text{Junction} \rightarrow \text{Traffic:Local+City+Regional} \rightarrow (\text{Pos}) \rightarrow \\
\text{Shop} \rightarrow \text{RCC8:TPP} \rightarrow \text{Café}
\]

Other participants in the workshop were able to use RCC8 icons to describe urban community relationships in terms of being ‘externally connected’, ‘disconnected’, ‘tangential proper part’ and ‘non-tangential proper part’ (NTPP). Interestingly, the latter instance of NTPP was used to refer to an activity taking place in a public park, which perhaps speaks to the production of a local social-space (a sporting activity) that is part of, but not physically integrated with, the public open space. In observing this and other examples of successful graph constructions, we feel confident in developing and refining this prototyped technique.

### 4. CONCLUSIONS

The proof-of-concept exercise described above demonstrated the viability of incorporating spatial logics schemata into a concept graph. The participants’ overall positive engagement with sets of graphic icons (representing urban spatial entities, movement scales and spatial relationships), evidenced an intuitive method for dealing with complex urban community data. However, we acknowledge that this has not yet produced a practicable tool for KR in urban domains. Towards this objective, we will next test how the graphic icons can be organized into an informational ‘flow’ to support domain diagnostics and decision-making.

One possibility in this area is to arrange these icons within an argumentation schema. Arguments often derive from expert opinion, from metaphors, analogies or precedents, or from practical reasoning (and, negatively, from ignorance, misinformation or prejudice). Challenges to an argument can be made by posing critical questions that serve to interrogate their inherent assumptions, premises and logical formulations (Walton, 2013, p.28). We anticipate that the field of argumentation may provide a range of informal logic schema for enriching and testing iconographic conceptual representations of domain knowledge. Testing this hypothesis will form our next phase of work.
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THE CENTER IN MONTES CLAROS (BRAZIL)

A diachronic reading based on configurational features

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ABSTRACT

The aim of this paper is to investigate how the urban fabric configuration influences the distribution of centralities in an urban system, in terms of accessibility. The case study is the city of Montes Claros, located in the North of Minas Gerais State in Brazil. The site, founded in the beginning of the 20th century, has presently almost 400.000 inhabitants and is one of the most important settlements in the region. Based on the strategies of Theory of the Social Logic of Space, the study analyses land use in a diachronic perspective and compares the data with modeled cartography associated with axial and segment map variables. The urban periods explored are: (1) early twentieth century, (2) 1950, (3) 1970; (4) 1980; (5) 1990; (6) 2005 and (7) 2015. Findings have suggested a correlation between the configurational features highlighted by Space Syntax tools and the changes in centralities through the periods investigated. It seems that configuration plays an important role in the urban dynamic of Montes Claros, allowing the use of the approach in an urban planning perspective.

KEYWORDS

Urban configuration, centralities, Montes Claros

1. INTRODUCTION

Urban configuration is believed to be related to the distribution of centralities in the urban space. The paper explores this relation based on the case study of Montes Claros (a city in the state of Minas Gerais, Brazil) by comparing potential and real urban centralities and subcentralities from the perspective of Space Syntax.

Space syntax explores the relation between the built environment and society. The built environment is seen as a system of possibilities for encounters, whose arrangement affects social relations and, in turn, is also affected by them. The tools developed by Space Syntax enable the identification of which are the streets (axes) or street segments with greater potential for concentrating movement, a crucial feature of urban centralities (Barros and Medeiros, 2014).

The paper is organized in four sections as follows: (2) the context of Montes Claros; (2) the methods used; (3) presentation of results; and (4) conclusions.
2. URBAN DEVELOPMENT IN MONTES CLAROS

Montes Claros has approximately 398,000 inhabitants, 95% of which live in the urban area (IBGE, 2016). Founded in the early twentieth century, it is today the most populous city in the mesoregion north of its state. As such, it has embraced the role of regional center, serving as a beacon to other municipalities that have less diversity of functions (Pereira, 2007).

Gomes (2007) explains the development of the city on a time-space axis with distinct periods: “(1) rural city – (2) mercantile city – (3) incomplete industrial city- (4) service city.”

The first period is the formation of the urban settlement, with an economy based in agriculture and livestock. In the late nineteenth century, the city became a regional trading post, hence the name ‘mercantile city’ used to describe this period. Industrialization came alongside electric power lines in 1965, with significant resources from the federal government for the economic development of the region, as it is located in a dry zone of the country (Leite, 2006).

The transition to a ‘service hub’ came in the mid-seventies, followed by an inevitable urban expansion (Leite, 2006 and Gomes, 2007). Until then, it could be said the city had only one core. Most of the commerce, services and industries were located in the same neighborhoods until the 70s, which generated an intense flow of people and goods. This led to problems with circulation, since the area was characterized by narrow streets (Gomes, 2007).

From the 1980s onwards, the city witnesses the onset of new commercial subcentralities. This phenomenon was a byproduct of the increased population density in areas further away from the city center. The horizontal city sprawl was facilitated by the local flat topography (Leite, 2011).

3. DATASETS AND METHODS

The study of potential centralities was based on the methods and tools of the Space Syntax. According to Medeiros (2006), out of the many ways urban systems could be represented in order to carry out a configurational analysis, “linear [representation] is useful to investigate movement and its related aspects. It is the best suited for large systems, such as the city”. Axial and segment maps, the linear representation of the street system, were adopted for the present analysis.

Using the software AutoCad®, some representative maps of the process of urban expansion were drafted: (1) early twentieth century, (2) 1950, (3) 1970, (4) 1980, (5) 1990 and the years (6) 2005 and (7) 2015. The axial maps were produced based on cartography in format DWG, available in the website of the City Hall, for the year 2005. The maps for year of 2015 were complemented with data from Google Earth. The remaining maps (1950, 1970 and 1990) were drafted by subtracting axes from the most recent map, based on information provided by the works of Leite (2006) and Gomes (2007).

Later, the maps were processed in the DepthMap software for axial and segment analysis, with focus on the following variables: Global and Local Integration, Choice and relation between Choice and Global Integration.

The system’s Global Integration values (Rn HH), measured both for the axial map and segment map, result from the size of the city and its topographical context. In addition, the results highlight important features of the urban layout, such aspects of dispersion and compactness, orthogonal versus organic layout (Medeiros, 2006). The integration values achieved by each line/axis are displayed graphically in a color-coded map, with red hues being the most accessible areas.

Barros and Medeiros (2014) emphasize the importance of check “the layout of the set of most integrated axes”, which form the “Integration Core”. The authors explain that these most accessible areas tend to concentrate more diversity of uses, such as commerce and services, being thus considered potential urban centralities.

The variable Choice allows us to evaluate how an axis or segment may be crossed, considering topologically shorter routes, from all places to all other places, both in the system as a whole and within a predetermined radius (Medeiros, 2006).

Considering that Integration measures represent the potential of segments to become destinations and the measures of Choice represent their potential as routes, the relation between these two variables expresses a street's potential to be destination and route simultaneously. This relation were measured based on the mathematical formula used by Hillier (2008), for three different radius: 400m radius (pedestrian perspective), 1200m radius (cyclist perspective) and global (vehicle perspective).

Moreover, based on the studies of Gomes (2007) and Leite (2006), a map with the centrality and subcentralities of Montes Claros was produced. The areas with predominantly commercial use were then superimposed over the map, based on Leite (2011). As the result, we obtained a map with the real centralities of Montes Claros, considered an actual rendering of the city's current situation.

4. RESULTS

The evaluation of potential centralities was based on the analysis of axial and segment maps. First, an interpretation of the variable Global Integration (Rn HH) was carried out based on a diachronic perspective. In the maps for Global Integration (Rn HH) in each period (Figure 1), it is possible to see that the Integration Core of Montes Claros has increased in size along with the urban expansion. The polygon determined by the set of axes in red hues has historically always encompassed the initial core (the city from the early twentieth century) and expanded outwards, along the present most important roads, which are BR251, BR135 e BR365.
Visually comparing the Global Integration map with the location of the city center and subcentralities (Figure 2), we can see that the city center is encompassed within the Integration Core. In addition, the streets with greater integration values are connected to the subcentralities. The lowest global integration value is 0.39, and the maximum 1.38, being the system's average 0.86. Isolating the axes present in these centralities (or that cross them in one point or another), the average is 0.97. That means these centralities are composed of streets which are better integrated than the others in the system.
The interpretations relating the potential for segments to be destination and route simultaneously were developed with the segment map. These maps were then superimposed with the areas of intraurban centralities (figure 03).

In terms of global analysis, there is a visible correlation between the potential and the real situation, since the segments with greater values are comprised in the polygons of the urban centralities. For the radius 400 m and 1200 m, the strength of several potential subcentralities is made very clear. Some of these areas function as a real centrality, whereas other are predominantly residential (circled in the map). The potential of these neighborhoods to attract movement can be crucial to urban planning and government and private resources allocation.
5. CONCLUSIONS

During its urban history, Montes Claros has expanded its urban area immensely. The active center has not shifted, corresponding to the site where the city first originated. The interpretation of configurational measures of Space Syntax corroborated that the Integration Core encompasses the original urban core, however it spread towards East and West, which are the main routes out of the city, connecting with federal roads.

The current situation (2015) has allowed us to verify what are the axes or neighborhoods with greater movement potential, using axial and segment maps, thus uncovering the potential for centralities which underlie the city’s configuration. These maps were qualitatively compared to the present situation of centralities (based on Leite, 2006; Gomes, 2007 and Leite, 2011) and there was a significant correspondence between potential (from Space Syntax) and the land use reality. Furthermore, some predominantly residential neighborhoods were identified as potential new urban subcentralities.

Figure 03 - Relation between Global Integration (Rn HH) and Choice (segment map): Rn, R=400m and R=1200m, respectively. Source: Ramos (2016).
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#191
DEFINING DOMESTIC ACCESS PATTERNS:
The link between the house and street network in Newcastle upon Tyne

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ABSTRACT
The spatial interface is situated in an interesting place between a street, part of a macro-scale network, and a building, a single urban cell with its own internal structure. In this paper we investigate the relationship between residential buildings and the street, while searching for links between syntactic measures of the street network and micro-morphological properties of building entrances. Building on the syntactic concept of the spatial interface, we analyse the structure of the space between a building and a street segment in speculative developments in Gosforth, a district of Newcastle upon Tyne. We argue that understanding the logic behind the building-street interfaces provides additional data in order to better explain and describe both street and building entities. The study of through-movement potential in the district of Gosforth and micro-morphological properties of the interfaces in speculative estates revealed common access patterns amongst all estates. We observe a change in the treatment of the interfaces over time and in relation to the position in the street network hierarchy. We conclude that micro-morphological information introduces another dimension into macro-scale analysis. In order to make both micro- and macro- analysis as complete as possible we must not treat them as isolated entities but as a part of the system.

KEYWORDS
Urban interface, access pattern, micro-morphology, space syntax

1. BETWEEN BUILDINGS AND STREET: INTERFACE IN SPACE SYNTAX
Each residential building is, in some way, connected to a street network by being situated on either a residential street, a walkway, or a courtyard. The space, which is an outcome of the requirement to provide a building-street access and the relationship between those two different entities, can be defined as the interface.

The concept of the interface in space syntax theory was introduced in The Social Logic of Space as public space situated between buildings, primary cells in the urban system, and the space outside of the system (Hillier and Hanson, 1984). Interface, which creates and maintains the relationship between the inhabitant-orientated domain of the building and the outside world of strangers, is an amalgamation of open spaces, streets and secondary in-between spaces (ibid, 1984). Through the interface, each settlement constructs its unique way of handling the
relationship between the inhabitants and strangers within the system. Although the importance of the urban interface was emphasised in The Social Logic of Space, the concept was not developed further and space syntax literature has focused either on macro-scale studies of street networks and urban forms, or on analysis of building interior configurations. Outside the space syntax community, interface is considered as an important element in maintaining liveability in the street and generating probabilistic encounters while exercising individual control over the private-public boundary (Whitehand et al., 1999; Brown et al., 1998; Skjaeveland and Garling, 1997; Lawrence, 1987; Gehl, 1986; Jacobs, 1961). Recently, the concept of interface was re-introduced to space syntax research in the form of micro-scale spatial analysis, described as the ‘missing link’ in the macro-orientated space syntax community (Palaiologou et al., 2016; Koch, 2013; van Nes and López, 2007).

Interface cannot be viewed on its own as it is an outcome of the amalgamation between the house and the street and is strongly affected by their characteristics. Therefore, we argue that the syntactic properties of the streets and their position within a bigger network influences the structure of the interface. We treat the interface as a set of boundaries and thresholds which guide inhabitants and strangers through the transition between the public street and private house. In the on-site observational study in Gosforth, a district of Newcastle upon Tyne, we gathered data on access patterns between street segments and the adjacent buildings, documenting whether there is an access point, the type of access point and its position in relation to the building. While our preliminary analysis of access patterns showed that in most cases there are at least two access points, this work chooses to focus only on main entrances. Furthermore, to compare the data gathered on the access patterns of each building to syntactic properties of a street segment we grouped individual building interfaces adjacent to the same side of a street segment into a cluster, referred to as a block interface. The properties of the block interfaces were juxtaposed with through movement potential, a measure of the likelihood of a street segment being used (Hillier and Hanson, 1984).

2. INTERFACE AND ACCESS PATTERNS IN NEWCASTLE UPON TYNE

The street pattern of Gosforth developed as connections were made between the urban nucleus, Bulman Village and the mines, collieries, churches and private villas in the area. The urban form was developed through the building of speculative developments on empty rural areas. Five main time periods representing phases of the urban development of Gosforth can be distinguished dating back to the first speculative estates in 1890s, which followed a rapid industrialization and a booming mining industry. With the first estates sprouting up around the Coxlodge and Gosforth Collieries, the area grew steadily without major adjustments to the existing urban tissue. As the growth of Gosforth’s urban form was influenced largely by the development of new speculative estates built in different morphological periods (Whitehand, 2001), we treat each estate as a unique entity and the surrounding district of Gosforth as the ‘outside world’.

![Example street network of an estate from the 1890s illustrating choice value](image1)

![Example street network of an estate from the 1890s illustrating block interface types](image2)

Figure 1 - Mapping comparison between through-movement potential of street networks and types of block interfaces within a 1890s estate. Diagram a) illustrates syntactic differences between street segments and shows which street is more likely to be used. Diagram b) represents four interface types observed in 1890s estates.
Speculative estates are essential elements in the urban development of Gosforth and Newcastle upon Tyne. Therefore, to preserve the syntactic properties of the street network within each estate we conducted angular segment analysis within radius $R = 600m$ from every house in the estate. The radius was chosen based on the average dimensions of each estate. Within each speculative development, we distinguished between two types of streets, either busy or quiet. To distinguish between those two types, we chose to use through movement potential value (choice), which describes the likelihood of a street segment being used based on the structure of the system (Hillier and Hanson, 1984). Because we analysed each estate in separation, in order to compare the block interfaces across all the estates we assigned a relative measure – relative choice value. We define relative choice value as a ratio of the choice value of an analysed street segment to the highest choice value of the street segment in each estate. The relative choice value ranges between 0 and 100, with 100 being the highest relative choice value street segment within the estate. We then compare the relative choice values to the observed block interface morphologies. The main properties we identified were: the type of exterior wall adjacent to the street segment (e.g. front, side or back) which expresses the possibility of access, and whether there is an access point. After analysing 20 estates and 683 street segments we documented up to four types of block interfaces: front exterior wall with an access point, side exterior wall with access point, side exterior wall with no access point and back exterior wall with no access point. To simplify the description, we refer to those block interface types as front access, side access, side no access and back no access respectively.

Figure 2 - Illustrating the change in the distribution of four interface types over time. Diagrams a) and c) show the frequency of front and side exterior walls with access points, while diagrams b) and d) represent back and side exterior walls with no access.
The earliest examples of terraced housing estates date back to the 1890s and exhibit the highest variety of block interface types – four (see Figure 1). The street segments with adjacent block interfaces consisting of either front access or side access have high choice value. While street segments with interfaces consisting of either side no access or back no access are potentially more secluded streets with low choice value (in this case back alleys). The access patterns of terraced housing in the 1910s change completely in comparison to the previous period. The number of block interface types is lowered to three: front access, side no access and back no access. The high choice value street segment is adjacent to the block interface with the side no access type. Moreover, the low choice value street segment is adjacent to the block interface with either the front access or back no access types. With the introduction of a new housing typology, semi-detached, in the 1940s the number of block interface types was reduced to two. The block interfaces of type front access are adjacent to low choice street segments, while the side no access interfaces occupy the high choice value segments. In the 1970s the street segments were adjacent only to the interfaces consisting of one type: front access. Any other types of block interface were absent. The detached tree-like estates in the 2000s returned to the variety of block interfaces types previously seen in the 1890s with a different distribution of types. The street segments with front access interfaces were more secluded and private with low choice values, while the back no access and side no access interfaces were exposed to high choice value segments separated by a wall running the entire length of the street (see Figure 2).

