KTH School of Architecture

Place Syntax
- Geographic Accessibility with Axial Lines in GIS

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1. Introduction: integrating space syntax and accessibility research

Since the beginning there has been a strong and pervasive emphasis within space syntax on description. In a not so often referred to text (Hillier et al 1984a) this is put quite straightforward: “For the architectural researcher, the question ought to be crystallised as his or her most pressing concern, since how can any investigation be truly systematic unless the architectural variable can be controlled?” It might sound self-evident to researchers within most disciplines but within architecture the subject of description is often treated without the necessary scientific care. From the beginning there has also been a strong conviction that architecture needs to be described and studied in its concrete manifestations, that is as architectural physical form rather than as architectural ideas, hence the residence of space syntax in architectural and urban morphology rather than architectural history and theory. It also seems likely that this development of form-studies within architectural research can contribute much to other disciplines.

One such discipline that could gain from architectural research of this kind is geography and transportation science with its wide range of subdisciplines, where the field of accessibility research is the one that comes closest to space syntax. As a matter of fact, from within this field space syntax is likely to be regarded as nothing else than a special case of accessibility, for example: “[…] space syntax which we consider a special case of accessibility within graphs” (Batty 2004a). In a simplistic sense the difference between space syntax and accessibility research in general has to do with scale, where accessibility research to the most part have been conducted on a comprehensive geographic level, while space syntax deal with a more detailed geometric or morphological level. But in a more specific and interesting sense the difference has to do with the epistemological foundations for either field, where space syntax, even though to a large part rooted in a mathematical paradigm just like accessibility research, also draws in an interesting way from an experiential and cognitive paradigm, something pointed out by Seamon (1994) and specifically discussed in recent papers by Hillier (2003a and b).

Against this background it seems most useful to try to use space syntax descriptions when bringing accessibility research to the more detailed scale of urban settings, foremost by bringing the experiential dimension to such studies. This has also been both suggested and done by Jiang et al (1999), where both the mathematical background and the actual development of a software extension Axwoman for the GIS ArcInfo using space syntax are presented. In our paper a similar route is taken leading to the development of a software extension called The Place Syntax Tool for the GIS Mapinfo, but where the emphasizes lie on the empirical testing of such a device rather than its mathematical theory.

Our tests we believe show results that open new possibilities for not only accessibility research in general but specifically space syntax as well. For accessibility research in that the descriptions developed within space syntax, such as the axial map, are shown to work better in predicting such things as pedestrian movement than conventional descriptions within spatial analysis. For space syntax in that the results show how similar predictions within space syntax can be improved with the possibility to load the axial map with geographical data. We furthermore believe that this marriage between accessibility and architectural research have epistemological implications of great use for urban planning practice, in that it brings to such practice knowledge that rests on descriptions that take into account the experiential dimension, where knowledge traditionally within this field rests on rather abstract system-descriptions. Implicit in this we see nothing less than a possible displacement of power.

2. Accessibility research: geographic and geometric accessibility

For a long time accessibility research of human behaviour was limited by the kind of data and analytical tools available. For example “there was no effective means for representing or dealing with the spatial complexity of a realistic urban environment”, neither did past studies “incorporate data about a person’s cognitive environment into the analytical framework” (Kwan 2000). In the past decade many steps have been taken to overcome these limitations, for example, “instead of using the straight-line distance between two locations, the actual travel distance over the transportation network can be used” (Kwan 2000). Kwan et al (2003) states that still much remains and especially the understanding of our cognitive environment is pointed out to be a crucial issue (Kwan et al 2003).

Accessibility is a widely used spatial analytic measure defined as the relative ‘proximity’ of one place *i* to other places *j*. In generalised terms, the measure can be defined as:

$$A_i = \sum f(W_j, d_{ij}) \qquad [1]$$

where W_j is some index of the attraction of *j* and d_{ij} is a measure of impedance, typically the distance of travel time of moving from *i* to *j*” (Jiang et al 1999). From this definition it is easy to see how space syntax does not deal with the full concept of accessibility, in that one rarely deal with W_j or any indexes of place attraction.[1] Another way of putting it is that accessibility research deals with ‘places’, where ‘place’ simply means a geographically specific space, a location, or a space with a specific content, while space syntax only deals with ‘spaces’, i.e. spaces or locations with no specified content and thereby no measurable attractivity. This straightforward distinction, between space and place, can be said to be the basis of what Jiang et al (1999) distinguish as ‘geographic’ and ‘geometric’ accessibility.[2] Hence, if geographic accessibility is the proximity of places, then geometric accessibility is the proximity of spaces, i.e. setting $W_j = 1$. Geometric accessibility can be defined as:

$$A_i = \sum A_{ij} = \sum f(d_{ij}) \qquad [2]$$

[1] As discussed in the introduction, this is one of the points with space syntax, trying to develop descriptions whereby the architectural variable can be controlled.

