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INTEGRATION IS NOT WALKABILITY

The limits of axial topological analysis at neighbourhood scale

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ABSTRACT

Spatial syntax analysis has become an influential method of analysing street networks as spaces of pedestrian movement. While significant correlations have been found between pedestrian flows and axial topological models, these models are inconsistent in the way urban morphologies are represented and measured. Meanwhile, in the fields of health, transport and urban design research, correlations have been found between walking and a range of urban morphological attributes that topological models ignore. This paper shows that while space syntax analysis has become increasingly sophisticated over the past decades, substantial limitations persist.

Focusing on the limits of the theory in its own substantive field, it is shown that the abstraction of the street to its axial line poses three fundamental problems. First, it eliminates the street section and thus does not recognise that the social logic of space is also transversal across the street. Second, it ignores permeability as a key morphological attribute linked to walkability at neighbourhood scale. Third, it transposes smooth urban conditions into striated measurable models that iron-out ambiguities, eliminating conditions of liminality, porosity and complexity. Yet all these dimensions have been recognised as key attributes of urban intensity at street level. In conclusion it is argued that while axial integration may be useful in studying larger urban networks to capture particular morphogenetic tendencies, it can be misleading as a measure of walkable access at neighbourhood scale.

KEYWORDS

Walkability, urban morphology, spatial syntax, topological analysis

1. INTRODUCTION

Spatial syntax analysis has become an influential method of analysing street networks as spaces of pedestrian movement (Hillier and Hanson, 1984; Hillier, 1996; Hillier and Vaughan, 2007). At urban scale it is based on an axial model of the street network corresponding to 'lines of sight'. The 'topological' or 'syntactic' properties of this model are then measured using specifically developed software and represented through colour maps. Over the decades many such measures have been developed, the most common being integration and choice (Al-Sayed et al., 2014). The main testing ground for these methods has been London and other European cities with irregular street networks. These methods have been shown to be problematic in planned grid networks such as Manhattan (Ratti, 2004) and modernist morphologies as in southern Stockholm (Sayyar and Marcus, 2013). In response new syntactic models and measures have been added, including 'segment analysis' where the axial lines are divided into segments at each intersection. Measures have also diversified beyond axial topological to angular and metric as well as combinations of these (Al-Sayed et al., 2014). Thus while again and again significant correlations have been found between pedestrian flows and space syntax models, these models vary in the way urban morphologies are represented and measured. Even within the same study, Hillier and Iida (2005) found that pedestrian flows in four central London neighbourhoods variously correlated with topological or angular models combined with integration or choice measures, with turn radii ranging from 12 to 102. There has been however only limited exploration as to why some models work better for some morphologies or scales and not for others (Berghauser Pont and Marcus, 2015). While space syntax models have become increasingly sophisticated, substantial limitations persist.

The broad critique of spatial syntax theory so far has been focused on reductionism and spatial determinism. Reductionism includes the reduction of spatial practice to movement, human interaction to bodily presence and urban space to its syntactic dimensions (Netto, 2016). Thus the social importance of urban squares and parks (Whyte, 1980; Sennett, 1992), the role of social networks in virtual space (Castells, 2009) and the role of orientation signs and landmarks (Lynch, 1960; Venturi et al., 1977) are disregarded. Furthermore, the broad body of research examining the relation between walking and urban spatial structure within the fields of health, transport and urban design research has linked walkability to a much broader range of attributes, including footpath quality, permeability, proximity to attractors and density (Lin and Moudon, 2010; Moudon et al., 2006; Porta and Renne, 2005; Frank et al., 2006; Cervero and Kockelman, 1997; Maghelal and Capp, 2011; Forsyth et al., 2008; Forsyth and Southworth, 2008). The critique of spatial determinism is focused on Hillier's (1996: 169-170) key argument that more integrated areas tend to lead to higher densities, and higher densities tend to produce more functional diversity, which then leads to the emergence of urban buzz or urbanity. The high importance attributed to movement networks and the 'movement economy' is congruent with the work of other key urban theorist. For example Cerdá defined cities as 'points along the universal economy of ways' (Soria y Puig, 1999: : 103-115), and the capacity of the urban fabric to allow easy movement was one of four preconditions of vitality for Jacobs (1961). What is different in spatial syntax theory however, is the a-priory primary role attributed to street network configurations ahead of other morphological dimensions and various social practices (Holyoak, 1996; Soja, 2001).