3. CONCLUSIONS

Due to a gradual development of the urban form in Gosforth, we are able to observe a variety of spatial interface types across a number of different housing typologies. We identified similar interface patterns across the housing typologies and distinguished four main types of block interface based on whether there is an access point and its position in relation to the building. There is a clear change in the structure of the interface in relation to the: time period, housing typology and syntactic properties of the street. With early terraced houses the main access points were situated on front and side exterior walls adjacent to the high choice value street segments, while late terraced housing reversed this pattern locating their main access on the low-choice value streets. Despite the introduction of a new housing type, semi-detached, the access followed previously established patterns. We observed a chronologically diminishing number of access patterns with the earlier four types of the 1890s being reduced to one type in the 1970s. Additionally, the main access points changed from facing the potentially busier high choice value streets to more privacy-orientated streets with low choice values. This could be interpreted as a reflection of the socio-cultural trends towards a more segregated and privacy-orientated society. The addition of the micro-morphological level to the macro-scale syntactic analysis helps to explain more complex intricacies of the urban form and prevents the culture-specific characteristics of both buildings and streets from being overlooked. Moreover, including the macro-scale measures into the micro-scale analysis may provide insight that otherwise would be lost.
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THE LUISENPLATZ STUDY:
The relationship between Visual fields and perceived stress in a public transport hub

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ABSTRACT
This paper investigates the relationship between visual fields and subjective ratings of perceived stress in an open public space (OPS) and transportation hub. The aim of this paper is to investigate how these characteristics influence pedestrians’ subjectively perceived stress. To achieve this goal, the sample is described with a visibility graph analysis and isovist properties. The constructed data is then paired with participants’ ratings of perceived stress.

This article uses data from surveys conducted in Darmstadt, a town of 120,00 in Germany, in summer 2015. Subject is the Luisenplatz, the city’s main public square. It houses various amenities, services and residency, and is as well a central transportation hub, where the majority of the tram and bus lines meet. Previous research suggested that the Luisenplatz in its current state is perceived as one of the most stressful OPS in Darmstadt.

Correlation between visual fields and statements about perceived stress show that users are more likely to feel stressed when in areas with high visibility, while visual complexity may contribute to less stressful scenarios. The method presented in this article is been shown effective to analyse how variables of the built environment may contribute to perceived stress in public transport hubs. It will be useful to further interdisciplinary research that sets out to better understand the role of the built environment as integral contributors to stress in urban mobility.

KEYWORDS
Isovist, public transport hub, perceived stress, spatial perception, configuration

1. INTRODUCTION
In spite of the many positive aspects of life in cities, several others may harm health and wellbeing of its residents, the so-called “environmental stressors” (Evans and Cohen, 1987). Especially in the city, some of these stressors – such as noise, pollution, crowds and high traffic – are often intense and take a notable toll on the people who work and live in them.

Emerging research spurs the discussion how visual field characteristics relate to complex emotions in the built environment (Knöll, 2016, Knöll et al., 2014, Kuliga et al., 2013, Bielik et al., 2015). In this article, researchers investigate how visual fields – commonly used in space syntax research to describe places – relate to users perception of an OPS and major public transport hub as being stressful, and how they interact with further environmental stressors such as noise and lack of vegetation. The authors focus on Isovist properties such as total area, jaggedness,
number of vertices and symmetry as indicators for the perception of spaciousness, openness, complexity and order of open spaces.

The article uses data from surveys and observations conducted in Darmstadt, a town of 120,000 inhabitants in Germany, in summer 2015. Subject is the Luisenplatz, which was renovated in 1980 and has been since then praised for its value as a "framework to balance potentially conflicting functions – a large public transport terminal versus a recreational square for pedestrians" (Gehl and Gemzøe, 2008). Previous research assessing the spatial perception of its users, suggested that the square in its current state is perceived as one of the most stressful OPS in Darmstadt (Knöll et al., 2014). Currently the space is subject to various redevelopment plans as part of the town’s master plan 2030. Identifying the parameters that spike stress and compromise users’ behaviour and wellbeing, delivers relevant understanding for future planning.

This paper seeks to contribute a set of subjective spatial experience data (which has been gathered as part of a larger, extensive spatial perception and psychophysiological effects study) to the on-going discussion between the space syntax community and spatial, environmental researchers and planners.

2. BACKGROUND

2.1 STRESSFUL OPS

In an online survey among students in 2014, the Luisenplatz was rated as the most stressful place in the city (Knöll et al., 2014). From the study, loudness, heavy traffic and poor vegetation were identified as determinant environmental factors for "stressful" OPS. In a later study, Knöll and colleagues found relations between street network characteristics and the users’ ratings of stress and spatial qualities in OPS (Knöll et al., 2015). Building on these studies, Knöll et al. (2017) presented a set of environmental factors related to perceived stress in open public spaces including building coverage, street network and isovist characteristics and open space typologies (see table 1). Overall, the model achieves a predictive power for perceived

<table>
<thead>
<tr>
<th>Dependent Variable: Urban Stress Level (*)</th>
<th>Standardized Beta Coefficient (SBC)</th>
<th>Percent of the absolute sum of all SBC</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Building Density</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building Coverage Ratio</td>
<td>0.514**</td>
<td>17.17%</td>
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</tr>
<tr>
<td><strong>Street Network</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Ln Citywide Integration</td>
<td>0.210**</td>
<td>7.02%</td>
<td></td>
</tr>
<tr>
<td>Ln Local Integration</td>
<td>-0.394**</td>
<td>13.16%</td>
<td></td>
</tr>
<tr>
<td><strong>Isovist</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visibility</td>
<td>0.321**</td>
<td>10.73%</td>
<td></td>
</tr>
<tr>
<td>Ln Perimeter</td>
<td>0.417**</td>
<td>13.93%</td>
<td></td>
</tr>
<tr>
<td>Square Vertices Number</td>
<td>-0.369**</td>
<td>12.33%</td>
<td></td>
</tr>
<tr>
<td><strong>Open Space Typology</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Park (park=1)</td>
<td>-0.140*</td>
<td>4.68%</td>
<td></td>
</tr>
<tr>
<td>Heavy traffic streets</td>
<td>0.100</td>
<td>3.34%</td>
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</tr>
<tr>
<td>Courtyard</td>
<td>-0.223**</td>
<td>7.45%</td>
<td></td>
</tr>
<tr>
<td>Medium traffic street</td>
<td>-0.124*</td>
<td>4.14%</td>
<td></td>
</tr>
<tr>
<td>Pedestrian street</td>
<td>-0.181**</td>
<td>6.05%</td>
<td></td>
</tr>
</tbody>
</table>

Notes: a) Random-effects GLS regression ([corr(u_i, X) = 0 (assumed)])** and * indicate significance at the 1% and 5% level.

Table 1 - Taken from Knöll et. al (2017).
urban stress of $R^2 = 54.6\%$ from a combination of built environment factors commonly used in planning and research. The model seems robust for central European cities, since it covers a broad spectrum of open spaces, but it is also exploratory, as it needs validation for wider user groups and cities of different sizes, cultural and climatic backgrounds.

2.2 THE LUISENPLATZ

The OPS was selected for a more detailed analysis because of its importance to the everyday urban life and manifold surrounding land uses. In spite of being free of car-traffic, it is the central transfer point in the city, adding to a total of about 2200 buses and trains running daily through it.

The Luisenplatz recorded the highest frequency for bus lines as well as trams in comparison to the service stations within the 500 m range, positioning itself as a dense transport service station with the highest number of diverse pedestrians utilizing the service.

2.3 MEASURES

A key aspect for analysing the built environment seems to be users’ perception of an OPS’s amenity quality, which expresses how attractive a space in particular can be for its users; e.g. if it’s perceived as relaxing, enjoyable or maybe stressful, discomforting. In order to obtain spatially detailed data about the amenity quality of the Luisenplatz, participants were encouraged to use the context-sensitive mobile application MoMe, which allowed them to rate spatial qualities and stress perception through eight core aspects of environmental and behavioural properties using a ten-step scale. The application records quantitative and qualitative data by making use of the context-awareness of mobile devices, which consists of GPS tracks and waypoints with time-stamp (navigation), and photographs and ratings (perception) (Halblaub Miranda et al., 2015).

<table>
<thead>
<tr>
<th>English</th>
<th>German</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low extreme (1)</td>
<td>High extreme (10)</td>
</tr>
<tr>
<td>not stressfull</td>
<td>maximum stressfull</td>
</tr>
<tr>
<td>not relaxing</td>
<td>maximum relaxing</td>
</tr>
<tr>
<td>poor vegetation</td>
<td>much vegetation</td>
</tr>
<tr>
<td>poorly maintained</td>
<td>well maintained</td>
</tr>
<tr>
<td>low traffic</td>
<td>high traffic</td>
</tr>
<tr>
<td>quiet</td>
<td>loud</td>
</tr>
<tr>
<td>no seating available</td>
<td>seating available</td>
</tr>
<tr>
<td>unsafe</td>
<td>safe</td>
</tr>
</tbody>
</table>

Table 2 - Adjectives used by participants to rate perception of OPS on a 10-point interval. Original adjectives-scales and their translation to English.

The set of bipolar adjectives (table 2) was the basis for qualitative data on perception of public spaces and was first presented by Knöll et al. (2014). 2.4 Research Questions

The previous findings revealed many open questions, in particular with respect to visual fields and stress perception. How do the chosen environmental and spatial parameters influence the perception of the built environment and its users’ behaviour?

Hypothesis 1: Visibility correlates positively to perceived stress

The authors assume that high visibility, defined as the relative rate of the area that can be overseen from a given location in OPS, has a positive correlation to perceived stress.
Hypothesis 2: Vertices number is negatively related to perceived stress.

In this study, the authors propose that low and high rates of visual complexity mediate perceived stress, while medium rates of visual complexity are negatively related to stress ratings in sub areas that are loud and highly exposed to tram and bus traffic.

3. DATA SETS AND METHODS

A combination of Visibility Graph Analysis (VGA) and point isovist analysis was constructed and paired with participants’ ratings of perceived stress. Both VGA and isovist measures have been limited to a 250-meter radius from the square centre. Environmental properties such as loudness and exposure to traffic were controlled with structured observations. In a further step, linear correlation coefficients were calculated.

3.1 USERS’ RATINGS

The assessment was done on-site by a group of visiting international students (n=17). Participants were asked to walk freely within the OPS and mark distinctively stressful and relaxing areas, and rate environmental and behavioural properties using the smartphone application MoMe.

This paper presents the areas identified as stressful and their specific ratings along spatial quality and emotional perception.

![Profile of the Luisenplatz](image)

Table 3 - Profile of the Luisenplatz. Representation of the aggregated ratings of the stressful areas in the OPS.

3.2 VISIBILITY GRAPH ANALYSIS (VGA)

VGA has been used to calculate the visual integration of the space itself (Turner, 2001). The urban space has been reduced to a grid system of a 1-meter mesh in order to construct the visual relations and the OPS’s relation to its surroundings. This dense mesh allows sufficient representation of every urban element and narrow street in the vicinity, as presented by Cutini (2003).
THE LUISENPLATZ STUDY: The relationship between Visual fields and perceived stress in a public transport hub

3.3 ISOVISTS

The photographed motifs were clustered by themes and spatial proximity in areas of 10-metre radius, delivering vantage points, which are chosen according to how often the areas – and not phenomena such as crowding or litter – were rated as stressful.

4. RESULTS

The data shows that visibility has a positive relation to perceived stress. A weak relation has been found between visibility and the vertices density of isovists to ratings of safety. The data corroborates the findings in Knöll et al. (2017) regarding the ambiguity of visibility as the relative size of an area that one can oversee and the area from which one can be seen at a specific point. Here, high visibility was assumed as key factor for actual pedestrian safety (Stoker et al., 2015) . But data shows that areas with high visibility and higher motorized traffic are still perceived as stressful. This is so, even though the isovist properties are similar to an area with lower motorized traffic. This can be examined well in the Luisenplatz, since it is a symmetrical OPS, where the only unbalanced elements are the train tracks and transit areas for buses.

On the other hand, the complexity of the isovist shape has a strong relation to perceived stress: high number of vertices indicates a place that has lower rating as stressful (Hypothesis 2).
Visibility and perimeter—which describe the shape of the OPS—and vertices number—which indicate the complexity of the shape—are important characteristics to explain perceived stress. These findings have potential implications in the redevelopment including location and shape of street furniture, such as roofing and seating along the waiting areas near high-motorized traffic.

5. CONCLUSIONS

The current study has provided user ratings about the Luisenplatz in order to explore how OPS users describe complex emotional appraisal of OPS, the areas users identify as maximum stressful, and to what extent space syntax measures correspond to user statements.

This line of thought will have to be validated with bigger samples of OPS and in further cities of different size and cultural context.

A further aim is to deliver “high definition” measurement of psychophysiological effects on site to expand emerging theoretical frameworks to explain built environment factors on pedestrians’ wellbeing. While the focus was on spatial perception and stress perception, other behavioural data, such as participants’ heart rate, has to be the focus of further research.

ACKNOWLEDGEMENTS

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REFERENCES


THE INFLUENCE OF SOCIAL GATHERING OF COMMUNITY: 
Space syntax analysis on the public space in Beijing’s neighborhoods

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ABSTRACT
Community outdoor environment plays an important role in residents’ gathering, however, the spatial factor is also a leading reason. This paper analyses four case areas which represent two kinds of neighborhoods in Beijing: Hutong and Mega-courtyard which composed by multi-story social housing. The research is based on the detail fieldwork mapping of social gatherings in both weekday and weekend in summer and winter of 2016-2017. It also uses space syntax as a main tool to analysis the impact of street pattern. The results show that in the summer, Hutong area can generally support more social gatherings, yet, it is different in winter. While within each type of neighborhood, comparing with the simple rules texture, the street whose topology is relatively complex can better support the social gathering, especially in Hutong area.

KEYWORDS
social gathering, public space, relevance factor, space syntax

1. INTRODUCTION
As a daily living room for urban residents, community public space plays a crucial role on promoting social interaction and enhancing community quality. In addition, community residents’ gatherings and activities can mostly reflect the relationship between residents and community public space. Indeed, with the social networking platform and the smartphone widely used in urban, more and more communication transfers to the virtual network platform. However, daily social activities in public space are still an essential part in the life of community residents. For architecture and city designer, how to fully tap the community public space to support outdoor social gathering, promote spontaneous social gatherings reasonably and enhance the quality of public space have been the focus of study.

In the field of theoretical research, the relationship between social gathering and space environment characteristics is a basic topic of environment-behavior study. Jan Gehl has classified outdoor space activities into three types: necessity, spontaneity, and social activity. This paper focuses on the study of spontaneous social gathering. In the recent ten years, researchers of environmental behavior have accumulated a large amount of basic empirical research. Jan Gehl and Whyte pointing out that most social activities depend on the quality
of outdoor public space. They believe that the sun, greening, infrastructure, road width and pavement and the like, affect residents’ social gathering (Jan, 1987; Whyte, 1980) and based on these findings some people have some further analyses (Zacharias, 2001; Liu, 2015). Most of these studies have confirmed that environment quality has impact on the social gathering.

While the social gatherings of residents are often part of their long-distance travel, and many empirical studies only focus on how the "local" spatial elements impact the gathering behaviour. In the field of research, lacking of the analysis between the spatial logic and the social gathering. For the spatial analysis of social gathering, on one hand, Newman proposed the public space privacy plays a key role of the residents’ sense of territory and communication. On the other hand, Dutch architects Maartin Hajer and Arnold Reijndorp put forward the concept of “threshold space”. The existing research is an indispensable part of the analysis, but at this stage lack of the study of analysis methods.

Space syntax, as a spatial theory and analysis tool based on topological connection, has been widely used in quantitative researches of urban traffic, land use and interior space shape of buildings for many years. In the field of social gathering, someone has applied the axis and perspective analysis tool to conduct an empirical study on the company employees and urban superblocks (Allan, 1977; Manuela, 2015). What’s more, Trova analysis the cases of street social gathering and the conclusions are mostly confirmed that the social gathering has a similar spatial pattern with the crowd’s flow distribution. After many years of research accumulation, spatial syntax has a considerable empirical basis research on the movement of traffic. What has been proved is space syntax model can simulate human flow movement successfully. Although the above researches have adopted qualitative and quantitative analysis method, lacking of the data collection and data filtering. Therefore, though a large scale data collection and data analysis, this paper compares the social gathering in different types of blocks in Beijing.

2. DATA AND RESEARCH METHOD

2.1 SURVEY REGION

The neighborhoods concerned in this paper include the Hutong area which has a clear historical value, and the multi-story social housing which was built after the establishment of PRC in China. The choice of these two types of neighborhoods is mainly based on the following reasons: First of all, Hutong, as a typical street type in Beijing, although have a high historical value, rarely used for a reference in large numbers of residential transformation. It is useful for culture inheritance to study the different with other neighborhoods. And then, from the heighborhood type, the stree type of Hutong has a obvious distinction with the modern multi-story social housing. The differences can compare the two types neighborhoods usefully.

Therefore, this paper chooses four typical examples of the above two types neighborhoods: Dashilan, Baitassi, Rendinghu and Baiwanzhuang, as shown in Figure 1, below. Dashilan and Baitassi are traditional Hutong area in Beijing, low population density, and courtyard buildings. While, Baiwanzhuang area and Rendinghu area are Mage-courtyard housing. Baiwanzhuang area has richful residential districts, which makes a clearly constrast. comparing with Baiwanzhuang, the district tyrp of Rendinghu are more similar.
2.2 RESEARCH METHOD

This study mainly by the methods of behavior note and photographic technique to obtain the data of the four cases. In order to weaken the influence of accidental factors, this study recorded the social gatherings in four time periods (8:00-9:00, 10:00-11:00, 14:00-15:00, 16:00-17:00). Particularly, this study eliminates the necessary gatherings in the records, such as street cleaners, Traders, shop clerks, and people waiting for the bus. After the data disposed, only the spontaneous social gatherings are analysed. However, with the long-term outdoor works in local area, shop clerks and toilet cleaners who are familiar with the surrounding residents are already become a catalyst for the local social gatherings. Therefore, in this study, figure 2, as below shows the data of outdoor gathering is divided into two categories: the “net” gathering which means only the local residents’ social gathering and the data both workers and residents are included which can be use to analyse the support of commerce.