[2] What is called ‘geometric’ here seems to come close to what is also known as ‘pre-geographic’ (e.g. Miller 2000).

From this Jiang et al (1999) has shown why space syntax from the point of view of accessibility research is a special case of geometric accessibility.

Defining how to measure d_{ij}, the ‘distance’, ‘transport cost’ or ‘energy effort to move’ from *i* to *j*, is then obviously a critical part of a accessibility measure, and in a geometric accessibility measure *the* critical part. The most common distance units used within accessibility research are: topological steps in a network, Euclidian metric distance, travel time, travel cost and monetary charges. But it is exactly concerning such descriptions and measurements of distance one have encountered problems within accessibility research when moving from the comprehensive level of geography to the detailed level of urban settings: “what is dramatically absent are tools for developing accessibility measures at fine spatial scales which involve the geometry of urban structure in terms of streets and buildings in contrast to the measurement of accessibility at the geographic or thematic level” (Jiang et al 1999).

We then also see that it is here the morphological descriptions developed within space syntax can prove useful and can contribute to accessibility research.

3. Space syntax: mathematical and phenomenological descriptions

The kind of morphological descriptions developed within space syntax, such as the ‘axial map’, turns out to be rather unusual entities. The normal procedure when using graphs to describe a street network, the street-junctions are represented as nodes and the street-segments connecting these as arcs. In the axial map this is done the other way around, the streets (axial lines) are the nodes and the junctions are the arcs. This is unusual within spatial analysis and has called for space syntax to “be translated into a more familiar analytical frame” (Batty 2004a).

The morphological descriptions developed within space syntax, ‘the axial line’, ‘the convex space’ and ‘the isovist’,[3] all have their rationale from the point of view of human experience; visibility in respect of movement, visibility in respect of co-presence and visibility per se, respectively. In short they are all representations of the phenomenological bottom-line of being in the world. It is here that David Seamon (1994) has pointed to a characteristic of space syntax, not so often acknowledged, namely a strong phenomenological strand inherent within its ideas as well as descriptions.[4]

Now, the truly original thing is the brave reduction of these existential notions - that within architectural theory often has lead to concepts difficult to handle analytically[5] - into simple geometry. The originality should not be under-estimated, since what happens is that the two fundamental epistemological paradigms of mathematics and phenomenology here merge in a simple geometric description. This must be a fundamental reason why the rather plain appearance of the axial map turns into such a powerful tool.

4. Distance unit: the axial line

According to Bill Hillier (2003b): “From an experiential point of view, cities seem to be about seeing and going. Syntactic analysis confirms this by showing they are structured both to make the physical movement of bodies efficient and to be intelligible to minds.” This is a strong argument for the axial map, which consequently seems to capture both the characteristic spatial structure of different urban areas, as well as the cognitive character of such areas. The argument

[3] The isovist was introduced by Michel Benedikt (1979).

[4] In recent papers by Bill Hillier this is brought to the forefront and discussed in depth (Hillier 2003a and b). In the future we therefore might see as many references to Merleau-Ponty as to Levi-Strauss in future space syntax literature.

[5] For example the concept of ‘Genius Loci’ (Norberg-Schultz, 1980).

for the axial line rather than e.g. metric distance can then be made: If we make a straight line crooked “we do not add significantly to the energy effort required to move along it, but we do add greatly to the informational effort required” (Hillier 2003b), a dimension impossible to capture with metric measures.