Further to such broad critique, this paper focuses on what Netto (2016) calls the 'limits of the theory in its own substantive field', that is the limits of space syntax theory and its analysis methods as tools for understanding access networks and pedestrian movement. First the paper discusses the problems of dismissing the role the micro-morphologies of street sections have in mediating sociality. Then it shows that axial topological analysis is misleading as a measure of walkability at neighbourhood scale. Finally, it exposes the limitations of reducing geometry to algebra in the study of urban morphologies.

2. THE SOCIAL LOGIC OF STREET SECTIONS

The primary space syntax technique of axial analysis is a topological approach that abstracts street width and length to a node in a graph model (Fig.1). Here the conventional graph representation of streets connected by intersections is inverted: the streets become nodes and the intersections become the links (Hillier and Hanson, 1984). While the conventional graph model suits vehicular transport analysis where the focus is on intersections as traffic nodes and streets are seen as connections between nodes, space syntax focuses on streets as social nodes, while intersections are connections between these nodes (Marshall, 2005: 108-109). This inversion is assumed to be consistent with pedestrian behaviour where the streets are the main social spaces of interaction, origin and destination of trips, while the intersections are primarily links between them (Hillier and Hanson, 1984).

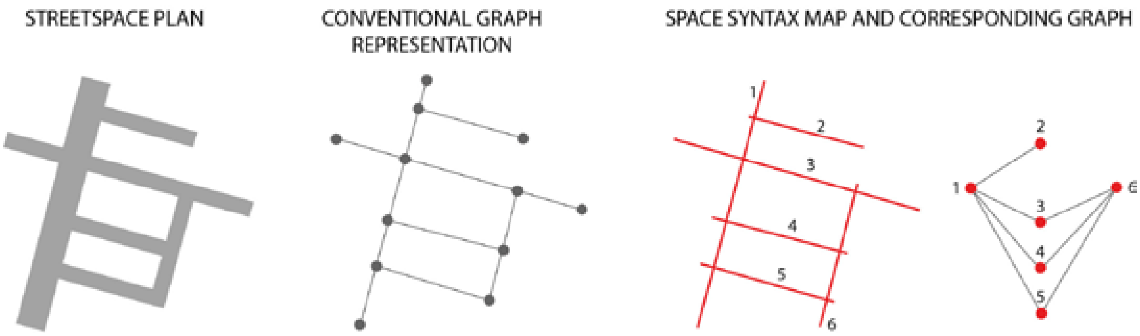

Figure 1 - Street network connectivity models (Source: based on Marshall (2005)).

In this process of abstracting the street section to its axis, the micro-morphology of the street section, including its width, public-private interfaces and footpaths are ignored (Fig.2). Yet it is well established that sociality in public space strongly relates to micro-morphological elements, including public-private interfaces, footpaths, seating opportunities and climate protection (Gehl, 1987; Gehl, 2010; Whyte, 1980; Gruen, 1965).

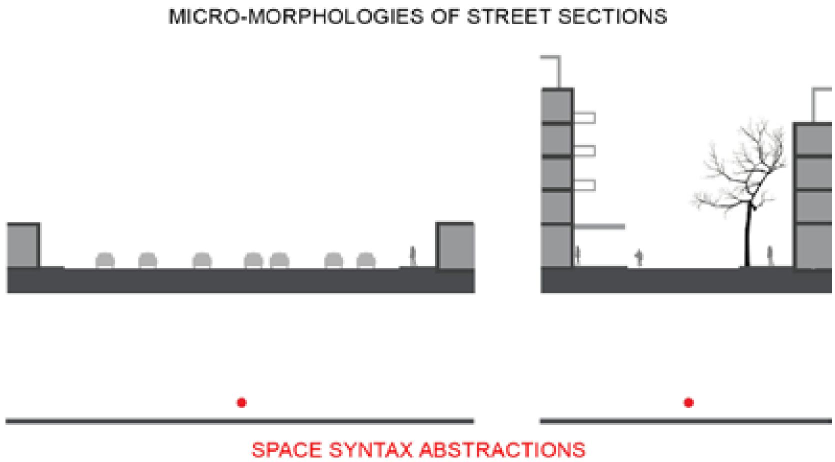

Figure 2 - The micro-morphologies of street sections and their space syntax abstractions.