Based on the methods as above, this study recorded 2037 social gathering locations in the four case areas in summer of 2016 with a total of 6101 resident and 450 social gathering locations in winter of 2016-2017 with 1931 residents were totally recorded.
2.3 ARRANGEMENT OF NON-RELEVANCE SPATIAL FACTOR OF NEIGHBORHOOD

According to the street form and residential type, the four case areas are divided into 20 small blocks to record the activities of residential activities, shown as Figure 3, as below. Based on the number of residents, block size, street length and the social gatherings of each small block, calculating the social gathering proportion, the number of gathering of unitized area, and the number of gathering of nitized length to compare the spatial vitality of each block.
2.4 ANALYSIS OF RELEVANCE SPATIAL FACTORS OF NEIGHBORHOOD

According to the structure of urban road network, a detailed segment map model of space syntax is established by using depthmap. The meaning of the integration is to compute the shortest topological distance (defined as an integrated turn angle) of a line segment to all other segments within a certain geometric distance reachable range, which reflects the centrality of the line segment to other line segments. The choice is the number of times that a line segment is traversed by the shortest topological path between all other two segments in a certain geometric distance reachable range (also defined as an integrated pivot angle). Based on these two basic parameter, by the end of 2012, Hillier, Yang Tao and Turner put forward the normalized angular choice (abbreviated NACH) and normalized angular integration (abbreviated NAIN). By using the two parameters, the influence of the number of segments can eliminate, which makes the comparison of the different scales and complex degrees come true.

In this research, spatial syntax tools are used to analyse the influence of outdoor spatial factors on social gathering. Firstly, in the scale of the four case areas, with the weighted statistical, NACH and integration are used to macroscopic study the distribution of social gatherings in the four case areas.
Secondly, in the scale of each area, NAIN and NACH are used to analyze the impact of street texture and accessibility on the social gatherings.

3. ANALYSIS OF NON-RELEVANCE SPATIAL FACTORS

Figure 4, as below, shows the analysis of the number of residents, block size, street length and the social gatherings of each small block. It can be seen that the number of residents and the number of social gathering are more relevant. Therefore, further research is focused on the social gathering proportion as the criteria of the outdoor public space activity.

Figure 4 - Non-relevance factors and social gatherings the correlation degree

Figure 5, as below, by comparing the social gathering proportion of Hutong area and Mega-courtyard area both in summer and winter, it is can be found that the the social gathering proportion in summer is higher than winter. What is more, the social gathering proportion of Hutong area is more than Mage-courtyard area. Whilst, in winter, it is opposite. The reason for this phenomenon maybe that the social gatherings in public space in summer are more about outdoor behaviour in both neighbours and the residents’ activities are more widely. either of Hutong area or Mega-courtyard area can support the social gathering effectively. In winter, more activities happen indoor but in the Mage-courtyard area, each the courtyard district paly the role of "living room".

Figure 5 - The proportion of the number of social gathering
A future analysis of social gathering of the 20 small blocks in summer, the social gathering proportion of block 2 of Rendinghu area is high, for the reason that the block is high-rise residential which has a higher use of the public space. Yet, the block 4 of Baiwanzhuang is also high-rise residential which has a low proportion. Base on the survey, the block provides less public space and service facility. The block 4 of Rendinghu area and block 6 of Baiwanzhuang are high because of the commercial effect as shown figure6. It is also found in block 2 and 3 of Baitasi, which are higher than block 1. Through the comparison of the small blocks in winter, what we can see is that the blocks which have more businesses do not enhance the social gathering in public space, especially in block 2 and 3 of Baitasi.

The block 6 and 7 have more gathering proportion than in summer when compare with other block in Baiwanzhuang.

4. ANALYSIS RELEVANCE SPATIAL FACTOE

4.1 LARGE SCALE SPATIAL ANALYSIS: ANALYSIS OF INTEGRATION AND NACH OF HUTONG AND MEGA-COURTYARD NEIGHBORHOODS

According to the results of spatial analysis in the previous sections, this part will analysis the spatial factors on social gatherings. In this section, the social gatherings of the four case areas are divided into six levels by the number of resident to observe the spatial parameters of the gathering groups. Figure 7, as below, shows the weighted statistical of the areas. It means the relationship between the spatial parameter (integration and NACH) of the gathering groups and the spatial parameter of whole Beijing. The comparison shows that the radius of outdoor activities of Mage-courtyard area is small, as figure8 shows more red lines in this area. From the results of NACH (eliminate the impact of the number of segments), in both types area, the social gatherings are more rely on the spaces which have higher parameter of NACH of small radius. However, the Mage-courtyard area is higher. What this means is that the social gathering public spaces of Baiwanzhuang and Rendinghu area are more outward. Due to the outward space (high value street of large radius of integration) of Qianmen and Baitasi area are occupied by urban businesses, social gathering has to be more in-depth of the district.
4.2 SMALL SCALE SPATIAL ANALYSIS: ANALYSIS OF NAIN OF THE FOUR CASE AREAS

Figure 8 shows the parameters analysis of the standardization of the integration in these four cases, which is excluded from the integration of the degree of precision (as the number of segments), and more effective measurement of the complexity of the road texture.

In the picture, each area marked all the streets 800 meters radius of the average value of the NAIN parameter. In summer, though research of the four cases, the data shows the block which street texture more complex and the value of NAIN relatively lower, has effective support of resident social gatherings. In winter, this phenomenon is more evident in the Mega-courtyard area which seems like a small mixed area compare with the four case areas. This preliminary finding suggests that the value of street texture is not a simple linear relationship with social gathering. In a certain range, it is easy to promote the community communication. If the value is too high, it will be weakened.
5. CONCLUSION AND DISCUSSION: ANALYSIS OF THE DYNAMIC AND COMMUNICATION MODEL OF THE NEIGHBORHOODS

Through the research and analysis of the statistical data of the four cases in summer and winter, the influence of public spaces on resident social gatherings is summarized the following points:

According to the field investigation of the four case neighborhoods of Beijing Hutong and Mega-courtyard, this paper research the social gatherings in summer and winter. From the statistical data, the number of social gathering in summer is higher than winter, obviously in Hutong area. In addition, the medium gathering groups reduce sharply. In term of the promotion of the businesses, it is better in summer. From the view of spatial factor, in the large scale and smaller scale, the public spaces which street texture is relatively complex and have a better connection with the external street may have more social gatherings.
The above preliminary conclusion shows that the spatial activity maybe attracted by two aspects:

firstly, the space has a better accessibility will increase the chances of external pedestrians crossing.

Under the appropriate environmental factors, it is favourable for social gatherings. Secondly, public space gatherings are closer to the courtyard front the buildings and private spaces. In brief, it is a kind of spatial law based on the street pattern and architectural type, which means, it is necessary to provide more opportunities to meet the “right” people.
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**GENERATIVE URBAN DESIGN MODULE:**
Integrating Space Syntax and Spatial Cognition Experimental Methods

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**ABSTRACT**

Traditional planning tools often fail to respond to the rapid changes of the urban context. In this paper we suggest to explore how new methods of spatial analysis together with advances in behavioural research of spatial cognition can be used to support an alternative approach, in which adaptive design systems are able to respond more accurately to the needs of the contemporary city and its dwellers. We present the results of the educational module, where quantitative research techniques, traditionally developed as part of Space Syntax, were introduced in conjunction with qualitative behavioural methods. Architecture students were familiarized with the basic techniques for evaluation of spatial configurations, including isovist, viewshed, axial mapping and visibility graph analysis. At the same time, they were presented with perceptual concepts from cognitive and environmental psychology, such as orientation, wayfinding, navigability and intelligibility. To analyse an urban site, to evaluate design outcomes and to compare alternatives, the students were taught methods used in research of human spatial cognition, such as observations, behavioural experiments, in-depth interviews, cognitive mapping and virtual reality tracking. Finally, these innovative methodologies were synthesized by use of parametrization and optimization frameworks to explore developing of generative design systems in urban domain.

**KEYWORDS**  
Configuration-informed urban design, generative tools, research-based design, spatial cognition, pedagogic methods and experience

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**1. INTRODUCTION**

Urban Design is an indispensable activity where the dynamics of contemporary social and technological conditions continually introduce unforeseen changes. Rigidity of the traditional planning tools fail to respond to the rapid changes of the urban context (Batty, 2013; Mehaffy, 2008). New methods of spatial analysis together with advances in behavioural research of spatial cognition can be used to support an alternative approach, in which adaptive design systems are able to respond more accurately to the needs of the contemporary city and its dwellers (Marcus et al, 2016; Dalton and Hoelscher, 2007).
This paper discusses the results of the educational module, where quantitative research techniques, traditionally developed as part of Space Syntax, were introduced in conjunction with qualitative behavioural methods (Montello, 2007; Hillier, 1996). This experimental module was integrated in an urban design studio together with theoretical studies on qualitative research in the field of cognitive psychology. The module aimed to familiarise architecture students with research-based design and to examine how this approach could contribute to new strands in architectural practice and education.

2. DATASETS AND METHODS

One semester design studio was combined with training on cognitive user aspects, excursion, and navigational experiments in immersive virtual reality laboratory. The studio was oriented towards discussion of contemporary processes and trends in urban renovation and aimed to examine conceptual alternatives in the design of large scale urban projects.

The main assumption of the studio was that urban planning in general and residential planning in particular cannot be introduced solely from top down, but must allow some flexibility of the system’s lower components in order to influence the entire planning process (Batty 2013). Through exploration of ideas in cognitive science and environmental psychology, we examined the principle of mass-customization in the creation of new residential neighbourhoods.

The site chosen for the re-design was located in Ben-Zion Neighbourhood in Netanya. This neighbourhood which was established in the 30’s of the 20th century and traditionally populated by immigrants, is found today in an accelerated process of urban renovation (Figure 1).

![Figure 1 - Ben-Zion Neighbourhood in Netanya, Israel. (a) One of the current views of the neighbourhood; (b) City map with official proposals for future development (Courtesy of madlan.co.il).](image)

The site reflects tension between formal institutional planning for housing, an intense commercial pressure of real estate and informal illegal development of local dwellers.

The Office of Netanya’s City Engineer was part of the studio and contributed to better understanding the current tendencies of ongoing development in the area.

Most importantly, students’ design process was supported by a series of theory lectures exploring the role of human perception and cognition in built environment. These lectures aimed to address following objectives:

- Conceptual framework of user behaviour and cognition in built environment.
- Methods and tools for assessing user cognitive performance.
- Study and analysis of key architectural elements affecting spatial cognition.
- Understanding of the role of urban designers and architects in analysing spatio-cognitive aspects.
Practical learning topics included: elements and structure of cognitive representation, cognitive mapping, spatial knowledge acquisition and perceptual concepts from cognitive and environmental psychology, such as orientation, wayfinding, navigability and intelligibility (Montello 2007; Weisman, 1981). Students were familiarized with the basic techniques for evaluation of spatial configurations. Among them a number of methods and computational tools for assessment of environmental quality characteristics affecting performance of urban spaces: (1) visual accessibility, (2) study of the isovist and viewshed and the ways to estimate them. As well as related cognitive issues such as visual exposure, security and safety (Benedikt, 1979), (3) measurement of movement by Space Syntax axial mapping, visibility graph analysis and other graph-theoretical measures (Natapov et al, 2013; Turner, 2001; Turner Penn, 1999), (4) innovative technologies in virtual reality and eye-tracking (Natapov and Fisher-Gewirtzman, 2016; Portman, at el, 2015). Study of each method was accomplished with practice of the relevant computerized tool. These methods were used to analyse given urban morphology of the site, to evaluate design outcomes and to compare design alternatives. Finally, these innovative methods were synthesized by use of parametrization and optimization frameworks to explore options of developing generative design systems.

3. RESULTS
In order to meet existing urban conditions and market demands, different variations of computer-aided mass-housing production systems were proposed. These systems enable the automation of urban data collection, pattern generation and construction on site. By integrating the systems with the processes of urban planning, fitting architypes and final adjustment, mass customization can be realized in the housing industry. While design principals of mass customisation are applied to many high tech industries, such solutions are still missing in the residential sector; although they could match a variety of urban individual forms and styles. For now the governing principle of housing design is based on the industrial assembly-line production of replicative units to form buildings and entire neighbourhoods.

A generative potential of the conjunction between digital tools and cognitive methods allow the use of parametrisation techniques as a design and conceptualisation tool for the changing needs of urban population as well as for the development of a new architectural language. The projects in the studio used different methodologies to integrate urban phenomenon of emergence with planning prescriptions to be able to process from the bottom up. These methodologies work as an interface allowing the synthesis of bottom up and top down processes in the urban domain. They are adapted to complex urban systems and show a unique flexibility.

In this short paper we present a sample of the most representative projects developed in the studio (Figures 2 and 3). The project in Figure 2 analysed common Israeli dwelling typologies and explored a correlation between the physical settings of the built environment and the street’s sense of community. Students have argued that understanding the correlation may help to design better streets and dwellings, with a potential to support a strong sense of community. They used parametric mapping (Grasshopper) and two Space Syntax tools (visibility graph analysis and justified graphs).

Three housing typologies were analysed: private houses, tower blocks and project houses. The methods used by students allowed them to evaluate and quantify the relation between the dwellings units themselves and between the dwellings and the street. In addition, these analytical methods allowed to compare the different environments.

In the small specimen of the research, students found a correlation between the sense of community and the physical settings. There is a correlation between environments with a deep justified graph, the distance from the street, and the percentage of people they knew in their community.

Figure 3 shows another project that started from a critique of the ongoing housing proposed by developers which is primarily concerned with quantitative market-oriented parameters with little reference to human scale. There are large areas of open space in the plans, however, they
are not developed, badly connected and full of fences and parking lots that block pedestrians’ view. The project chose to focus on in-between spaces - the spaces between the buildings in the neighbourhood. It tried to examine these spaces through the lens of human scale perception and to use this approach as a tool to look at housing development in Israel.

Survey of sense of community in three common Israeli dwelling typologies: (a) private houses, (b) tower block, (c) project houses.

Justified graphs of the three typologies: (a), (b) and (c).

Visibility graphs analyses of the three typologies (DepthmapX, Turner, 2001).

Figure 2 - Project entitled “Street-Dwellings Relations”, authors Sheer Han and Adi Kupershmit.

The idea of the project was to create a new system of spaces that on one hand connect the old parts of the city with new ones, and on the other, allows to increase density and to intensify the level of activities. This new space is intended for shared public activities. Using vistas and isovists, the student developed a parametric system that is concerned with possible walking scenarios. It connects the existing urban tissues with public buildings and towers at the west side of the site. First, the main pedestrian axes were connected to the building on the west, then, these were superimposed with preferred views measured by isovists from the key locations.
This innovative methodology helped the student to create a new urban infrastructure that accumulates movement, strengthens the existing urban fabric and improves streetscape. It integrates, arranges and maintains all the visual elements of the street, including the road, adjoining buildings, sidewalks, street furniture, trees and open spaces, etc, that are combined to form the character of the city.

4. CONCLUSIONS

Integration of cognitive tools with parametric tools for simulation and optimization assisted students in developing the projects’ organizational logic and in testing design options and iterations. Module’s experience offers several pedagogical inputs to how new design skills and techniques, could contribute to expanding design methodology for architects and planners. Based on the outcomes of the module we draw conclusions for the further research-based design education that will bring together research and practice in computation, spatial analysis, spatial cognition and urban design. We also identify key issues, technologies and applications useful for adaptive, generative urban design.
REFERENCES


COMBINING ENVIRONMENTAL PSYCHOLOGY AND SPACE SYNTAX ANALYSIS:
The extent of users well-being influencing variables control, protection and privacy in an open plan office

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ABSTRACT
In an environmental psychology study by Wackernagel (2017), 191 employees from many different professions and many diverse industries assessed a number of elements of design in their workplace environment in a questionnaire procedure. Via a factor analysis, three space factors were identified and a new type of questionnaire was developed. In the 2017 study the three space factors, Positive Stimulation Through the Space, Coherence of the Space and The Space Provides Control showed a significant connection between health, well-being, and contentment with the design. In this study the floor plan of an automotive company is checked via various space syntax analyses for the features of the The Space Provides Control factor. In addition to this floor plan, this research work also examines various layouts for optimizing the space. The analysis visualises the space configuration with which the workplaces in an open plan office have a high level of the following features: the workplace is protected from the eyes of other users; it is not possible to look on the screen; it is not possible to approach the workplace from behind; people do not walk by the workplace; colleagues are not directly aware of your presence at the workplace; colleagues' workplaces cannot be taken in entirely with one glance; there is a visible demarcation of one’s own workplace; there is an agreeable distance from colleagues’ workplaces; demarcations enable protection from acoustic disturbances; there are retreat possibilities for concentrated working, for quiet and tune out, and there is the possibility of confidential talks.

