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Background

The instruments presented here are: Spatial Integration Accessibility (SIA) and Angular Segment Analysis by Metric Distance (ASAMD) and they both belong to the wider theoretical and methodological field of space syntax developed in the Space Lab of University College London.

Space syntax is both a *theory* of urban planning and design and a software-based *technology*. It is an evidence-based approach to planning and design, with a focus on the role of spatial networks in shaping patterns of social and economic transaction. Through a configurational analysis of a street network, the Space Syntax methodology investigates relationships between spatial layout and a range of social, economic and environmental phenomena. These phenomena include patterns of movement, awareness and interaction; land use density, land use mix and land value; urban growth and societal differentiation; safety and crime distribution. Research using the space syntax approach has shown how: movement patterns and flows in cities are powerfully shaped by the street network; this relation shapes the evolution of the centres and sub-centres that affects the well-being of people in the city; patterns of security and insecurity are affected by spatial design; spatial segregation and social disadvantage are related in cities; buildings can create more interactive organisational cultures (Hillier and Hanson, 1984).

Space syntax methodology analyzes the movement network to quantitatively measure “spatial accessibility”. This approach utilises graph theory indices of accessibility, which measure spatial separation. The key focus is to describe the spatial impedance factors that separate locations, without considering the nature of the activities separated; to measure accessibility from a particular location to either all other locations in the study area or to all other locations that fall within a certain distance from the location under study. All destinations are accounted as equals and land uses are not considered during the initial analysis.

Conceptual framework and theoretical underpinnings

Both instruments are measuring what has been described above as spatial accessibility. However, each instrument is measuring spatial accessibility in a different way. SIA is using a spatial representation called axial line and on the topological distance between axial lines based on the number of steps from one line to the other while ASAMD includes in the axial analysis furthermore the angles of incidence between lines, the segmentation by junction of the axial line and the effect that metric radii would have on the choice of routes and the trips destinations.

SIA is concerned with the number of changes of direction that a journey from one place of the movement network of a city, to another would require. The notion of proximity in general and the perception of a location’s accessibility in a network of city streets in particular are affected by the experience of physical travel through an urban environment, which involves much more than a simple distance or time cost of reaching a location. Unlike metric accessibility measures, which rely strictly on distance or travel time, cognitive research on access also accounts for the ‘complexity’ involved in walking to a place. Spatial integration is considered very important because it measures the complexity of routes within an urban area and takes into account the important *subjective* dimension to accessibility.

Space syntax analysis argues that which locations appear accessible or remote and which paths are chosen to access a place, depend on people’s wayfinding skills and mental conceptualizations of the environment. It is suggested that the most accessible locations are not necessarily those closest to all other locations in terms of metric distances, but rather those closest in terms of topological turns (Hillier *et al.*, 2007). From a behavioral point of view, this assumption postulates that the cognitive complexity of the route, described as the number of directional changes on a route, is the primary consideration in pedestrian path choice, even more so than metric distance. Pedestrians are thus expected to prefer routes that involve less turns along the way, rather than shortest routes.

For ASAMD the indicators that are used in addition to the axial lines connectivity and topological distance are: the axial lines segmentation by junctions (segment map), the angularity between axial lines and the metric distance measured on axial lines' segments.

Consequently, this instrument is based on the axial lines segments between junctions; it allows three types (measures) of distance:

- Metric (shortest paths);
- Topological (fewest turns paths);
- Geometrical (least angle change paths).

The instrument then calculates accessibility at different scales (radii), local – intermediary – global, using the different types of distance. The scales (radii) can be assigned by the researcher depending on the research question, so that local can be for example 200m, intermediary at 800m and global at 2000m.

Both SIA and ASAMD calculate two main measures:

- Integration (closeness): how close each segment is to all others under different types of distance and at different scale, this is known as "to-movement". Integration describes how easy it is to get to one segment from all other segments. In practical terms this would mean that pedestrians would end up to such a space more often and with less effort. This spatial attribute can then define the type of land use that would fit best in this space. (for mathematical formula see Hillier & Iida, 2005);
- And choice (betweenness): how much movement is likely to pass through each segment on trips between all other segments, again using different types of distance and different radii. Choice describes how likely you are to pass through the segment on trips, and so it's potential as a route, from all segments to all others. Again, this spatial attribute can define the type of land use that would fit best in this space, possibly certain land uses would require spaces with a high integration value. (for mathematical formula see Hillier & Iida, 2005).