This reduction of the street section to its axis also means that the connectivity between the two sides of the street is not considered. Yet the morphology of the street section has been long recognised as of key importance for the social life of the street. Thus Cerdá recognised that while widening streets increases their longitudinal transport capacity, at the same time it reduces the transversal connectivity between buildings on opposite sides. He observed that the transversal connection was crucial to sociability in the neighbourhood, and was negatively affected by large street width (Soria y Puig, 1999: 194-196). The relation between axial vehicular traffic and transversal connectivity has been also explored by Appleyard (1981). His survey of residents of three streets in San Francisco showed that social relations across the street were strongly reduced where vehicular flows were greater. Similarly, in retail streets transversal connectivity enables synergies between the two sides of the street that tend to emerge in pedestrian malls where walking from one side of the street to the other is easy.

3. INTEGRATION, PERMEABILITY AND WALKABILITY

One of the most common criticisms of axial space syntax analysis is that it generally discounts physical distances, assuming that people's preference to move straight prevails over their preference for choosing the shortest distance (Ratti, 2004). While in an open space the shortest and straightest route may coincide, this is mostly not the case at the neighbourhood scale. The tendency to move straight is more likely to be relevant in areas where most pedestrians are visitors, and thus visual connectivity (legibility) is more relevant. It is less likely to be relevant in residential precincts where most pedestrians have a well formed mental map of the area. Nevertheless, both the straight-line and shortest-distance assumption are reductionist, and discount aspects of walking that are non-utilitarian, driven by curiosity, exploration, excitement (Cullen, 1961).

While in space syntax literature the relevance of physical distances has been generally dismissed, this has been done on the basis of comparisons between pure topological and a combination of topologic and metric attributes (Hillier and Iida, 2005), rather than the basic spatial concepts of permeability and pools of use (or walkable catchment). The lack of distinction in the literature between permeability and connectivity, and the use of proxy measures that do not directly measure permeability, adds a further layer of confusion (Pafka and Dovey, 2016).

In the following the contrast between topological integration and the metric properties of permeability and pools of use (Jacobs, 1961) will be explored, using the advanced metrics of area-weighted average perimeter (AwaP) and interface catchment (Pafka and Dovey, 2016). AwaP is superior to previous measures in that it registers the effect of both block area and perimeter, ensuring that the impact of a large impermeable block is not lost in the average. Interface catchment, a derivative of metric reach (Peponis et al., 2008), takes into account the actual morphology of the urban tissue (i.e. street width and open space), and is focused on the morphological element that is directly linked to streetlife - the public/private interface. Figure 3 compares the way a single morphology with heterogeneous block size can be measured and mapped according to integration, catchment and permeability. The model shows an orthogonal network of one square kilometre. Integration shows a mixed pattern with high and low levels juxtaposed on intersecting streets with one of the most integrated streets adjacent to the most impermeable block. By contrast interface catchment peaks in the middle of the smaller blocks because it is reduced by proximity to either large blocks or edges. On the other hand permeability is highest at the top of the map, farthest from the large blocks. This figure demonstrates how much of a different measure integration is than either catchment or permeability.