KEYWORDS
Space syntax, environmental psychology, well-being, open plan office, privacy, control, workplace design, visibility graph analysis, agent analysis

1. INTRODUCTION
Many people in today's information age do their work at a computer in an office environment (Flade 2008). And yet office work is not a stressless activity. According to the German Federal Institute for Occupational Safety and Health (BAuA 2010), commercial and administrative jobs show the highest number of days absent due to illness. Occupational psychology has in the last decades identified many risk factors that can affect the health of employees. Approaches for the optimisation of operational work conditions mainly relate to the organisation of the working environment. But what effects does the built work environment has on the user experience? Individuals in western societies spend up to 90% of their lifetime in buildings (Evans & McCoy, 1998). Thereby we live and work the majority of our lifetime within rooms (cf. Flade, 2008). According to Bechtel and Churchman (2002) the goal of every planning of built environments,
is to enable the maximum quality of life for the people. To achieve that, unfavourable building structures that induce stress and negatively influence our well-being, have to be identified (cf. Bell, Greene, Fisher & Baum, 2001).

2. THEORETICAL BACKGROUND

Ulrich’s (1997) *Theory of Supportive Design* shows that an environment conducive to health enables control, privacy, social support and access to nature. Similar aspects are named by Evans and McCoy (1998). The authors analysed the studies conducted until 1998 by environmental psychology. The results found were summarised by the authors into five dimensions of stress influencing interior design elements that can influence the experience of stress by people and therefore are related to their state of health: Stimulation, control, coherence, restorative and affordances.

<table>
<thead>
<tr>
<th>Stimulation</th>
<th>Control</th>
<th>Coherence</th>
<th>Restorative</th>
<th>Affordances</th>
</tr>
</thead>
<tbody>
<tr>
<td>intensity, complexity, mystery, novelty, noise, light, odor, colour, crowding, visual exposure, proximity to circulation, adjacencies</td>
<td>Crowding, boundaries, climatic &amp; light controls, spatial hierarchy, territoriality, symbolism, flexibility, responsiveness, privacy, depth, interconnectedness, functional distances, focal point, sociofugal furniture arrangement</td>
<td>Legibility, organisation, thematic structure, predictability, landmark, signage, pathway configuration, distinctiveness, floor plan complexity, circulation alignment, exterior vistas</td>
<td>minimal distraction, stimulus shelter, fascination, nature, solitude</td>
<td>Ambiguity, sudden perceptual changes, perceptual cue conflict, feedback</td>
</tr>
</tbody>
</table>

Figure 1 - Interior design elements influencing stress (Evans & McCoy, 1998)

In a current study by Wackernagel (2017) it was reviewed, if these five dimensions of stress influencing interior design elements can be detected in office environments. The author researched by means of a unique online survey 191 office workers in Germany. The participants came from many different professions and many diverse industries. For the survey of the dimensions mentioned above, a novel questionnaire was developed. In doing so 105 items were applied for the first time. Via a principal component analysis (orthogonal varimax rotation) and a reliability analysis subsequently 41 items, associated to three factors, were identified. Factor 1 is unambiguously related to the topic stimulation (α = .88) by Evans and McCoy (1998). Factor 2 (14 items) unmistakably represents the topic control (α = .88). Factor 3 (12 items) can also definitely be related to the topic coherence (α = .83). Thereby three of five space factors that Evans and McCoy had been positing, were proved. A more accurate description of the dimensions is 1. Positive Stimulation Through the Space, as only positive elements of the dimension stimulation have flown into this space factor, 2. The Space Provides Control and 3. Coherence of the Space.

All three space factors show at a one-sided level of significance a significant to most significant positive relation with health, well-being and contentment with the design. For the survey of well-being WHO-5 (Bech, 2004) with five items was used. For the survey of health the BEL-PSSM – discomfort acquisition list by Iwanowa (2004) was used with 40 items. The scale of contentment with the design was newly constructed and consisted of two items.

Generally the correlations of stimulation, control and coherence with health, well-being and contentment with the design intensified with a high attendance (≥ 36 weekly hours) in the company (median split). Important hereby though is that these effects are diminished or cancelled out through the existence of negative organisational work conditions. The evaluation of demographic variables showed slight, but negligible influences on the result.
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COMBINING ENVIRONMENTAL PSYCHOLOGY AND SPACE SYNTAX ANALYSIS:
The extent of users’ well-being influencing variables control, protection and privacy in an open plan office

<table>
<thead>
<tr>
<th>The Space Provides Control</th>
<th>Positive Stimulation Through The Space</th>
<th>Coherence Of The Space</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protection against insights</td>
<td>Interesting additional areas</td>
<td>System in design recognisable</td>
</tr>
<tr>
<td>Comfortable distance to colleagues</td>
<td>Diversified design</td>
<td>Consistent structured space</td>
</tr>
<tr>
<td>No approach from behind</td>
<td>Interesting furniture Colourful objects</td>
<td>Central theme in design</td>
</tr>
<tr>
<td>Confidential conversations possible</td>
<td>Colourful design Interestig floor areas</td>
<td>Good orientation</td>
</tr>
<tr>
<td>Retreat for concentrated work</td>
<td>Extraordinary forms Interesting design</td>
<td>Functions of rooms/furniture clearly</td>
</tr>
<tr>
<td>Retreat for quiet</td>
<td>Plants</td>
<td>recognisable: technics &amp; room setup</td>
</tr>
<tr>
<td>Protection against noise</td>
<td></td>
<td>Different areas discernible</td>
</tr>
<tr>
<td>No view to screens</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Areas for tune out</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 2 - Three space factors - and their elements - correlating with health, well-being and contentment with the design (Wackernagel, 2017)

The study at hand has the goal of combining the environmental psychological study of Wackernagel (2017) with a Space Syntax Analysis to examine spatial configurations of an office environment in relation to the factor *The Space Provides Control*.

2.1 *THE SPACE PROVIDES CONTROL*

People have the need to make events and conditions in their environment controllable. Even if an environment may offer more possibilities for control than an individual may want or be able to handle (Lawton, 1989), the need for control is motivator for many behavioural patterns of the individual (Fischer und Stephan, 1996).

From an environmental psychological perspective, the human pursuit of control is also an expression of the fact that we want to regulate the extent of stimulation by environmental excitation (Cohen, 1978). Too strong an influence of excitation going hand in hand with overstimulation may be seen by the individual as an impairment of control over the environment. Cohen, Evans, Stokols and Krantz (1986) bring continuing experiences of uncontrollable environmental conditions into a relation with learned helplessness. This again stands in connection with distress as well as physical diseases (Peterson, Maier & Seligman, 1993).

Interior design elements that do stand, according to Evans and McCoy (1998), in relation with the factor control, are physical demarcation, regulation of light and climate, territoriality, privacy, crowding, flexibility, responsiveness, spatial structure (like depth), functional distances, defensible space and certain symbolic elements. The study by Wackernagel (2017) proves, that the spatial configurations of an office environment with a high characteristic of the following features provide control for the user.

Personal space for the individual starts with the existence of physical boundaries. This personal space constitutes a function of defence for the individual and serves to regulate intimacy (Fischer, 1990). In the office environment the user experiences control if the workplace is protected from the eyes of other users and the user cannot be watched working. Colleagues should not be directly aware of the presence at the workplace and have the possibility to look on the screen. But also colleagues’ workplaces should not be possible to be taken in entirely with one glance (Wackernagel, 2017). The experience of privacy is, according to Kruse (1980), closely related to the rooms where individuals live. They protect the human from unwanted view and uncontrolled access. Distances protect against noise and sounds that you don’t want to hear and the ability to hide adds to the feeling of security. Privacy also means that a room is not for all and not at all times to be entered by others (cf. Kruse, 1980). Thereby the experience of privacy enables the protection against unwanted onlookers und unwanted critics and offers protection for behaviour that is not for everybody to be seen, as, according to Kruse (1980), with every self-exposure comes vulnerability.

For Evans and McCoy (1998) the experience of privacy enables the possibility to regulate social interaction and adds, according to Altmann (1975), strongly to a feeling of control indoors. Users do not feel safe, if other persons are able to approach them from behind. To approach a workplace from behind should not be possible (Wackernagel, 2017). The User experiences control if his workplace has an agreeable distance from colleagues’ workplaces and when there is the possibility of confidential talks.
The study at hand further underlines that physical demarcation is an important aspect of control. The user experiences control, when there is a visible demarcation of one’s own workplace (Wackernagel, 2017). That can be achieved either by demarcation or by other nonverbal signs like markings (cf. Altmann, 1970). Furthermore it should not be possible that people walk by the workplace (Wackernagel, 2017). Well designed nodes are located centrally close to multiple main routes, act as neutral territory und offer wide views (Bechtel, 1976; Becker 1990). For workplaces with a high extent of The Space Provides Control the opposite is true. They should not be placed directly at main routes, as users will experience here more distraction (Kupritz, 1998).

The ability to control the environment is also experienced if a regulation of physical workplace conditions like sounds or noise is possible (Walden, 2008). The study of Wackernagel (2017) furthermore shows that users experience control when demarcations enable protection from acoustic disturbances, also if there are retreat possibilities for concentrated working, for quiet and tune out. Opportunities to retreat offer the individual the possibility of a timeout from overstimulation, continuing environmental demands, stressors and work routine. That reduces stress because opportunities to retreat offer a break which in turn supports the recovery of cognitive abilities (cf. Flade, 2008). Also niches for retreat and shielding from stimuli reduce the straining effect of high levels of stimulus and reduce the negative effects of crowding and noise (Wachs & Gruen, 1982).

3. METHODOLOGY

For the analysis of the space factor The Space Provides Control it was possible to use the planned introduction of a new workplace concept at the headquarter of a German automobile manufacturer. The company buildings at the site have all very similar floor plans. Before the new workplace concept is implemented in all office spaces, a pilot space is to be set up and tested. This pilot space is to be developed for a complete regular floor with about 170 employees. For evaluation and optimisation of the new workplace concept the current floor plan is contrasted with the draft of the new workplace concept. Thereby the decision making process during the planning phase is to be facilitated.

![Figure 3 - Comparison of the old and the new floor plan in the same building on the same floor](image)
The old workplace concept equates a classic open plan office. The whole floor is an open space. In the area the workplaces are arranged in cubicles, separated by dividing walls – mainly 160 cm high – from the aisles. At the insides cellular offices – mainly single offices – for managers are situated. In addition there are four conference rooms for the whole 170 employees. The central core cannot be crossed regularly.

In the new workplace concept the big area is more often crossed. Here too the workplaces are arranged in the open space. There are no individual offices, but a large number of meeting rooms and retreat rooms that can be used by all of the employees. Furthermore there are informal zones established at the inside. The central core in this floor plan can be regularly crossed. In the front area a vast encountering zone was established that can be adapted specially to the requirements of the departments.

Both the floor plans are being examined with regard to the space factor *The Space Provides Control* by means of a visibility graph analysis (VGA) and an agent-based analysis by UCL Depthmap.

4. ANALYSIS

In the following the interior design elements of the factor *The Space Provides Control* are successively presented and the respective graphical analyses explained.

4.1. THE WORKPLACE IS PROTECTED FROM THE EYES OF THE OTHER USERS

Initially the visibility while standing, walking or crossing the area was examined. For the application of the VGA all components of the area smaller than 2.5 m were removed. This result is however only valid if all employees are standing, as at farther distances sitting colleagues cannot be seen directly.

Figure 4, 5 und 6 show the spatial indicator of visual integration (Hillier/Hanson). High integrated spaces are visualised in warm colours like red, orange and yellow. More distant and inaccessible areas - segregated spaces or low integrated spaces - are shown in cooler colours like green and blue.
A – A very high integration exists in the red-orange areas which includes the major part of the workspaces. Hereby the standard workplaces exhibit a high measure of insight. The offices of the managers consist of glass, so these also show insight, even though they only show little integration. The closed rooms show the lowest integration (dark blue). Solely here the user is protected from the eyes of other users. Cf. Figure 4 A.

B – The VGA of the new workplace concept exemplifies that only the front area, reserved as encountering zone, shows a very high integration. The working areas show a medium characteristic (green). The meeting rooms with glass walls have medium blue portions and therefore lower visibility. The closed think tanks and meeting rooms have a low visibility (dark blue). Therefore standard workplaces have a lower visibility as in floor plan A. Locally the users still can be seen by their colleagues. The users nevertheless have a lot more retreat rooms where on demand and temporarily they are protected from the eyes of other users. Cf. Figure 4 B.

Figure 5 - Visualisation of the interior design element The workplace is protected from the eyes of other users, Colleagues are not directly aware of your presence at the workplace and Colleagues’ workplaces cannot be taken entirely with one glance (Wackernagel, 2017) while sitting, method visual integration (VGA)

To examine the visibility while sitting, e.g. at the workplaces, another VGA was conducted. For this all components of the area smaller than 1.6 m were removed.

A – First of all it becomes clear that the areas with standard workplaces show a different rate of integration. A very high integration exists in the red – orange areas, these workspaces are not protected from the eyes of other users. However some workplaces show a low integration (middle to dark blue) as well as the closed offices and meeting rooms. Cf. Figure 5 A.

B – For this comparison the same VGA of the floor plan was used as in figure 4, as there are no dividing walls. The visual integration of the workspaces is very evenly distributed and even though the employees are less exposed to the eyes of their colleagues the workplaces are not protected. Cf. Figure 5 B.

4.2. COLLEAGUES ARE NOT DIRECTLY AWARE OF YOUR PRESENCE AT THE WORKPLACE
This characteristic is covered by the analysis under 3.1.

4.3. COLLEAGUES’ WORKPLACES CANNOT BE TAKEN IN ENTIRELY WITH ONE GLANCE
This characteristic is also covered by the analysis under 3.1.
4.4. IT IS NOT POSSIBLE TO LOOK ON THE SCREEN

A - old floor plan

B - new floor plan

Figure 6 - Visualisation of the interior design element *It is not possible to look on the screen* (Wackernagel, 2017), method visual integration (VGA)

To examine the possibility to look on the screen of the user, another VGA was conducted. For that all components of the area smaller than 1.22 m were removed. Lockers up to 1.22m and dividing walls up to 1.6m were left to stay in the floor plan.

A – Under figure 6 it becomes apparent that the major part of the workplaces do have a low visual integration (mid to dark blue). Here the workplaces and with that the screens are only visible to a small number of persons (mid blue) or not at all (dark blue). Generally there is a high protection against the eyes of their colleagues.

B – The visual integration of the workspaces in this analysis is again very evenly distributed with a low integration (mid blue). Even when the protection is not as high as in floor plan A, there is just a small possibility by other colleagues to look on the screen. Additionally the retreat rooms are available to every employee without a possibility for other persons to look at the screen.

4.5. IT IS NOT POSSIBLE TO APPROACH THE WORKPLACE FROM BEHIND

A - old floor plan

B - new floor plan

Figure 7 - Visualisation of the interior design element *It is not possible to approach the workplace from behind and People do not walk by other workplaces* (Wackernagel, 2017), method movement density
For the examination of the interior design element it is not possible to approach the workplace from behind a limited agent-based analysis can be conducted.

Figure 7 shows the agents’ movements in space. Mid to dark blue areas depict less frequented areas and a low overlap of path network. Yellow, orange and red areas visualise highly frequented areas with a high overlap of path network.

A – The highly frequented paths (yellow to red) offer no access to the workplaces from behind the users. A general access from behind is made difficult. By looking at the floor plan it is evident that in most cases four users sit back to back, for these four users it is possible to approach the colleagues from behind.

B – In the new floor plan the highly frequented paths (red to yellow) also do not offer direct access from behind the user. By looking at the floor plan it is evident that all standard workplaces are protected at the back. This is achieved by lockers and walls. Access to the workplace can take place from the side. With this floor plan it is therefore made difficult to approach the workplace from behind.

4.6. PEOPLE DO NOT WALK BY THE WORKPLACE

To analyse if people do not walk by the workplace the agent-based analysis from figure 7 is used. An overlap of many paths is shown in red, while an overlap of few paths is shown in blue.

A – The highly frequented paths (yellow to red) directly lead past the standard workplaces. As a separation to the workplaces there are however 1.6m high dividing walls along the main paths. The offices of the managers are also shielded by dividing walls from the highly frequented paths. Workplaces that are positioned next to the exterior walls offer a much higher protection against passers-by.

B – Also in the new floor plan highly frequented paths (yellow to red) lead past standard workplaces. Because of the opening up of the building core, a major part of the user streams will be diverted from the higher frequented paths in the area of the standard workplaces. At standard workplaces with green – yellow characteristics of medium movement density, demarcations 1.22 m high in the form of lockers are situated to divert the flow of traffic. Also in this floor plan the situation of the workplace close to the exterior wall increases the probability that people do not walk by the workplace.

4.7. THERE IS A VISIBLE DEMARCATION OF ONE’S OWN WORKPLACE

Figure 8 - Visualisation of the interior design element There is a visible demarcation of one’s own workplace (Wackernagel, 2017), method visual integration (VGA). Floor plan A shows only walls and dividing walls to illustrate the existent demarcations.
The analysis of this interior design element by means of a Space Syntax Analysis is only limited possible. The utilisation of a VGA only plays a minor role.

A – In figure 8, the 1.6m high dividing walls were deliberately delineated, however these demarcations contain in most cases several workplaces. Other visible demarcations of one’s own workplace cannot be identified.

B – By means of visual analysis of the floor plan there are hardly any visible demarcations to be identified. Only at eight desks that border on higher frequented traffic paths, 1.22m high lockers offer a visible demarcation of one’s own workplace.

4.8. THERE IS AN AGREEABLE DISTANCE FROM COLLEAGUES´ WORKPLACES

An analysis of this interior design element with a Space Syntax Analysis is for the time being not possible. An outlook is depicted under item 4.4.