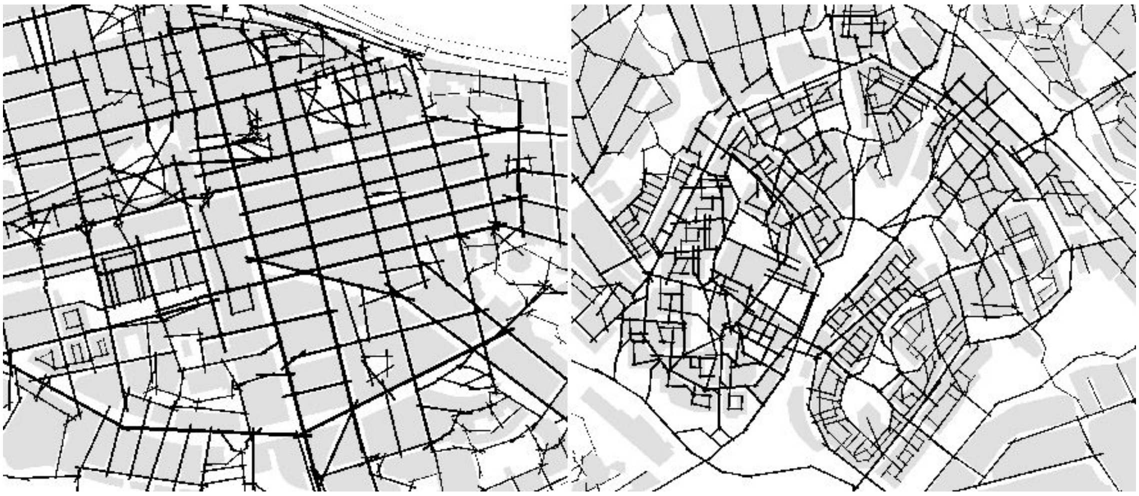

Figure 1. Global integration (radius-n) for the ‘deformed’ grid in Södermalm (left) and the ‘interrupted’ grid in Högdalen

The axial map can be said to both embody what Jurgen Habermas (1984) call the system and the life-world or what Henri Lefebvre (1974) calls space as conceived and space as lived and perceived. Firstly, this points to the conclusion that what is truly original within space syntax is maybe not so much the configurative approach, which can be found within other directions of spatial analysis, but its descriptive elements, like the axial line. Secondly, it points out how one within space syntax has developed something that could be called an ‘anthropocentric geometry’, a category that can be both applied and further developed within other fields of science as well.

5. Spatial integration and movement: the problem with interrupted grids

The ability of axial maps to capture movement has been proven in a magnitude of studies over the world by now. Still, we need to be absolutely clear that this is ‘natural movement’, which is defined as “the proportion of movement that is determined by the configuration of space itself, rather than by the presence of specific attractors or magnets” (Hillier et al 1993). In organically developed urban settings, such as the city-centres of most European cities, what within space syntax is referred to as “deformed grids”, population densities are quite evenly distributed. Over time this has also lead to an even distribution of other ‘attractions and magnets’, such as shops and tube stations. Hence this can explain ability of the axial map to capture movement in itself in such urban areas (Hillier 1999).

Now, what about urban areas that are not of this kind, with uneven distributions of populations, with distribution of attractions that contradict the configurative descriptions of space? The question is essential since so large parts of contemporary cities are constituted by suburban fabrics of this kind, which within space syntax are referred to as “interrupted grids”. It is furthermore often these areas that are problematic and call for further planning and design interventions and therefore need to be understood better.

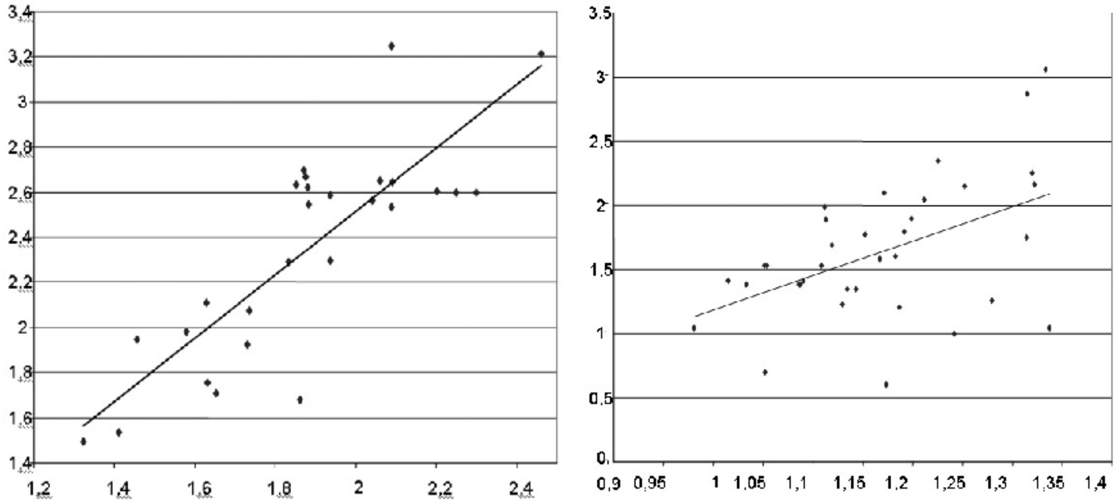

Figure 2. Correlation of global integration (radius-n) and observed pedestrian flows in Södermalm (R^2=0,6812) and Högdalen (R^2=0,2467)

Two areas in Stockholm with the distinct character of ‘deformed’ and ‘interrupted’ grids respectively, Södermalm and Högdalen, were analyzed according to praxis for axial maps and integration. Observations were carried out at 28 gates for Södermalm and 41 gates for Högdalen, once again following normal procedure within space syntax. The observation data was then correlated with global and local integration showing a very strong correlation in the deformed grid of Södermalm (radius-n, R^2=0.68) but a considerably weaker correlation in the interrupted grid of Högdalen (radius-n, R^2= 0.25). Even though objections could be raised that the amount of gates are rather low, we believe that the study shows are rather well known fact; axial integration analysis does not predict movement in interrupted grids as well as in deformed grids.