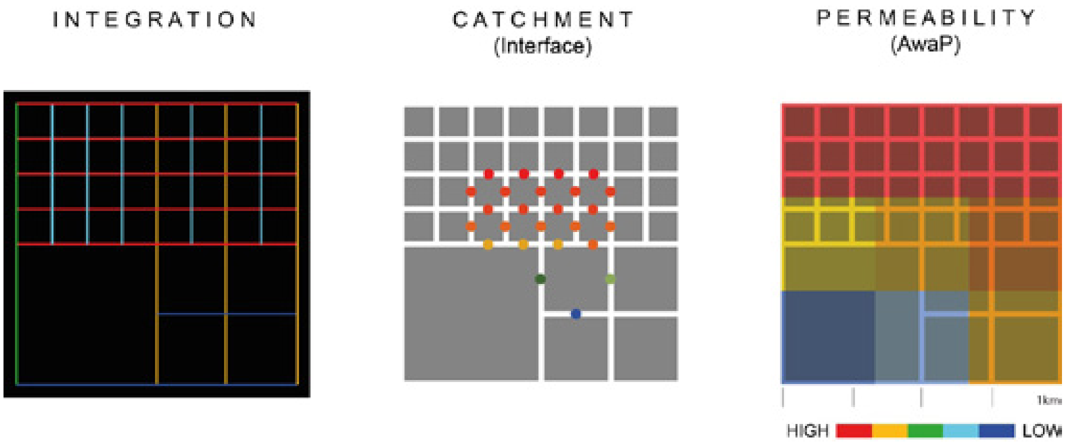

Figure 3 - Integration, catchment and permeability: three methods / one morphology.
(Diagram developed with Kim Dovey)

It has been argued that properties of urban networks are dualistic: metric at 'local scale' and topologic at 'global scale' (Hillier et al., 2007). However, it is not clear how the local scale is defined, whether there could be relevant intermediary scales between the 'local' and 'global', and whether the distinction is progressive or at a threshold scale. Within recent research, increasingly axial integration properties are combined with metric properties, by limiting the integration radius to a given metric value (Al-Sayed et al., 2014). This caps problems related to the implicit high integration value attributed to very long straight streets in grid networks and high sensitivity to the definition of the study area boundary, also known as the 'edge effect'

(Ratti, 2004). As such thresholds (of 400, 800, 1000 metres) are arbitrary, typically multiple values are tested in search for finding correlations with other morphological or social indicators. This is a peculiar hybrid method, that would assume that integration (visual or walking) stops at a fixed threshold value, rather than fading gradually, as suggested by behavioural observation and research (Pushkarev and Zupan, 1975; Gehl, 1987).

Further attempts to address such critique within space syntax include proposals to incorporate linear topologic (space syntax), node topologic (conventional graph) and metric attributes of networks (permeability) into a complex model (Batty, 2013: 179-244). However, the differences between metric, linear and node topologic properties are lost when converted to numbers. This is perhaps most evident in the accessibility 'heat maps' of street networks, where the linear topologic properties of street segments are converted into numeric values that are then spread out on a map starting from the centre of each axial line (Batty 2013: 204-205). Such hybrid approaches highlight the risks of converting geometry to algebra and then vice-versa without losing the connection with the physical space that is supposed to be represented and understood. The combination of mapping and algebra is a key aspect of space syntax that has been a source of confusion, as the maps show accurate geometric relations while the displayed topologic values ignore them.

4. AXIALITY AND SMOOTHNESS

A different kind of limitation of the axial space syntax approach is revealed by the various attempts to model smoothly curved and sinuous paths (Fig.4a). The process of abstracting curved streets to axial lines has a significant degree of arbitrariness (Batty, 2013). Their representation as a series of short axial lines (Fig.4b) leads to much lower integration values than a single straight street would have, even if the experienced difference is minimal. One alternative approach is to consider changes in direction below a threshold angle as insignificant (Figueiredo and Amorim, 2005). In such a model a meandering street like Broadway is represented as a single axial line (Fig.4c). A key problem however is that the threshold value for discounting angular turns is arbitrary, while visual continuity is gradual and dependent on street width.

In response to the same problem another alternative version to conventional axial analysis was proposed in the form of the 'angular segment analysis' that differentiates between various degrees of turns (Al-Sayed et al., 2009). The popularity of this method is due in part to the practical advantage that it can rely on broadly available street centreline data (Turner, 2007). The 'angular shortest path' is the one that minimises the degrees of angular turns, rather than the number of turns (fig4d). In other words the assumption here is that three 30º turns equal one 90º turn. This however is questionable given that the distance between turns can be of any length.

Yet another approach is the named-street topological analysis, where a street semantically identified as continuous is represented as a single entity (Fig.4e) regardless of the number and configuration of straight segments it is composed of (Jiang and Claramunt, 2004). Here the problem of setting an angular threshold for continuity is deferred to formalised semantic expressions. While this approach may appear broader for acknowledging some semantic dimensions of social space, it does so only in a simplistic way, instrumentalising one particular semantic dimension in order to build a computable network model.