4.9. DEMARCATIONS ENABLE PROTECTION FROM ACOUSTIC DISTURBANCES

The analysis of this interior design element with a Space Syntax Analysis is hardly possible. Here the utilisation of a VGA does not play a role.

A – In figure 8 the 1.6m high dividing walls were deliberately delineated. Also under the present item they constitute a visible demarcation that not only limits the diffusion of sound and noise, but is also a visual symbol for an acoustic protection from acoustic disturbances. Even if these demarcations encompass several standard workplaces, in this workplace concept demarcations enable protection from acoustic disturbances.

B – By means of a visual analysis of the floor plan there are hardly any demarcations that enable protection from acoustic disturbances to be identified. That is why you can only assume a very minor characteristic of this interior design element.

4.10 THERE ARE RETREAT POSSIBILITIES FOR CONCENTRATED WORKING, FOR QUIET AND TUNE OUT

To analyse if there are retreat possibilities for concentrated working, for quiet and tune out, the VGA of figure 5 is used

A – The VGA visualises the few meeting rooms as low integrated (middle to dark blue). These could be used sporadically as a retreat for concentrated working, but the function of these rooms indicates that they were not thought for this purpose. Furthermore there is much too small a number of these rooms for the about 170 employees working on this floor.

B – In this floor plan there are additionally to the standard workplaces and the four larger meeting rooms a multitude of retreat possibilities planned. These can be used for either concentrated work as well as for tune out or to follow a need for quiet. For this, about 25 modules are planned. These are small rooms like think tanks, library, small meeting rooms and downright relaxation rooms. These are shown in figure 5 as low integrated (mid to dark blue). So the design element There are retreat possibilities for concentrated working, for quiet and tune out is depicted in floor plan B.

4.11 THERE IS THE POSSIBILITY OF CONFIDENTIAL TALKS

For the analysis of this design element there is here also the reference to the VGA under figure 5.

A – As explained under item 4.10, the VGA shows the few meeting rooms as low integrated (mid to dark blue). These might be used sporadically for confidential talks. Furthermore there is a possibility of confidential talks in the single offices of the managers, these also show a colour range from mid to dark blue and can provide as the case may be, visual as well as acoustic confidentiality.
B – In addition to the bigger meeting rooms the users have, as already mentioned, a multitude of retreat possibilities available. These provide acoustic as well as visual confidentiality. Furthermore there is a high number of possibilities for informal meetings in the form of benches, seating corners, bean bags or standing tables. These are shown e.g. under figure 4 and 8 as low integrated (light blue) and may also offer an increased measure of confidentiality. So for the 170 employees there is a much higher number of possibilities of confidential talks available as in floor plan A.

5. CONCLUSION AND OUTLOOK

This paper had the goal of combining the environmental psychological study of Wackernagel (2017) with a Space Syntax Analysis to analyse spatial configurations of an office environment in relation to the factor The Space Provides Control. The attributes of the latter could mostly be analysed by means of a visibility graph analysis (VGA) and an agent-based analysis by UCL Depthmap. This makes it possible to review floor plans with a Space Syntax Analysis ahead of the approval of implementation into the working environment of the office and to optimise them based on these results. Thus this kind of analysis should be integrated in planning processes to design a new workplace. Furthermore it is a very good change management tool to meet the needs and concerns of users. The user can be informed and integrated into the planning process at an early stage.

The factor The Space Provides Control is a significant factor in relation to health, well-being and contentment with design. The Space Syntax Analysis thus can have a positive influence on the condition of the user of an office environment.

Based on this evaluation the workspace concept as shown here will be further optimised for the roll-out. For the 11th Space Syntax Symposium in July 2017 the 3rd draft will also be analysed and contrasted with the other two floor plans.
REFERENCES


COMBINING ENVIRONMENTAL PSYCHOLOGY AND SPACE SYNTAX ANALYSIS:
The extent of users well-being influencing variables control, protection and privacy in an open plan office

Gestaltung des digitalen Wandels – kreativ, innovativ, sinnhaft, Brugg und Zürich, Switzerland.
SPACE AND CRIME IN THE NORTH-AFRICAN CITY OF ANNABA:
Using space syntax to understand the strategy of offenders in the choice of location of street crime.

ABSTRACT
This paper describes the preliminary results of a PHD research study conducted in Annaba city. Annaba is one of the un-safest city in Algeria, due to high occurrence of street crime.

The study investigates the relationship between space and crime by using space syntax. The aim is to describe the spatial characteristics of the built environment and the spatial distribution of crime pattern. The space syntax variables are connected to the statistical data on street crime data registered in Annaba.

This inquiry seeks to identify the spatial features of the crime locations to understand the relationship between the spatial configuration and crime behaviour. Most studies on space and crime in European cities deal with burglars and auto-theft. However, this inquiry focuses on two types of street crime, occurring frequently in urban open public space of Algerian cities, namely snatch theft and mugging. Therefore, the results from space syntax analyses of Annaba’ street network is made and put into GIS. Likewise, a crime registration map was generated in GIS to visualize the overall distribution patterns of crime. This map is correlated with various space syntax measures.

Most European studies on space and crime shows that crime takes place in the more segregated and poorly connected streets. However, the finding of this research shows that the more integrated and well-connected and controlled streets are, the higher numbers of snatch theft and mugging. One explanation might be that segregated streets tend to have no potential victims, and hence, it affects the numbers of snatch theft and mugging.

KEYWORDS
Spatial Configuration, Street Crime, Axial Analysis, Urban Morphology
1. INTRODUCTION

What are the spatial features of the built environment where snatch theft and mugging takes place? Annaba is a mid-sized city in the North East of Algeria with 257,359 inhabitants. The city is considered among the un-safest city of the country, where it has been recorded 9.5 offences per 1000 inhabitants in 2008.

Current crime theories have long presumed that criminal incidents are closely linked to the physical environment. The results of those theories can be resumed as following:

- There are researchers that consider urban space shape criminal offence opportunities. According to these theories crime takes place on a criminal’s daily routine activity and rational choice of opportunities taking place in a built environment (Brantingham & Brantingham, 1993).

- There are researchers focusing on certain spatial aspects on the physical environment that generates fear for crime. Examples on this are the prospect and refuge theory (Fisher, Nasar, 1992).

- Recently, research projects based on space syntax methodology, are examining the relationship between the spatial configuration of urban space and the occurrence of criminal events (Alford, 1996; Hillier, 1998; Shu, 1999; Hillier & Sahbaz, 2005; Nubani & Wineman, 2005, van Nes & López, 2010).

This on-going research project intends to investigate how crime patterns occur in certain areas, and not in other, in an Algerian city context. The aim is to analyse the spatial features through space syntax of the physical environment’s crime location and how the occurrence of a criminal incident constitutes itself the criminal offence opportunity by employing statistical analysis of every dimension measured.

2. DATASETS AND METHODS

We could not get access to the confidential police data on crime for Annaba. Therefore we conducted a victimization survey through a questionnaire addressed to 704 randomly chosen inhabitants of the city. Where the interviewees mentioned if they were or they have been witness of any kind of victimization in the period of the last three years, we asked them to localize the incidence on a map. The survey reveals that more than 53% of respondents have been victimized or have been witness of victimization. Through this survey, we managed to map the spatial location of each specific criminal incident and not on where people feel unsafe through rumours. Thereby, the crime occurrences were mapped in GIS to observe the overall distribution patterns of the offences before they were linked to the syntactical analysis measures.

Only the analyses of the snatch thefts and mugging are presented in this short paper. Those offences events represent the most recurring offences reported by the interviewees, which represent respectively 35% and 20% of all crime registered.

Moreover, a geo-referenced axial map of the whole city was made in GIS. The results from space syntax analyses of Annaba’s street network are imported into GIS. Figure 1 shows the distribution of global integration values and the distribution patterns of both of the street crime analysed.

The occurrence of thefts and mugging are correlated with a various space syntax measures. In this case, we focused on those related to accessibility measurements.

In order to verify the effect of the co-presence on the occurrence of the two type of street crime, we observed pedestrian flow rates at 41 gates (Figure 2), distributed in several streets of the city, which includes both safe and unsafe streets. The gate counts measure the number of people that cross the street during a given time interval. The movement measure reported in the analysis refers to the number of people per minute and is average from 8 observations taken...
at different time of the day. Those data have been correlated with the street crime registration to check any possible relationship (Correlations improve when we take the logarithm of people per minute).

3. RESULTS

Figure 1 - Global integration map and the registration of snatch theft and mugging.
The findings indicate that both snatch theft and mugging takes place mostly during the day in integrated urban areas in highly frequented and trafficked streets with shoppers (in the time period from 12:00 to 20:00). The spatially highly integrated streets have also the highest pedestrian flow rates according to the registrations.

As the registration and spatial analyses show, the snatch theft rate is much higher than the mugging rate. Both of them tend to cluster in a linear way around the highly globally integrated, and well-connected streets (Figure 1). These streets are the commercial busiest streets in the city’s downtown, creating what Hillier & Sahbaz called ‘hot lines’ (2005, p. 458). However, these incidents also take place in the border areas separating the integrated districts from the segregated ones. Next to the commercial streets there are several opportunities for the offenders who are operating in the downtown area to escape into the Medina area. Since most offenders know the spatial opportunities for the downtown area very well, they seems to be aware of the spatial as well as the temporal opportunities of what this built environment offer.

![Figure 2 - Location of the observation gates in the city of Annaba](image)

Statistical analysis of the correlation between spatial parameters and street crime occurrences were made. The following findings can be revealed in figure 3:

There is a clear correlation between the occurrence of street crime and the streets’ degree of spatial integration. The variable of the choice R3 is the one who correlates best in both street crimes. We find there respectively for mugging $r = 0.52$, and snatch theft, $r = 0.47$. This local dynamic measure with radius 3 inform about the degree of probability that the location where these crime events occur are situated on the shortest topological routes.

The scatterplots and statistical data in the figure 3 below shows that snatch theft and mugging take place on the globally as well as locally highest integrated streets. Some gate counting was carried out for testing out the snatch theft and gate counting risk. As the results show, the higher spatial integration, the higher number of people in streets, and therefore, the higher availability of potential victims for snatch theft and mugging. Moreover, streets with high connectivity offer also several escapes routes, in particular when the integrated town centre is adjacent to a segregated low-income neighbourhood.
SPACE AND CRIME IN NORTH-AFRICAN CITY OF ANNABA: Using Space Syntax To Understand The Strategy Of Offenders In The Choice Of Location Of Street Crime

(A)

Pearson coefficient of correlation (r) 0.473 (0.000)  
Regression R Sq = 0.224

Pearson coefficient of correlation (r) 0.520 (0.000)  
Regression R Sq = 0.27

Pearson coefficient of correlation (r) 0.448 (0.000)  
Regression R Sq = 0.20

Pearson coefficient of correlation (r) 0.543 (0.000)  
Regression R Sq = 0.295
SPACE AND CRIME IN NORTH-AFRICAN CITY OF ANNABA:
Using Space Syntax To Understand The Strategy Of Offenders In The Choice Of Location Of Street Crime

Pearson coefficient of correlation ($r$) 0.402 ($0.000$)
Regression $R^2=0.162$

Pearson coefficient of correlation ($r$) 0.441 ($0.005$)
Regression $R^2=0.194$

Pearson coefficient of correlation ($r$) 0.455 ($0.000$)
Regression $R^2=0.207$

Pearson coefficient of correlation ($r$) 0.065 ($0.688$)
Regression $R^2=0.004$
SPACE AND CRIME IN NORTH-AFRICAN CITY OF ANNABA:
Using Space Syntax To Understand The Strategy Of Offenders In The Choice Of Location Of Street Crime

Figure 3 - (A) Scattergrams showing the relationship between snatch theft and mugging occurrences and axial accessibility measures (Based respectively on 75, 60 axial lines were both street crimes are observed). (B) Scattergrams showing the relationship between snatch theft and mugging occurrences and pedestrian flow movement (Based on 41 axial lines where pedestrian flow was registered). (C) Scattergrams showing the relationship between snatch theft and mugging risk and global spatial integration (Based on 41 axial lines where pedestrian flow was registered).

In fact, offenders choose street segments with high local integration, because they are the most well-connected and shortest routes to all parts of the vicinity. This helps enormously the criminals in their strategies of escape, once when the act is done, or where in case there might be somebody to help to the victim.

The connectivity variable seems to influence the snatch theft \( r:0.44 \). This variable informs about the degree of connection of the space where these acts occur and the surrounding spaces. The connections relate to information to accesses and egress as regards the potential escape routes (Hillier & Sahbaz 2005, p.456). So, these roads could be used to access and to escape for the offenders.

The episodes of snatch theft seem related to the local integration HH R3 variable, \( r 0.40 \). These criminal acts occur more in the most locally integrated street.

The results of the correlations between the 41 points of movement registration and the occurrence of street crime on those segments show the following results:

Pearson rank’s correlation coefficient of the relationship between the average flow of people per minute and snatch theft shows \( 0.44 p<0.005 \). There is no significant relationship with mugging.

The degree of crime risk is calculated by dividing the degree of snatch theft and mugging incidences with the average of the pedestrian flow movement observed in 41 counting gate. The Spearman rank’s correlations of those risks with the spatial integration show a radius-0.335 with the mugging incidences and no significant result with the snatch theft incidences. The more streets are integrated, the lesser the real risk to be mugged is present. We can also observe that the risk of being victim of snatch theft still is high in the highly frequented commercial streets.

The more streets are frequented by people the more they are vulnerable at snatch theft. Besides, frequent used streets have no impact on the production of the various acts of mugging. Indeed, Brantingham and Brantingham (1993) suggest that some type of crime, such the theft seem typically to cluster together along the busiest streets (Friedrich. E, Hillier. B, Chiaradia, 2009).
This results seem opposed to the recommendations of Jacobs (1961), who by the principle of the natural surveillance assured by the pedestrians, stipulates that the safety reigns in the busiest streets and that it is the opposite in the deserted one.

4. CONCLUSIONS

To conclude, streets characterized by the presence of street crime events, namely snatch theft and mugging, appears in highly integrated, permeable and accessible streets. The main routes network in a city has these kinds of spatial features. As resulted, this spatial configuration increases the risk of being a victim of one of those street crime and which allow for several escape route possibilities for the offenders.

Besides, integrated and busy urban areas located adjacent to segregated areas shape opportunities for high crime risk. Offenders operate and find the opportunities in the integrated areas where a high number of potential victims frequent. The segregated areas offer several escape route possibilities by using the short well-connected routes between these two areas. The benefit of the closeness between these two areas, and the local knowledge of the offenders of the spatial opportunities of the neighbourhood for escape possibilities, correlates with the routine activity and the rational choice theories from the writings from environmental criminology.

High movement or co-presence of people is a necessary generative attractor for commercial activities. Likewise, a high number of people in streets function also an attractor for the potential offender searching for opportunities. Indeed understanding the strategy of the offenders to carry out a certain types of street crime, can contribute to some extend to plan safer built environments.
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ABSTRACT

Incidents of sexual harassment are unequally distributed in the Greater Cairo Region because cities, generally speaking, have uneven patterns of movement and activity with higher rates of pedestrian and vehicular movement and activities in some quarters than others. Central areas usually have concentrations of people and activity, hence higher crime opportunities. However, simplistic explanations of urban crime patterns will be misleading and will imply that people are a source of danger. Furthermore, previous research attempted to interpret the phenomenon of sexual harassment based on social effects, but failed to address the problem from a wider approach.

Instead, the purpose of this research is to identify built environment features related to sexual harassment occurrence in the context of Cairo, to suggest different ways to create safer urban environments, based on a design-based approach. Consequently, Space syntax is used to provide evidence-based explanations and conclusions. Analysis is done at two different, yet interrelated scales: city scale and urban block scale. That is, to provide a holistic understanding of the influence of built forms on sexual harassment.

The results show that touching incidents take place along globally accessible street segments, where local territoriality and social control are missing.

KEYWORDS

sexual harassment; space syntax, Greater Cairo

1. INTRODUCTION

Since the early 1990s, sexual harassment has been inevitable daily danger for Egyptian women (Abaza, 2013). Sexual harassment occurs on a daily basis all over Egypt (Harassmap, 2014). It occurs mostly on streets rather than elsewhere. According to ECWR 2008, about 69% of harassment incidents take place on the street. Furthermore, according to a study conducted by UN Women 2013, a percentage of (92.1%) interviewees stated that the females walking in the streets are the most exposed to harassment (UN Women, 2013). Remarkably, the largest proportion of women do not seek police help as action is not always taken on reports. According to the Penal Code regarding sexual harassment, a woman must take the harasser to the police station, and has to provide two witnesses to a claim of sexual harassment; however, bystanders are usually unresponsive (ECWR, 2008). Eventually, sexual violence violates women’s and girls’
access to educational and economic opportunities. If this is the case, offering serious solutions for women's empowerment in Egypt is very urgent.

A significant attempt to deal with the problem of sexual violence particularly in Cairo is HarassMap. It uses an online platform to report and map incidents of sexual harassment. The aim is to create a “zero-tolerance” urban environment against sexual harassment through breaking the silence around the problem. HarassMap has successfully provided a safe platform for the voice of victims, and has also increased awareness around the issue through initiatives like #MeshSakta (Harassmap, 2015) (won’t be silent). Nevertheless, collected data is mostly analysed, discussed and debated from a socio-cultural perspective (Schiemer, 2015). Importantly, the creation of a visual cartographic representation of incidents of harassment will possibly expand the state’s policing powers. Expressed differently, identifying hotspots of sexual violence might have the effect of increasing state intervention in publics through targeting and criminalizing subjects, specifically political dissidents, and spaces (Grove, 2015).