Operational aspects

Both SIA and ASAMD measure spatial integration accessibility which is the degree of spatial separation/integration in terms of the number of changes of direction and the angle of change of direction that a journey from one location to another would require. The analytic tool used is the "one-dimensional" or axial organisation: this refers to the global organisation of the system from the point of view of those who move in to and through the system; that is, in terms of its lines of access and sight. Syntactical analysis is commonly based on the axial map, the set of fewest and longest lines of sight passing through every public space in a city's street network. The map shows the relation of each line to the network of the whole city ('global' relations) or the relation of each line to the immediate surroundings ('local' relations). Space Syntax researchers measure travel from one line to another across the graph in topological terms, using the count of lines traversed (i.e. changes in direction on axial lines) as a metric of proximity, referred to as *depth*. It is used as a kind of distance measure, which represents the minimum number of axial lines needed to go from an origin to any other segment in the network. The depth measure leads to another central metric: *integration,* which quantifies relative depth from any space to all other spaces (see Hillier, 1996). The integration measure is a relative description of each axial line's depth with respect to all other axial lines in the graph. It is obtained by repeating the depth measure from each line to all other lines in the system and normalizing the obtained sums for each line by the total number of lines in the graph. The integration measure thus outlines which axial lines require the least amount of connections to access from all other axial lines in the network. Maps are coloured in a scale from red to blue, or black to white in an grayscale map, to indicate the high-to-low range of values (see Figure 1 and Figure 2).

Data that are required for the calculation both of SIA and of ASAMD is only a vector basemap of the area or the city. If the basemap is on vector format the segment map will be automatically generated but even image files of maps can be adequate, although the segment maps would need to be drawn manually. Research by Turner (2007) which replaced the segment lines with road-centre lines has shown that road-centre lines can work equally well for transport analysis. Furthermore, road centre line data allows for whole regions or even whole countries to be modelled without spending time on the manual production of the axial/segment map. Obviously, the data requirements are at minimum and easily, in most cases available, which count for easy use.

The analysis of the segment map can be produced by Depthmap (Turner, 2001; Hillier, 2009). Depthmap runs on Windows (2000 and XP are the older versions). The software was available only for academic use until recently but now is publicly and freely available and it is provided as open-source.

The calculation time depends on the size of the urban area analysed in combination with the number of lines or segments per map. Usually for small urban areas of a neighbourhood it wouldn't take more than a few minutes. The analysis of a whole city can take up to a few hours depending on the size. The analysis is calculated automatically without any special knowledge or technical expertise by the user. As soon as a correct segment map is imported in the programme it is matter of a sequence of simple commands to produce the model. However, wide knowledge based on the theory of space syntax and on basic principles deriving from it is required in order to interpret the results. Inadequate knowledge of the main concepts behind the analysis can confuse or lead to naïve and simplistic assumptions.

Depthmap also offers the capability of extension through two levels of interface. The first level, a scripting interface based on the Python language, allows researchers to calculate new derived measures as well as to add graph measures, such as circuit lengths, for each of the graph types. It also allows the ability to select groups of nodes according to value or according to simple algorithms. The second level, the Software Developers' Kit (SDK) allows programmers to write new forms of analysis.

Relevance for planning practice

The information that the instrument produces can be relevant for planning practitioners:

- To inform them on the constraints and opportunities of urban areas with regard to the street network and how it can attract or deter pedestrian movement so that land use strategy is better aligned to the pedestrian movement opportunities;
- To offer insights on how the area can be optimised in its context regarding its commercial viability, the potential for retail, the design of sustainable development and the creation of vibrant and lively urban spaces;
- And finally it offers the possibility to test different strategic guidelines and design proposals.

The space syntax approach has been used in practice since 1984, particularly the Angular Segment Analysis by Metric Distance since 2006, in a variety of urban problems in several countries which include the UK, Saudi Arabia, China, USA, Chile and many more, with partners from both the private and public sector. In Greece it has been mostly used for research urban projects and therefore there hasn't been any feedback from applications in practice. At the moment SIA is in the process of being applied in Cyprus through a research project which has been prepared jointly by Nicosia Municipality (planning department) and academics, including the author, from the University of Cyprus.