Besides axial lines and segments, a third key type of street network model is based on routes (Marshall, 2005: 111-115). A computable approach labelled 'intersection continuity negotiation' has been proposed by Porta et al. (2006) who define spatial elements based on the most easily negotiated paths, considering that at each intersection the straightest direction is chosen (Fig.4f). A key problem here is that the result will largely depend on where the computation of paths begins, that is where one enters the network.

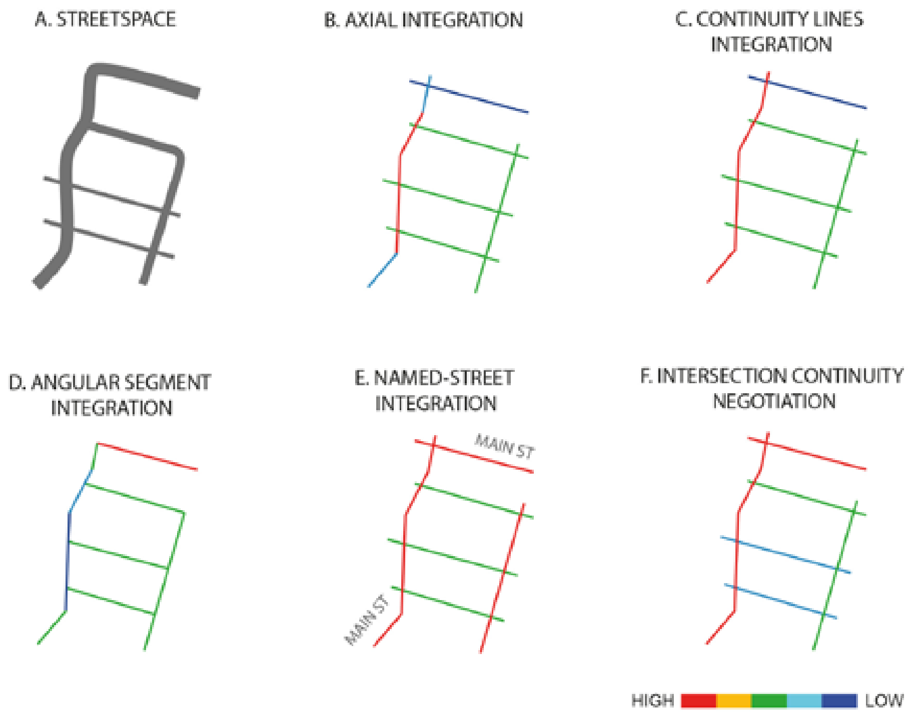

Figure 4 - Variations of the space syntax integration model.

While all these models and metrics are different, what they have in common is the attempt to translate smooth urban conditions into a striated measurable model, to iron-out ambiguities, hybrid and transitory conditions. They are reductionist, eliminating conditions of liminality, porosity and complexity, recognised as key attributes of urban intensity (Benjamin and Lacis, 1978; Sitte, 1889; Franck and Stevens, 2007). This is a similar problem as the use of cellular space syntax models for the analysis of fluid continuous interior spaces by converting them into models of clearly segmented spaces (Dovey, 2008: 61-83).

5. DISCUSSION

In actual cities, each of the limitations described above appear concurrently. In the following example all three types of limitations of axial models are exemplified based on a 1x1km frame of Amsterdam capturing part of the city core and the canal zone (Fig. 5a). The city core has irregular sinuous streets and small blocks as typical for informal settlements and medieval European cities. The 'canal zone' is defined by multiple regular polygonal rings around the core. This is typical for 17th-19th century urban extensions, such as in Vienna, Milan and Budapest. Translating the morphology into an axial model is problematic, because if it is based on 'lines of sight' the canals would need to be dismissed, but if based on access they need to be treated as city blocks. This highlights the problem of abstracting street sections to their axial lines. Similar problems become evident for wide boulevards with a median strip, or streets with a physical barrier along the axis. Some of these streets are easier to cross than others, and it is impossible to set a clear threshold as to when a wide street breaks down into two parallel streets.