Furthermore, previous studies, (UN Women, 2013), focus mostly on addressing political and socio-economic explanations of sexual harassment such as high unemployment, low-income, and a lack of appropriate legislation (Harassmap, 2014), but pay less attention to the influence of physical environment on human behaviour.

Literature has already shown that crime is strongly associated with urban space. A key concept about crime prevention and settlement safety is ‘defensible space’, but it is marked by the controversy between Jane Jacobs’ conception of spatially integrated spaces and Oscar Newman’s conception of segregated spaces such as cul-de-sac for safer environment (van Nes, 2005). So, how do the divergent views on urban space and safety help us to interpret where and how sexual harassment takes place?

So far, research on space and crime with the use of space syntax tools (Hillier & Hanson, 1984), shows that inaccessible streets (usually with low movement rates) are more vulnerable to antisocial behaviour than accessible ones (Hillier & Shu, 2000). Nevertheless, these outcomes cannot be generalised as the type of street crime depends on the spatial characteristics of built environment (Alford, 1996); for example, Alford (1996) found that different crimes have different patterns, and that the type of crime is powerfully related to the kind of space where the incident takes place (Alford, 1996). If so, various forms of sexual harassment will have different spatial features. Accordingly, this paper, based on a design-evidence approach, will focus on studying touching harassment, due to limitations on time and data.

2. THE METHODOLOGY

2.1 THE DATA

This paper uses various sets of data. GIS Street network map of the Greater Cairo is obtained from General Organization for Physical Planning (GOPP), while locations of sexual harassment reports are obtained from HarassMap.

Table 1 shows reported categories of sexual harassment and assaults in Greater Cairo over six years, from 2010 until 2016, according to Harassmap online platform. Remarkably, touching has the highest number of reports with 636 reports.
Proceedings of the 11th Space Syntax Symposium

STREET MORPHOLOGY AS A STARTING POINT FOR UNDERSTANDING SEXUAL HARASSMENT

<table>
<thead>
<tr>
<th>Category</th>
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<th>Category</th>
<th>Number</th>
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</thead>
<tbody>
<tr>
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<td>Online</td>
<td>7</td>
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<td>Facial expression</td>
<td>215</td>
<td>Phone calls</td>
<td>118</td>
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<tr>
<td>Catcalls</td>
<td>275</td>
<td>Touching</td>
<td>636</td>
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<tr>
<td>Comments</td>
<td>565</td>
<td>Indecent exposure</td>
<td>150</td>
</tr>
<tr>
<td>Stalking or following</td>
<td>396</td>
<td>Threat</td>
<td>15</td>
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<tr>
<td>Sexual invites</td>
<td>222</td>
<td>Sexual assault</td>
<td>174</td>
</tr>
<tr>
<td>Unwanted attention</td>
<td>12</td>
<td>Rape</td>
<td>1</td>
</tr>
<tr>
<td>Sexual photos</td>
<td>6</td>
<td>Mob attacks</td>
<td>16</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>1551</strong></td>
</tr>
</tbody>
</table>

Table 1 - Sexual harassment and assault categories according to Harassmap dataset 2016.

2.2 SPATIAL ANALYSIS

2.2.1 MACRO ANALYSIS: THE CITY

A first step is to measure spatial accessibility of the Greater Cairo Region against touching reports over a six-year period. The following syntactic measures are considered: normalised angular global integration $R_n$ (NAIN) and normalized angular choice $R_n$ (NACH $R_n$).

2.2.2 MICRO ANALYSIS: THE SETTLEMENT

In the second step, Cairo CBD is selected as a case to study the relationship between touching harassment and accessibility statistically.

A risk band analysis developed by Hillier and Sahbaz (2005) is used to measure touching incidents rates for the selected area. Simply, the segments with incidents data are categorized into bands according to the total number of dwellings on the segment (i.e. street segments with the same number of buildings are grouped in one band. Then a total number of reports in each band are divided by the total number of plots in that band. Once calculated, touching risk for each band can be plotted against means of spatial parameters of similar street segments. In the analyses of Cairo CBD, eight bands were made, which encompassed street segments with 1 and 2 dwellings, 3 and 4 dwellings, 5 and 6 dwellings, 7 and 8 dwellings, 9 and 10 dwellings, 11-14 dwellings, 15 and 16 dwellings and more than 16 dwellings.

3. SYNTACTIC ANALYSES OF GREATER CAIRO

At city scale analyses, spatial accessibility map in figure1 show that planned parts are permeable, whereas informal settlements are inaccessible. Furthermore, visually speaking, touching reports’ locations are more common in the globally more spatially accessible areas than elsewhere. Harassers tend to avoid areas with globally broken routes. Similarly, figure 2 shows that about 40.91% of verified incidents is captured by the top 5% route choice at n metric radius. This visual relation between incidents’ locations and spatial betweenness indicates that touching occurs mostly along highly trafficked routes. If so, urban environments designed in accordance with
Jacobs's defensible spaces are more dangerous than elsewhere. Nevertheless, we cannot draw conclusions based on visual explanations rather than the underlying data. Accordingly, the next step scrutinizes previous interpretations by investigating the statistical relationship between touching risk and accessibility.

Figure 1 - Normalised angular global integration Rn overlapped with touching reports in Greater Cairo (Source: authors).

Figure 2 - Top 5% normalised angular choice Rn overlapped with touching reports in Greater Cairo (Source: authors).
4. STATISTICAL ANALYSES

Statistical analysis is a primary step to examine the significance of the above-mentioned qualitative findings. With a total of 43,747 street segments and 295 reports in Central Cairo, there was a considerable dataset to run the analysis.

By employing risk band analysis introduced by Hillier and Sahbaz (2005) touching risk in each band was calculated. Table 2 shows the outcomes of the relationship between the normalised touching risk and the investigated spatial parameters at various scales. There are strong correlations between most spatial variables and touching risk. Notably, globally accessible street segments have a higher touching risk than the globally isolated ones. NAIN explains 74% of the variance (R² = 0.746, sign (2-tailed) = 0.006).

Preliminary results at this stage complement the results of analysis at a macro scale. Although spatial integration enhances sense of safety through the effects it has on the daily movement, it gives harassers escape paths and victims. This is in accordance with studies from Hillier and Sahbaz (2005). They stated the following:

“Overall, we can say that urban integration, and the increase in movement and levels of activity that it brings has a double effect; it can produce more natural surveillance and safety in numbers and so reduce crime; and it may mean that potential criminals also use integrated streets, and so make more accessible locations more dangerous. Both effects undoubtedly exist, and a key variable is the degree to which there is a residential culture in more active areas. Where it exists, crime risk is reduced, where is does not, risk is increased.”

(Hillier and Sahbaz, 2005: 67)
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STREET MORPHOLOGY AS A STARTING POINT FOR UNDERSTANDING SEXUAL HARASSMENT

<table>
<thead>
<tr>
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<th>Integration Rn</th>
<th>Integration R2000</th>
<th>Integration R4000</th>
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</thead>
<tbody>
<tr>
<td>Pearson Correlation</td>
<td>-.872**</td>
<td>.864**</td>
<td>.873**</td>
</tr>
<tr>
<td>R-Squared</td>
<td>0.760</td>
<td>0.746</td>
<td>0.762</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.005</td>
<td>.006</td>
<td>.002</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Har Cont Sin</th>
<th>NAIN Rn</th>
<th>NAIN 2000m</th>
<th>NAIN 400m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson Correlation</td>
<td>.836**</td>
<td>.531</td>
<td>-.068</td>
</tr>
<tr>
<td>R-Squared</td>
<td>0.698</td>
<td>0.282</td>
<td>0.004</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.009</td>
<td>.169</td>
<td>.641</td>
</tr>
</tbody>
</table>

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 2: demonstrates the correlations between touching reports count and spatial accessibility parameters in central Cairo.

In the next section of this enquiry we will try to understand gender movement pattern in Cairo CBD to address the relationship between potential natural interfaces of different kinds of people and the issue of sexual harassment.

5. CONCLUSION

This paper has attempted to explain unequal distribution of touching reports in Cairo’s urban context based on grasping different urban patterns. The preliminary results have shown that touching incidents concentrations relate mostly to the globally spatially accessible routes.

Global integrated areas seem to have a weak of territoriality (i.e. a lack of local social accountability and control). Therefore, women are more vulnerable to sexual harassment in these types of spaces.

Then, could design solutions based on restricting social interactions foster women’s safety? The answer is no as different kinds of people have diverse needs. To illustrate, objectives of planning interventions will meet only the needs of a certain group, especially with the absence of effective participatory planning. Furthermore, problems of militarised spaces and constrained individual liberties are very expected to occur, when a specific group is excluded from urban planning solutions (Kohn, 2004).

To avoid aforementioned issues, professionals should have a good knowledge about the people they are planning for. Finally, this paper is a starting point to understand sexual harassment based on spatial accessibility model. However, more effort is needed for a holistic understanding of the relationship between sexual harassment and physical features of built environment.
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A MODEL FOR PEDESTRIAN MOVEMENT IN AN URBAN ENVIRONMENT BUILT ON STEEP TOPOGRAPHY

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ABSTRACT
This work is concerned with pedestrian movement in a topographic, i.e. sloped, urban setting. The existing models for predicting pedestrian movement, like the powerful axial map (Hillier and Hanson, 1984), are limited in their reference to sloped surfaces. A new analytical model is proposed to address those limitations. This article describes in detail the logic of the proposed analytical tool and its mechanics. In the future, it will be tested in real urban environments for validation and refinement. This model is a part of a research aimed at creating a more accurate version of the axial map and provide better data for planners and designers to help them create sustainable, vibrant and economically viable environments that provide a high quality of life for their users. Tapping unto the potential of the axial map, and Space Syntax in general, and refining it is crucial for the dealing with the upcoming challenges of rapid urbanization in developing countries, urban revitalization in developed ones, as well as more cataclysmic events like the resettlement of coast dwellers displaced by rising ocean levels all over the world (who will be forced to migrate inland and settle on steeper and more rugged terrain).

KEYWORDS
Topography, Physical Effort, Axial Map, Spatial Modelling, Pedestrian Movement

1. INTRODUCTION
Topography presents two main challenges to the urban pedestrian. First, topography could block lines of sight and adversely affect one’s spatial awareness. Moreover, the need to traverse sloped terrain requires more effort, compared with walking on a plane. To better represent urban environments built on steep topography a cognitive mapping model that takes these issues into account is required.

The axial map is a cognitive mapping technique for analysing and predicting pedestrian behaviour in urban settings (Hillier et al, 1993). It is derived from 2D information on the environment and
therefore does not reflect the aforementioned problems. However, it has representative clarity, flexibility and a robust logic making it suitable for modification. For these reasons, the axial map was chosen as the basis for a new model, enabling a more accurate mapping of environments built on slopes.

Asami (2003) successfully addressed the issue of limited visibility by dividing the axial lines at peak points in topography. Yet, the issue of traversing sloped terrain was treated as a turn left or right would be in angular segment analysis (Conroy Dalton, 2003), rather than a case with different considerations.

An axial map based model that integrates physical effort into shortest-path choice by translating it into time units, was attempted (Nourian, 2015). Paths were evaluated according to the time it takes to traverse them, to decide which was the shortest. This model has a limitation: One must know in advance the time it takes to walk all possible paths to choose the shortest one. This is often not the case and many decisions therefore rely solely on information available on the spot. A great advantage of the axial map is its function as a model for wayfinding – an advantage Nourian’s model forfeits.

2. THE PROPOSED MODEL

This research is aimed at developing a model based on the axial map, dealing both with limited visibility and additional physical effort on steep topography. The first stage of the research, covered in this paper, is the development of a topography sensitive model that will tackle both problems. The second stage will compare the proposed model to the traditional axial map in real urban environments built on steep topography in terms of indices, and specifically integration. In the third stage, the results will be set against the scattering of commercial and public functions (Hillier, 1996).

The methods employed by the model in solving the aforementioned problems are described below.

2.1 THE FIRST PROBLEM – LIMITED VISIBILITY

Axial lines represent lines of sight, but topography can block them. The axial map must be redrawn in a way that represents actual lines of sight, considering the effect of topography. Finding the axial lines that correspond to reality, requires a 3D model of the topography and a corresponding 2D axial map. The model receives the axial map and topographic model as input and divides the axial lines into short, equal, segments. These points are then projected onto the topographic model. Not all points are useful for creating the new axes, so we have to pick only the ones that are at peak points, at the edges of a plateau and the end points of the original axial line (see Figure 1).
Each point is checked against the previous and next points in the line and their heights are compared; a point that is higher than the points on either side, higher than one and equal to the other or is an end point of the original axial line, is retained. Those points are then connected to create new axial lines. The resulting axial lines are then input into the next stage of the analysis.

2.2 THE SECOND PROBLEM – PHYSICAL EFFORT

Integrating the effect of physical effort into the model requires us to attempt a breakaway from the exclusivity of mutual visibility as the cognitive basis for axial maps (Bafna, 2003). The proposed model suggests differentiating between walking downhill or uphill and walking in plane in physical - rather than visual - terms. Physical effort can be an organizing element in the perception of space (Proffitt et al, 2003) but it is also closely related to visual information (Zadra and Proffitt, 2016). The perception of geometrical traits, like distance, is affected by the effort needed to traverse it (Witt et al, 2010) and is scaled in energetic terms, rather than visual ones (Zadra et al, 2016). This, combined with the fact that climbing a slope is harder than walking on a flat plane might explain why humans consistently overestimate distance on slopes (Stefanucci et al, 2005). Although the decision to take a sloped path is made in advance based on visual cues, the incentives for and against travelling the path also have to do with physical effort. Humans are good at visually judging the accessibility of sloped surfaces and can predict their own ability of traversing a slope fairly well (Shaw et al, 1992). Although city streets are rarely steep enough to prevent human travel, they might still discourage it or shorten the distance people are willing to walk (Sun et al, 2015).

In practical terms, integrating physical effort into the model is done by attaching weights to every axial line. Since it is easier to walk downhill than uphill, each axial line gets two different weights attached to it – one for each direction. The weights are determined by the slope of the axial line, the steeper it is the greater the weight for uphill movement (greater than 1) and the smaller the weight for downhill movement (between 0 and 1). Weights should never be zero (excluding a case described below) or negative. Completely plane axial lines have a weight of 1. The weights are calculated according to the slope of the axial line and not the difference in height between its’ ends because the traveling velocity of a pedestrian is affected by the slope and the relation between that velocity and physical effort is non-linear (Al-Widyan et al., 2016; Tobler, 1993). This makes slope “more important” than distance in effort calculation i.e. it might be harder to climb three meters over a distance of ten meters than over a distance of twelve meters.

The graph for the axial map in this model is therefore weighted and directional. The weights are used when calculating the shortest path in the graph utilizing a realization of a greedy shortest path algorithm (Dijkstra, 1959). The algorithm varies from the original in being implemented on a directional graph; therefore, it must be decided which weights to use in each specific path. Making this decision requires us to know the direction of travel, forcing us to further divide the axial lines, this time for calculation reasons. This division allows us to know which weight to use by comparing the height of the point of intersection of axial lines, which now becomes also an end point of both lines, to the second end point of the axial line to which we pass. If the intersection point is higher than the other point, we use the weight for downhill travel and vice versa (see Figure 2).
Without dividing the axial lines at intersections we would not know to which point to compare the intersection point, since we could not be sure which axial line we will move along next. Such a case would have forced us to calculate in advance all possible routes from all sources to all destinations, and then eliminate all non-minimal routes; a computationally wasteful process. This further division generates two problems. The first problem is that going along what is essentially a single axial line might now be treated as a turn. This is solved by checking whether two axial lines along a path are continuous and assigning no weight to the continuing axial line in this specific path calculation. The second problem occurs when calculating indices in the graph, as the number of axial lines in the system is artificially inflated. This problem is solved by counting all continuous axial lines as a single line for the purpose of calculating indices.

In this model, an axial line in a valley will have different integration, for example, than the same line in an identical system on a ridge (See Figure. 3).
3. CONCLUSIONS AND FUTURE DEVELOPMENT

This article listed the improvements that can be implemented in a 2D axial map to help represent a 3D environment. The suggested model deals with the problem of visual constraints stemming from topographic form by finding the points along an axial like that block lines of sight and breaking the line into shorter segments. The problem of integrating the extra physical effort required to traverse a slope is tackled by attaching weights for ascent and descent to each axial line. These two refinements provide a terrain-sensitive version of the axial map. The model is in early stages of development and is still being refined. It will be tested in real urban environments built on steep topography. This mapping tool can improve the ability of planners and designers to make informed decisions regarding the design of movement systems, public space, land use allocation and much more.
REFERENCES


DEVELOPMENT OF THE INTEGRATED APPLICATION SOFTWARE FOR SPATIAL ANALYSIS TECHNIQUES BASED ON VISUAL PERCEPTION

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ABSTRACT
This study aims to develop an analysis application software for spatial analysis techniques based on visual perception. Spatial analysis techniques based on visual perception refer to the methodologies which focus on human perception and behavior, especially on visual perception in architectural & urban spaces to analyze and interpret the spaces. Typical examples of such techniques include Isovist, Visual Access & Exposure (VAE) model (Archea, 1984), Visibility Graph Analysis (VGA) technique, etc. There are applications developed earlier and used widely such as DepthMap, Syntax 2D, OmniVista, VAEpc, etc. However, there is the inconvenience of using different applications for different analyses reflecting various standpoints. Therefore, in this study it is aimed to develop an analysis application software in which Isovist, VAE model, and VGA technique are integrally implemented as an AutoCAD 3rd-party application using ObjectARX technology. AutoCAD 3rd-party applications are ‘add-on’ applications loaded and run on AutoCAD, which effectively utilizes the powerful vector-based processing of AutoCAD and overcomes the weakness of existing analysis applications. To put it concretely, the newly developed application consists of three modules, which are Isovist module, VAE module, and VGA module. The Isovist module implements original Isovist, directed (or partial) Isovist, original/directed Isovist along path. The VAE module implements VAE model, weighted & layered VAE model, and Directed VAE model. The VGA module implements VGA, Evacuation Cost Evaluation Method (ECEM), and Angular & Cellular VGA. These methodologies commonly take vantage points as units of analysis, and the function to easily arrange vantage points is built in to the software.