The instrument addresses a number of issues relevant to the formation of a land use strategy and location: to help boost the economy, to revitalise central areas, to increase social sustainability and to improve cycling and pedestrian access. The instrument offers an evidence-based approach to decision making by informing on the accessibility and walkability of an urban area and by helping to test strategic interventions and design proposals. The value of the instrument in the planning outcome and in the decision-making process is that it gives a scientific and objective tool by which the proposals could be tested and evaluated regarding spatial accessibility and pedestrian movement and how these attract land use.

Strengths and limitations

The instrument is a strong tool for analysis and evidence based design that has been tested both in research and in real practice problems and been proved successful. One of its weaknesses could be considered the fact that it is based on a wide theoretical basis which makes it difficult for someone, in either the scientific or the practical field, to instantly understand and accept. In what follows some of the main positive and negative reactions of planning practitioners to the instrument are presented. These derive mostly from the application of the instrument in countries other than Greece and Cyprus as in these countries it has been only used for research.

Positive reactions include:

- The instrument provides clear and undisputable metrics and therefore it is objective;
- It has been proved very useful in stakeholder negotiations since it can be trusted more than just an architect's or urban planner's experience or intuition;

- It introduces science in the field of architectural and urban design in relation to accessibility, where this did not exist in the past. Traditionally, accessibility was mostly related to transport and land use planning;
- It reduces the risk in strategic or design decisions as it offers an evidence-based assessment regarding the spatial accessibility potential of each proposal;
- It provides very illustrative and easy to "read" visualisation.

Negative reactions are:

- The instrument is not a "theory of everything" as it is many times expected. People have too high expectations and anticipate that it should explain everything. However, the instrument explains pedestrian movement quite well and therefore also land use patterns and to a certain degree socio-economic sustainability;
- The instrument itself and especially the theory behind it are very complicated and take time to understand. This makes it more difficult to use in support of decisions in public engagement situations where time is limited;
- There is very often an overemphasis among urban designers on 'architecture' and 'attractors', so they don't believe that there is a strong connection between accessibility and the functionality of the city;
- There is reluctance among practitioners for the use of models in general. They believe that parties in possession of a model can argue whatever they want because they justify it with the modelling, and they don't seem to always like that.

Criticism of this approach from a scientific point of view is usually based on the fact that all paths/axes are weighted equally in the analysis. So, a street that has no buildings on it is weighted equally with a street that has a number of tall buildings; an area covered with residential land uses is weighted equally with an area full of commercial land uses. Criticism also points out that interpretations of the spatial phenomena need to take into account additional information that is not readily available through a configurational analysis. The method does not account for the three-dimensional geometry of the built environment for example, nor the land use characteristics of the network. The addition of three-dimensional built-form indicators as well as land use characteristics would allow graph measures to capture a more realistic description of the built environment and address some of the criticisms. Research towards these criticisms is in progress (for the three-dimensional built form see Mavridou, 2012; for land use characteristics see Ortiz-Chao, 2008).

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Figures

Figure 1 Spatial accessibility analysis of Nicosia, Cyprus

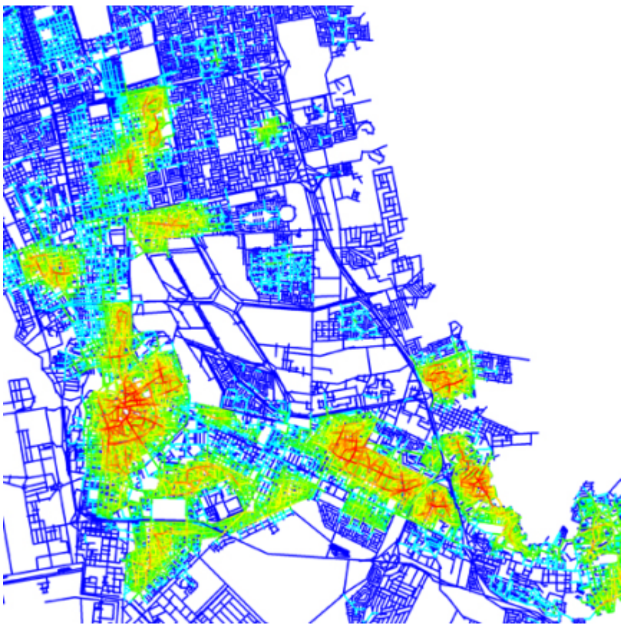

Figure 2 Angular Segment Analysis by Metric distance of the city of Jeddah, SA (by Space syntax Ltd.).