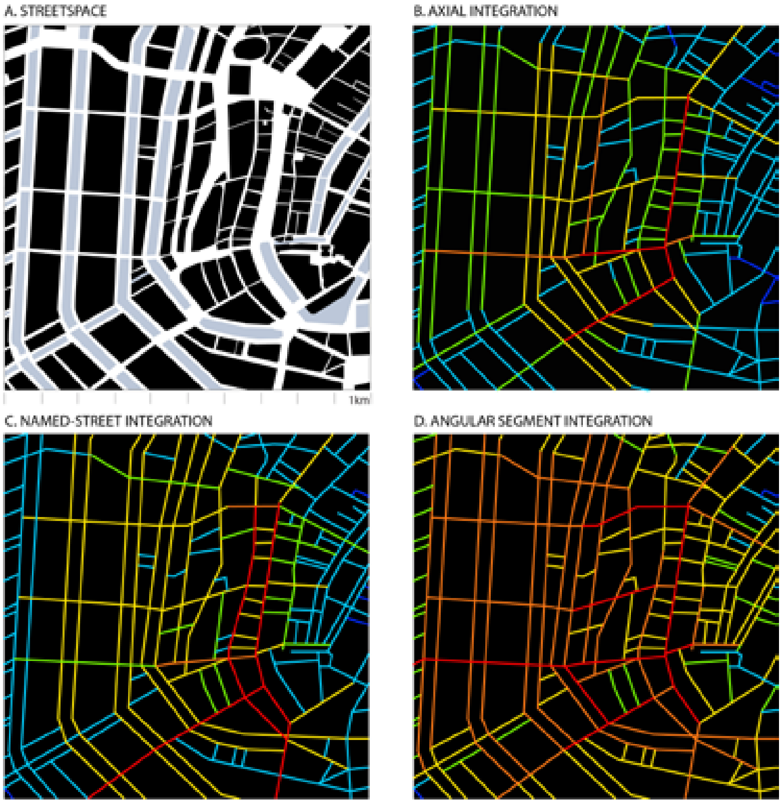

Figure 5 - Smooth morphologies in Amsterdam through three methods of space syntax analysis

Moving from the micro-scale to the neighbourhood-scale, reveals how representing continuous meandering streets as multiple axial lines doesn't correspond either to lines of sight nor to access conditions. The axial integration map (Fig. 5b) shows the canal zone as more integrated than the city core because of its straight streets, despite blocks being much larger. The polygonal rings are shown as less integrated where they turn in smaller increments. The named-street integration map (Fig. 5c) shows both the sinuous main streets in the core and the streets along the canals as highly integrated. This is entirely different from the integration map, and shows how meandering medieval streets and streets along canals are socially understood as continuous. The angular segment integration map (Fig. 5d) shows a less differentiated pattern, with the radial streets linking the canal zone to the core as the most integrated, again a very different outcome to the previous two maps. While each of these methods differ from each other, they are also very different from patterns of catchment and permeability, that are highest in the old core and much lower in the canal zone.

Through a series of models (Fig.2-5), it has been shown that the abstraction of streets to their axial lines poses several fundamental problems. First it eliminates the street section with its public-private interfaces, footpaths, benches and trees - all key elements of streetlife. Thus it does not recognise that the social logic of space is not just longitudinal but also transversal across the street. Second, it ignores permeability and interface catchment as key morphological attributes linked to walkability. Comparing these measures suggests that integration maps can be to analyse walkable access at neighbourhood scale. Third, such abstraction translates smooth urban conditions into a striated measurable model that irons-out ambiguities, hybrid and transitory conditions. This is a problem shared with much research based on statistical analysis in the fields of health and transport that seeks to establish direct correlations between a 'walkability index' and levels of walking. Such reductionism eliminates conditions of liminality, porosity and complexity, recognised as key attributes of urban intensity at street level.

Spatial syntax integration measures can be useful in studying larger urban networks, as they capture the morphogenetic tendency of busy streets to become straightened (Bosselmann, 1997; Kostof, 1999), but this is just one of many socio-spatial processes that shape cities. In order to better understand cities and their movement economies, a broad and open theoretical framework is necessary (Kärrholm et al., 2017; Dovey et al., in press), and correspondingly the use of a multiplicity of research methods. Spatial syntax analysis will be more useful, the more its limits are better understood.

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