KEYWORDS
Spatial Analysis, Analysis Software, Visual Perception, Software Development, VGA

1. INTRODUCTION
Spatial analysis software developed vis-à-vis the theoretical and methodological advances include Axman, Pesh, Depthmap, Axwoman, Confeego, Syntax2D, OmniVista etc. Most of these software were written to perform analysis of the theory of interest at the time of development. As a result, researchers are left with software that are different in OS environment, UI, and data input/output format. For this reason, researchers struggle to apply different analysis theories which would have only enriched their studies. Another problem with the current software is that they were written for very specific research interests, thus being exclusive to other researchers and non-researchers such as architects.

Therefore, this study makes an attempt to develop an analysis software that is generally accessible to those in the architectural and urban planning field by having the software operate within AutoCAD, which is arguably the most widely used CAD system in the field, and also have
the software implement various analyses integratedly, thus allowing the user to easily compare analysis results from different theories. Doing so, we can be expecting a better distribution of spatial analysis theories to the architectural and urban planning field, not only within academia but to practice as well.

This study focuses on spatial analysis techniques based on visual perception, excluding those based on convex spaces or axial lines. This is because visual perception-based models share theoretical similarities, thus can expect synergistic effect from an integrated analysis package. This study will be carried in the following order: First, analysis techniques based on visual perception will be reviewed alongside their respective analysis software in order to set the development outline of the new software. Secondly, key features and user interfaces will be set. Finally, the developed software will be tested its utilization by being used to analyse architectural space.

2. SOFTWARE DEVELOPMENT OUTLINE

2.1 REVIEW OF CURRENT ANALYSIS TECHNIQUES

It was Gibson’s ecological theory of perception that gave birth to the spatial analysis methodologies based on visual perception dealt in this study. According to Gibson, visual information of the surrounding environment is passed on to the human agent in the form of ‘ambient optic arrays,’ which are processed and thus reacted to. That is, the invariant structure of ambient optic arrays not only provide information on one’s surroundings but also make possible for the human agent to interact with his or her surroundings. (Lee, 2004) Gibson’s arguments resonated with those in the environmental psychology & behaviour field, stimulating studies and attempts to quantify and analyse visual information of the environment, which are being further reviewed below.

The Isovist was organized as a by Benedikt (1979). Isovist is the viewpoint-specific geometric shape of the space that can be seen by the human agent, taking the form of a closed polygon. To quantitatively describe an Isovist, Benedikt proposed several indices including area, perimeter, occlusivity, circularity, etc. Later, it was continuously developed by other researchers, such as the Directed or Partial Isovist, which reflects the directionality of vision.

The Visual Access & Exposure (VAE) model is a spatial analysis technique proposed by Archea (1984), focusing on the quantification of seeing and being seen by others within an environmental setting. Archea assumes that the human agent continually adjusts his or her behaviour according to the visual information of the built environment. The VAE model derives quantitative indices of the visual information such as Visual Access (VA) and Visual Exposure (VE). The VA of a certain point is the frequency of the human agent observing others, while VE is the frequency of the human agent being observed by others.

Cho and Kim (2011) extended the VAE model to a 3-dimensional setting and furthermore applied differential weighting for the vantage points within a visual field, thus naming the model Weighted & Layered VAE (WL-VAE), and Lim and her colleagues (2017) proposed Directed VAE (D-VAE) applying the directionality of vision to VAE.

Turner and his colleagues (2001) developed the Isovist model into a Visibility Graph where the graph/network of the visual connections is brought into consideration. The Visibility Graph considers each vantage point as a node, which has an edge to all vantage points within the node’s Isovist field, forming a graph/network. Visibility Graph Analysis (VGA) is the configurational analysis based on Visibility Graph, which derives indices such as connectivity, mean depth, integration, similar to Space Syntax.

Meanwhile, Kim (2006) applied ERAM onto Visibility Graph, resulting in Visibility ERAM model. ERAM is an analysis that utilizes Eigenvector Centrality mainly used in Social Network Analysis. (Choi et al., 2003) Choi and his colleagues (2007) applied Point Depth onto Visibility Graph to evaluate evacuation efficiency of a spatial setting. This is referred to as Evacuation Cost Efficiency Method (ECEM). Kim and Choi (2009) applied angular weighting onto VGA, thus Angular VGA.
2.2 KEY POINT OF SOFTWARE DEVELOPMENT

The above techniques have in common the assumption of points in space, vantage points, where human agents can be potentially present, and that they quantify the spatial characteristics based on visual perception. Furthermore, the techniques have in common that the vantage points are set at regular intervals, implementing Gibson’s concept of ‘ambient optic array’ by means of a grid system of observation positions. Such similarities allow the feasibility of an integrated software that this study attempts to develop.

<table>
<thead>
<tr>
<th>Analysis tools</th>
<th>Implementing techniques</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Syntax2D</td>
<td>Isovist, VGA, Axial Map</td>
<td>Raster-based, Graphic UI</td>
</tr>
<tr>
<td>OmniVista</td>
<td>Isovist</td>
<td>Raster-based, Graphic UI</td>
</tr>
<tr>
<td>Salsovist</td>
<td>Isovist</td>
<td>Vector-based, command-line UI, ACAD add-on</td>
</tr>
<tr>
<td>SaVAE</td>
<td>VAE, WL-VAE, D-VAE</td>
<td>Vector-based, command-line UI, ACAD add-on</td>
</tr>
<tr>
<td>Depthmap</td>
<td>Isovist, VGA, ASA, ...</td>
<td>Raster-based, Graphic UI, the most widely used</td>
</tr>
<tr>
<td>SaVisibility</td>
<td>VGA, V-ERAM, ECEM, A-VGA</td>
<td>Vector-based, command-line UI, ACAD add-on</td>
</tr>
</tbody>
</table>

Table 1 - Existing analysis software

The currently used analysis software are listed in the above table with the implemented techniques and characteristics. Considering the pros and cons of the software, the key points of the newly developed software were set as the following: First, the new software implements all analysis techniques based on visual perception, including Isovist, D-Isovist, VAE, WL-VAE, D-VAE, VGA, V-ERAM, ECEM, A-VGA, etc. Secondly, the newly developed software takes the form of an AutoCAD 3rd party application, by which the powerful vector image processing and the accumulated UX of AutoCAD become available. Thirdly, the newly developed software implements a user friendly graphical user interface including dialog box, menu, etc.

3. RESULTS

Based on the aforementioned key points, a new software was written. The software is named ‘SA Visibility United’, where ‘SA’ means ‘Spatial Analysis’, and contracted as ‘SaVisibilityUtd’. SaVisibilityUtd runs on the Microsoft Windows family of operating systems, supporting both 32-bit and 64-bit environments, and it is an AutoCAD 3rd party application, or an AutoCAD add-on. SaVisibilityUtd runs on AutoCAD versions 2007 to 2016. All commands have their own Dialog boxes (Fig.2), and are available through a main menu (Fig.1) of ‘SaVisibilityUtd’. The layers that the software uses are listed in table 2.

Figure 1 - Main Menu

Dialog box of ‘Visual Access & Exposure’
<table>
<thead>
<tr>
<th>Layer</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA_SPoint</td>
<td>Layer for vantage points.</td>
</tr>
<tr>
<td>SA_VBarrier</td>
<td>Layer for visual barrier lines such as walls.</td>
</tr>
<tr>
<td>SA_VPartition</td>
<td>(for L-VAE) Layer for visual barrier lines with a specific height (THICKNESS) each.</td>
</tr>
<tr>
<td>SA_VGlass</td>
<td>(optional) Layer for transparent barrier lines such as glasses.</td>
</tr>
<tr>
<td>SA_SLink</td>
<td>(optional) Layer for virtual lines of visibility btw. two vantage points</td>
</tr>
</tbody>
</table>

Table 2 - Layer list used in SaVisibilityUtd

Figure 2 - Generating analysis results: (a) Isovist-Area, (b) Isovist-Occlusivity, (c) Isovist-polygon, (d) VGA-Control, (e) VGA-Integration, (f) VERAM-ERAM, (g) ECEM-EC, (h) AVGA-Integration, (i) AVGA-Choice, (j) VAE-VA, (k) VAE-VE, (l) VAE-Quart
SaVisibilityUtd implements various analysis techniques proposed by various scholars, while allowing accessibility to the techniques in a familiar interface by running within AutoCAD. The strengths of the software are:

SaVisibilityUtd allows an easy comparison of the different analysis techniques. Because all analysis and visualization takes place within a singular user interface that is familiar to those in the field, comparison can be made at a glance. This is a great improvement from the current status where different platforms and different user interfaces were needed for different analysis techniques. This should be seen as an improvement in ‘research environment.’

Because SaVisibilityUtd runs within AutoCAD, it utilizes all the powerful features of AutoCAD that people in the architectural and urban planning field have become accustomed to, thus providing familiarity. This should break the barrier between those in and out of the spatial analysis community.

With SaVisibilityUtd, all analysis data are contained in the DWG format and thus can be managed together with architectural drawing data in one file. Furthermore, all analysis data can be exported to DXF format as well as XLS, TXT, and CSV. By using DXF format, data can be exchanged between other spatial analysis software and graphic software. This opens up the possibility to utilize features that were not available in SaVisibilityUtd.

4. CONCLUSIONS

The newly-developed software ‘SaVisibilityUtd’ takes the form of an AutoCAD 3rd party application, thus taking full advantage of AutoCAD’s user interface, data structure, and familiarity. By replacing the software that had their own platform and interface, the workflow is simplified, thus allowing accessibility to those outside of the spatial analysis field. By using DXF format, analysis data and drawing data can be combined and be exchanged between other spatial analysis software and graphic software. In sum, the software should contribute to the pervasion and utilization of spatial analysis in architectural practice.

ACKNOWLEDGEMENT

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REFERENCES


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PROPOSING A NEW LEAST ANGULAR PATH
Towards a new set of betweenness centrality measure

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ABSTRACT
The calculation of the least angular path between a pair of origin and destination is a key building block for space syntax measures. A common approach for solving this problem efficiently is the Dijkstra shortest path algorithm which finds in an angular weighted graph the global least angular path between a pair of origin and destination. We argue in this research that wayfinding is a complex endeavour where pedestrian may not necessarily have global knowledge of the network and that local knowledge as afforded by the environment can also be used for path identification. Thus, this research proposes a new least angular path method, that do not necessarily contain the global optimum path. The proposed algorithm starts from an origin and it selects the next node that minimises the angular distance to the destination repeatedly until it reaches it. Empirically, this research compares both qualitatively and quantitatively the extent to which the path generated by the proposed least angular path algorithm and the Dijkstra least angular path algorithm correlates with each other. It finds that the proposed least angular path overlap approximately 75% of the time with the Dijkstra least angular path. This means that the two paths are remarkably similar yet different. The importance of the result is it shows there is another perspective of identifying a least angular path and that the framework will allow for customisable priority of different weights during the routing process. Further research is required to better understand the difference between the two algorithms and importantly to validate the use of the method with pedestrian movement data.

KEYWORDS
Spatial networks, betweenness centrality, space syntax, wayfinding, shortest path

1. INTRODUCTION
One of the most important measure in space syntax is segment angular choice, also known as angular betweenness centrality in graph theory (Hillier et al 2011). The measure calculates the number of overlaps between every pairs of least angular paths for a dual graph street network. The structural measure is important as it correlates with movement hierarchy and retail uses distribution (Hillier and Iida 2005; Scoppa and Peponis 2015). Despite its importance, little
research in space syntax literature have examined the shortest path algorithm itself (Varoudis et al. 2011). One of the most common algorithm for this problem is the Dijktra shortest path algorithm which finds in a weighted graph the global shortest path between a pair of origin and destination. However, we argue in this research that wayfinding is a complex endeavour where the user might not have complete knowledge of all possible paths in a system to find the optimal one. This extends from previous wayfinding research where pedestrian engage in different strategy dependent on the knowledge of the environment, its demographics and the current condition. As a result, the aim of the research is to propose a least angular path method that simulates local route decisions rather than a single global route decision. This paper will compare both visually and quantitatively how the new least angular path method differs to the Dijkstra least angular shortest path algorithm. The method sets out a framework that could be used to identify least angular path differently and to produce a new set of betweenness centrality measures to be used for future research. This research is set out as follows; we first begin by illustrating previous wayfinding literature. Second, we describe the difference between the proposed least angular path and the Dijkstra global least angular path. Third, we illustrate the empirical method to measure the differences between the two. Fourth, we describe and discuss the results.

1.1. PREVIOUS LITERATURE

Wayfinding involves a complex cognitive process of identifying the paths between origins and destinations for a city or building that are affected by spatial configuration, signage, built environment and visual access (Weisman 1981). This research focuses on the spatial configuration aspect of wayfinding where two general strategies are often employed. One strategy is to take the least-effort metric shortest path to reach its destination and the other strategy is to take the simplest path such as minimising the number of turns to reach its destination (Conroy-Dalton 2003). In reality wayfinding is complex and sits somewhere between the two that depends on user familiarity, complexity of environment, demographics and information availability. Figure 1 shows the spectrum of these possible paths between an origin and destination from a spatial configuration perspective. For example, Novice users are more likely to take paths with less information required such as the least turns path while experience users are more likely to use a more complex path which often requires greater knowledge of the environment.

![Figure 1 - Least path versus least information path.](image)

Two important insights can be deduced from this. On the one hand, individual can choose from different strategy (least effort vs least information) dependent on who they are, where they are and what they know. This leads to the second insight which suggests individuals are in a constant process of routes evaluation based on the information afforded by the environment. This is related to the concept of bounded rationality in behaviour economics where we do not have perfect knowledge of the environment but rather partial knowledge (Simon 1993). This is also related to recent spatial cognition research where we are constantly retrieving information from our hippocampus (Javadi et al. 2017). Inspired from these concepts, this research proposes...
a new least angular path method that optimises at every step along the route. The path created is not necessarily an optimal path. This would allow future research to ask; do pedestrians have perfect information when they are navigating in an urban environment? Or do pedestrians have partial information when they are navigating.

These insights bring about two research questions; one is how we consider this local evaluation during the route search process between origin and destination, second is do different ways of identifying least angular path make any difference empirically and third is how can we consider different weights during the route search. This paper will set out a methodological framework to potentially look at the first question and to test the extent there is overlap between a Dijkstra least angular path and the new least angular path method. This framework can then be used to answer the second question, if the new least angular path improves pedestrian movement correlation and to answer the third question, on the consideration of different weights such as metric and angular weights during the route search process. The two ladder questions will be explored in future research and described in the discussion.

1.2. DIJKSTRA LEAST ANGULAR PATH

In order to describe the proposed least angular path algorithm, we first describe the Dijkstra least angular shortest path algorithm. Dijkstra least angular shortest path algorithm starts from the origin and it searches every neighbour’s node and from every neighbour’s node to its neighbour’s neighbour’s node. This creates a search tree that repeats until it reaches the destination. It adapts from the breadth first search (BFS) algorithm for a weighted graph. A least angular path is then found by minimising the global angular total depth between the origin and destination from all possible alternatives along the search tree. The algorithm involves two processes: the search and the path identification from all alternatives. This ladder condition finds the global least angular path. One must also note the least angular shortest path implemented in space syntax is a variation of the Dijkstra shortest path where the backward loop is not allowed. This was needed from a spatial cognition perspective as users do not backtrack to minimise angular depth. This constraint will not be studied in this paper.

1.3. PROPOSED LEAST ANGULAR PATH

The proposed algorithm uses the Dijkstra Least Angular Path algorithm within an iterative route decision process. We start from the source node. For each step within the routing process, these connected nodes calculate the distance to the target. The next node in the path is the one that is closest to the target. Here, the Dijkstra algorithm is used as a heuristic to select the next node and to approach the destination. This ensures the path will reach the destination by choosing a local optimum at every node but not necessarily its most optimal shortest path. The proposed least angular path function is described with a simplified code below which takes a graph, a source node, a target node and the angular cost as weights.

1. The function reads a dual graph, the angular weight, a source node and a destination node.
2. Start from the source node $s$, select the neighbour node $n$, that minimises the total angular length to the destination using the Dijkstra algorithm.
3. Set source node $s = neighbour$ node $n$
4. repeat step 2 and 3 until it reaches the destination
Algorithm: Path Function

Path_function(Graph, Source, Target, Angle):

1. current_distance = shortest_path_length(Graph, Source, Target, Angle)
2. distances = []
3. Neighbour = neighbour of Source
4. for node in Neighbour:
   1. distance = shortest_path_length(Graph, Neighbour, Target, Angle)
   2. if distance < current_distance: # Don’t choose ‘rear’ nodes
      1. distances.append(distance)
   3. if distance == min(distances): # Finding ‘closest’ node
      1. Target = node
5. return target_node

We illustrate the differences between the Dijkstra least angular path algorithm and the proposed least angular path algorithm using a simple example below. Consider an agent that needs to go from Origin (O) to Destination (D) highlighted in the abstract graph (G) of figure 2.

Figure 2 - Abstract graph (G).

Figure 3 shows the difference between the two methods. Fig 3a shows the Dijkstra least angular path which minimises the global total angular costs in reaching the destination. Fig 3b shows the new least angular path which minimises at each node the angular costs in reaching the destination but not necessarily attaining the global one. The new least angular path can differ or overlap with the Dijkstra optimal least angular path.
2. METHOD

The aim of the study is to empirically test the extent the Dijkstra global least angular path differs to the new least angular path. We will conduct a comparative study between the two least angular path methods through visual and statistical analysis. Further empirical analysis will be conducted in future researches.

The visual analysis illustrates in GIS the paths generated from the Dijkstra algorithm and the new least angular path algorithm to see how the two differ visually. The quantitative analysis on the other hand tests the extent the two paths associate statistically. The steps are as follow; we first identify a set of random origin and destination. As long as, the origin (O) and destination (D) do not match (i≠j), we run both the Dijkstra least angular path and the new least angular path between the OD pair. After this we calculate the similarity coefficient between the two paths to test the extent the two sets of elements correlate. This gets repeated 250 times. We then report a basic similarity coefficient for comparison.

\[
\text{Similarity} = \frac{2|X \cap Y|}{|X| + |Y|}
\]

X and Y are the number of elements in each set

Equation (1)

For the experiment, this paper uses three separate case study; the City of London, Barnsbury in North London and Soho in Central London. The City of London is the financial district for the Greater London Area. Barnsbury is a predominately residential area to the north of London which had been used in previous space syntax research (Penn et al 1998). Soho is a neighbourhood in Central London with a more gridded layout. The street network for the three case studies are visualised in figure 4.
Table 1 illustrates the descriptive statistics for the three case studies. It shows the three case studies have roughly 2000-3000 segments. City of London has a mean angular connectivity of 2.75 and a standard deviation of 1.04. Barnsbury has a mean angular connectivity of 2.70 and a standard deviation of 0.90. While Soho has a slightly higher mean angular connectivity of 3.08 and a standard deviation of 1.21. This shows that Soho in Central London has a more gridded street layout with a higher angular connectivity illustrating more choices at each junction.

<table>
<thead>
<tr>
<th>City of London</th>
<th>Angular Connectivity</th>
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<tbody>
<tr>
<td>N</td>
<td>2957</td>
</tr>
<tr>
<td>mean</td>
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</tr>
<tr>
<td>std dev</td>
<td>1.04</td>
</tr>
<tr>
<td>min</td>
<td>0</td>
</tr>
<tr>
<td>max</td>
<td>7.55</td>
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<table>
<thead>
<tr>
<th>Barnsbury</th>
<th>Angular Connectivity</th>
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<tbody>
<tr>
<td>N</td>
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<tr>
<td>mean</td>
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<td>min</td>
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<tr>
<td>max</td>
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<table>
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<th>Soho</th>
<th>Angular Connectivity</th>
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</tr>
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</tr>
<tr>
<td>std dev</td>
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</tr>
<tr>
<td>min</td>
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</tr>
<tr>
<td>max</td>
<td>10.39</td>
</tr>
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Table 1 - Descriptive statistics for the spatial network of the three areas
3. RESULTS

The result shows there are similarities and differences across the paths generated from the two algorithms both visually and statistically. We illustrate here some example paths using the two least algorithms in QGIS for the City of London case study. Figure 5 shows an example of the two least angular paths. The one on the left uses the new least angular path in red and the one on the right uses the Dijkstra least angular path in blue. The result shows the two paths can completely differ. The new least angular path in this case is metrically closer than the Dijkstra least angular path. Figure 6 shows another example. Similarly, the one on the left uses the new least angular path and the one on the right uses the Dijkstra least angular path. In this case the two paths overlap in the beginning and in the end but not in the middle. What is interesting is that the proposed least angular path meanders towards the destination while the Dijkstra least angular path takes a route with one large turn in reaching it. The result also shows that even for the path that differs there are still section of the path where the two overlaps. Figure 7 shows one more example where the two paths completely overlap. The path is noticeably shorter than the other two. There is a possibility that the shorter trips (fig 7) are more likely to overlap than longer trips (fig 5&6). This is logical as longer trips would also have more decision-making points than shorter ones. For brevity reasons, only three examples have been visualised here. On average, the two paths generated from the two algorithms appear to be quite similar. Further research on individual paths are needed to understand the two methods empirically.

To summarise, the proposed least angular path algorithm can create a different path in comparison to the Dijkstra least angular path algorithm by selecting a different tree during the routing process. Secondly, even when the two paths differ, there can be sections where the two paths might overlap. This means, the probability of having two completely different path is low. Thirdly, there are many cases where the two paths overlap completely or for large section of the path. This means the two algorithms produce similar results where the similarity coefficient is likely to be high.

Figure 5 - Shortest Path Comparison - When the two do not overlap (City of London)
3.1. QUANTITATIVE RESULTS

Table 2 shows the similarity coefficient for the City of London case study. Figure 8 shows the histogram of the results. The City of London area has an average similarity coefficient of 0.76 meaning that the two paths overlap roughly 76% of the time. The histogram shows nearly 50% of the path have a perfect match. The standard deviation is approximately 0.28 suggesting there are significant variations.

<table>
<thead>
<tr>
<th>N</th>
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<th>Min</th>
<th>Max</th>
<th>Median</th>
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<td>0.270</td>
<td>0.036</td>
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<td>0.889</td>
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</table>

Table 2 - Similarity Coefficient Statistics for City of London
Table 3 shows the similarity coefficient for the Barnsbury case study. Figure 9 shows its corresponding histogram. The area of Barnsbury has an average similarity coefficient of 0.75 meaning that the two paths overlap roughly 75% of the time. These results are consistent with the City of London case study.

Table 3 - Similarity Coefficient Statistics for Barnsbury

<table>
<thead>
<tr>
<th>N</th>
<th>Average</th>
<th>std dev</th>
<th>Min</th>
<th>Max</th>
<th>Median</th>
</tr>
</thead>
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<td>0.269</td>
<td>0.029</td>
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<td>0.847</td>
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Figure 8 - Similarity Coefficient histogram for the City of London

Figure 9 - Similarity Coefficient histogram for Barnsbury
Table 4 shows the similarity coefficient results for the Soho case study. Figure 10 shows the histogram of the results. The area of Soho has on average a similarity coefficient of 0.69 meaning that on average the two least angular paths overlap 69% of the time. The similarity coefficient is slightly lower for this case study. A plausible explanation is that this could be related to the more grid-like layout of Soho where there are greater choice at each junction.

<table>
<thead>
<tr>
<th>N</th>
<th>Average</th>
<th>std dev</th>
<th>Min</th>
<th>Max</th>
<th>Median</th>
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<td>0.762</td>
<td>0.313</td>
<td>0.049</td>
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</table>

Table 4 - Similarity Coefficient Statistics for Soho

Figure 10 - Similarity Coefficient histogram for Soho
4. DISCUSSION

This study compares the Dijkstra least angular path algorithm and the proposed least angular path algorithm. The proposed algorithm starts from an origin and it selects the next node that minimises the angular distance to the destination repeatedly until it reaches it. In simpler terms, way-finding between an origin and destination follows a ‘local’ turn-by-turn route decisions rather than a single ‘global’ decision. The results showed the two algorithms are both visually and quantitatively different. Quantitatively, the Dijkstra least angular path and the proposed least angular path overlap approximately 75% of the time. This means that the two paths are remarkably similar yet different. The similarity varies between different origin and destination and is greater for shorter trips and lesser for longer trips. The visual analysis reveals the new least angular path produce plausible paths towards the destination. The importance of the result is it shows there is another perspective of identifying a least angular path that adheres to the local knowledge of human cognition. The main contribution of the research is the methodological framework allows for further investigation on how local knowledge of the environment can influence wayfinding. Route choice algorithm that tries to represent this local nature of wayfinding should be further examined.

There are a number of limitations to the research. Despite the proposed algorithm in using the Dijkstra algorithm as its path heuristic, it was surprising to see the extent the two algorithms differ in the path identification. There is no clear explanation to this difference. As a result, more research is needed to explain and describe the difference. For example, to what extent is the path identified by the proposed algorithm longer than the Dijkstra least angular path algorithm. How do these differences scale when the total length of the route increase? More importantly, this research only proved the two paths can differ significantly but not if the methodology proposed is a better predictor for pedestrian movement than the Dijkstra algorithm. Empirical analysis is therefore needed to validate the extent the new least angular path associate better or worst with pedestrian route choice or aggregate pedestrian movement. A new set of choice or betweenness centrality (Brandes 2001; Hillier and Iida 2005) measures can be formulated for this purpose. The last limitation is this research only applied a single set of weights in identifying a shortest path. Further research can explore how different weights can be embedded in the route choice process dynamically. One of the original conception of the research is to design an algorithm that would allow a prioritisation process between different weights during the route search. This will be discussed, implemented and validated in the next stage of the research using this methodological framework.
REFERENCES


Conroy-Dalton, R.C. (2003), ”The secret is to follow your nose: route path selection and angularity” Environment and Behavior. (35) 107-131


#201

DEPTHSPACE3D

A Digital Tool for 3D Space Syntax Analysis

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1. INTRODUCTION

This poster is integrated into a set of actions presented to this 11SSS, presenting DepthSpace3D, a new digital tool for 3D space syntax analysis, free for academic use, including a workshop and a paper with a case study. Some questions as ‘why SS3D?’ or the demonstration of its potential appear in (Morais 2017).

2. OBJECTIVES

The research team began to work on a 3D SS software application, with some objectives in mind:

- operational features: ease of use, i.e. a rich user interface and good performance;
- but specially semantic features, more or less the same set of quantities / SS concepts to characterize the space, such as (with no hierarchy or structure at all) distance, visibility, isovist, depth, visual connectivity and integration, skewness, control, segregation and hundreds of others, that the SS research community had already produced. Those SS concepts constitute a remarkable connotational semantics that is widely used by the community, have already a strong denotational semantics in theoretical studies of architecture and urban planning. This means that the heuristic of this vision of SS is well established, if not yet in the mass of the architectural practitioners, at least in the extensive community of SS practitioners.
3. MODELS

(Duncan 2015) has the merit to bring to us a compilation of solutions for the problem of representation of 3D isovists. This effort was both weak and excessive for DepthSpace3D concerns. First, because the problem of the isovist flat representation is not only solved in the current 3D CAD software, but because it’s the kind of thing they can not avoid to do - showing isovists is their current graphical interface. And second, because some of what was intended to be 'ego-centered, phenomenological mode' (Thiel 1997) heuristic interpretations of the isovists are, in fact, non computational models and/or models that loose (and do not gain) information relative to the original - see (Thiel 1961, 1997), (Penn 1996) (Teller 2003) and the 3 proposals of (Duncan 2015).

However (Derix 2007), Ratti and Morello’s 2009 and (Varoudis 2014) have very important contributions, picked up by DepthSpace3D.

Nevertheless, the main model for DepthSpace3D development comes from 2D software. The team’s intention was to create a 3D SS software that was able to do in 3D models of the built environmental world the same type of analysis DepthMap/X (Varoudis 2012) do in 2D models. There was no intention to discuss Space Syntax paradigms. However, it soon became evident that some fundamental concepts needed not a global rethinking, but some amount of critique.

4. THE TRANSITIVE PROPERTY ISSUE

DepthSpace3D addressed the big problem of the possible transformation of SS analysis in an abelian group algebraic structure that would solve the transitive property issue. Please see *1 THE MISSING LINK.

5. VIEWING SPACE AND VIEWED SPACE

In 3D SS, following (Varoudis 2014), the active space has to be split in two conceptually different spaces, unlike SS2D, that mystifies their conceptual difference.

To view is an human activity, the objects in space are viewed by humans. Thus, DepthSpace3D considers two different spaces - the Viewing Space (space that humans can occupy), and the
Viewed Space that is offered to be seen by humans. Of course we can enlarge that concept to other possibilities, like video cameras.

Unlike (Varoudis 2014) and Ratti 2009, two kinds of Viewed Spaces are considered: besides the global Volume, the Surfaces of the objects that inhabit the global volume and are exposed to be viewed are also considered.

6. THE OBSTACLE SPACE

The Obstacle Space is composed by the set of opacifiers in the given space. There are two types of opacifiers:

- a set of surfaces, with a certain degree of transparency / opacity of the media. DepthSpace3D considers 2 opacities for each surface, one for each side of the surface. DepthMapX only considers this type of opacifier, but only with one value - total opacity.

- the linear loss of visibility over distance (in %/m) of the volume media, for example: fog limits visibility to a certain amount of meters.

7. THE VISIBILITY FUNCTION

As in DepthMapX, the primitive mathematical concept is the visibility function, not the isovista. But in DepthMapX, it is established between any two points of the active space. In DepthSpace3D this function is always directed from the Viewing Space to the Viewed Space (concepts not existing in 2D). The domain of the Visibility Function is the set of the cartesian product of all the View Points by all the Viewed Points. The codomain is a real between 0 and 1.

Besides this continuous visibility function, there is another similar function - the boolean accessibility function. This one is also the representation of a graph. Thus, DepthSpace3D deals with the ‘isovist model’ of SS as well as the ‘graph model’. Only the ‘axial line model’ is not supported, but 2.5D software for this model is already available.

8. OTHER CONCEPTUAL MODELS

DepthSpace3D can be considered a convergence of the development of the paths of (Varoudis 2014) and Ratti 2009, as well of DepthMapX. Both (Derix 2007, 2008) and (Shroder ?) present different conceptual solutions for the 3D SS problem.

Shroder solution seems comparatively weak, although much easier to implement. Nevertheless, his ‘slope’ SS concept seems to introduce new very promising semantic paths not yet developed by current visibility straight line primitive.
In the other end, Derix solution seems to have a very strong primitive semantic, with very high potential to develop new connotational concepts. Why not this path for DepthSpace3D? Well, DepthSpace3D privileged the safe path of using the established and disseminated VGA semantics.

9. NUMERICAL OR ANALYTICAL? DISCRETE OR CONTINUOUS?

DepthSpace3D had to deal with many issues relating to the operational paradigm that would have to process the conceptual paradigm just exposed. Decisions on ‘discrete versus continuous’ or ‘numerical versus analytic’ have been made by reasons this paper will not bring to the collation.

DepthMapX discretizes all the space in a regular grid. As seen, there are three conceptual spaces in DepthSpace3D, with two more two sub-spaces. Following Ratti and Morello’s 2009 and (Varoudis 2014), both the Global Volume and the Viewing Spaces are discretized in significant points. Not regular grids are allowed, in order to allow versatile solutions for case studies. This comes with a cost: two kind of weight functions had to be appended to each voxel, to normalize the model.

Unlike DepthMapX, obstacle surface space is discretized in analytic triangles and not discrete points in a grid. (Varoudis 2014) don’t have the problem, because there is no such space in this model. It’s more accurate then DepthMapX that pixelizes the obstacle line, although the solution brings some ‘friction’ in graphic representation.

10. SPACE VISIBILITY OF SPACE CONFIGURATION?

DepthSpace3D addressed the problem of the main objective of SS - space visibility or space configuration. Please see *1 THE MISSING LINK.

11. AUGMENTED VISIBILITY GRAPH ANALYSIS

(Varoudis 2015) presented some new features for new generation VGA. Most of those features are already developed in DepthSpace3D:

• introduction of 3D immediately solve most of the issues due to the reported difference between visibility and physical accessibility;
• the concept of path as aggregation of viewpoints and the conceptual differentiation between viewing and viewed spaces address directly to the proposal of directed land mixed links;
• transparencies (in the obstacles and in the global volume) are a standard feature of DepthSpace3D;
• proposed layered information of the model of the reality under study is partially solved by the concept of hierarchical Properties (developed in DepthSpace3D) that can be assigned to any subset of the viewed space. However some of the proposed new information (like temporal logic) can not be solved only with the expressivity of the SQL queries language, provided by DepthSpace3D. Some more expressive generative grammars had to be embedded in the calculations.

12. GRAPHICAL REPRESENTATIONS

DepthSpace3D has graphical representations of the SS concepts: one for the surfaces, one for the viewpoints of the Paths and three for the volume points.

These volume representations are either a generalized version of Ratti and Morello’s 2009 ‘isovistmatrix’ model (2D slices/sections through the isovistmatrix and, using a colour scale, indicate how visible individual voxels from street-level (Dalton 2015) or (Varoudis 2014) 3D arrays of coloured balls or collapse data to two-dimensional floor-level maps.
For a special purpose (Czyńska 2015) developed the *Visual Protection Surface (VPS)* model. Similar results can be produced by DepthSpace3D. But VPS uses two special graphical representations - *3D mesh* and a map with height levels marked above ground level that have add heuristic value and will be reproduced in DepthSpace3D in future releases.

![Graphical representations](image)

*Figure 3 - graphical representations*

*THE MISSING LINK*

As it is not possible for this short paper to present simultaneously the characteristics of the software and its theoretical framework, we tried to stick to the last theme, with the certainty that 1500 words was only able to surface the subject. So, see more in the site of OPO’ArchFormalMethods, please!
REFERENCES