6. Urban heterogeneity: the problem with densities and areas

The issue of densities and areas has to be mentioned here. To deal with densities of different kinds, is central to urban morphology and urban planning practice (Talen 2003). Conventionally density is calculated as the average density in a geographically defined area (city, district, block, plot). Density measures presuppose that all data are equally distributed within the defined area, and to some extent also that accessibility is equally distributed, when used in the planning scheme. The measure does not separate place data on the edge from place data in the centre of the area, neither the possibilities to move between them. A fundamental problem with a geographical area is in addition what happens on the ‘outside’, besides the problem of local differences ‘inside’. The problem of the ‘geographical area’ also increases with area size and the amount of place data.

Figure 3. Conventional map of population densities (living and working/sqm) per plot in Södermalm and Högdalen (darker higher density). Maps are comparable in terms of colour.

Urban planning and design maybe have use of density mapping for estimating development economy but they are of little use when it comes to predicting movement, crowding and potential urban life in urban space. While urban morphology traditionally in this way has focused on descriptions of urban elements (Talen 2003), one has within space syntax always stressed the relations between elements, the configuration, which is as mentioned the field of accessibility.

7. Place Syntax: geographic accessibility with axial lines

We now seem able to set up an almost symmetric problem. On the one hand we have accessibility research and urban morphology in general where one lack of experiential descriptions of urban form. On the other hand we have space syntax where one has problems integrating place data in certain urban areas for, e.g. predicting movement.[6] Thus it seems very natural to try axial descriptions as a measurement of distance within geographic accessibility. On the one hand this would mean a possibility to 'load' geographical data for improved predictions of pedestrian movement within space syntax. On the other hand, and more interestingly, this would mean an improved tool for accessibility analysis in general; the linear, rather than for example the metric, accessibility to any asset or service we find in a city. It is exactly such a tool we have developed as an extension to the GIS software Mapinfo and given the name The Place Syntax Tool.[7]

From the perspective of Space Syntax, in Place Syntax we mean to put back attraction of W_j into the geometric accessibility formula [2]. And from geographic accessibility formula [1] we want to put the axial line into d_{ij}

$$d_{ij} = h(\Gamma(x_{ij}^m, y_{ij}^m, t_{ij}^m, e_{ij}^m, ...), \theta^s) \qquad [4]$$

where, $\Gamma(\cdot)$ is a representation of space, and θ^s is a vector characterizing the preferences of individuals. The representation of physical space may utilize many different variables. For instance, x_{ij}^m is walk distance and y_{ij}^m is bird's distance both by mode in meters, t_{ij}^m is travel

[6] We shall keep in mind that the 'lack' of description of spatial content is deliberate within space syntax, since one wants to 'control the architectural variable'.

[7] The name *Place Syntax* was first suggested by our colleague Daniel Koch, who furthermore has been a great support for our work with *The Place Syntax Tool*.

time by mode, and e_{ij}^{m} is the number of axial steps by mode m. The full Place Syntax formula, a ‘geographic accessibility measure with axial lines’ then looks like this.

$$A_i = \sum_j f(g(W_j, \theta^a), h(\Gamma(e_{ij}^m), \theta^s)) \qquad [5]$$

This formula is the major task for The Place Syntax Tool. The tool however also manages to calculate x_{ij}^{m} and y_{ij}^{m}, respectively, and also a combination of e_{ij}^{m} and x_{ij}^{m}.

8. The Place Syntax Tool

Together with a group of students at the Department of Numerical Analysis and Computer Science at KTH,[8] we have developed the Place Syntax Tool (PST), an application for the desktop software MapInfo[9]. PST consists of two main components, MB (MapBasic) and DLL (Dynamic Link Library). The MB-component is written in MapBasic and implements reading and writing in MapInfo’s own databases. The DLL-component is written in C/C++ and is compilated as a DLL. It takes care of the GUI (Graphical User Interface) and does the accessibility calculations. The two communicates through a communication interface integrated within the DLL.

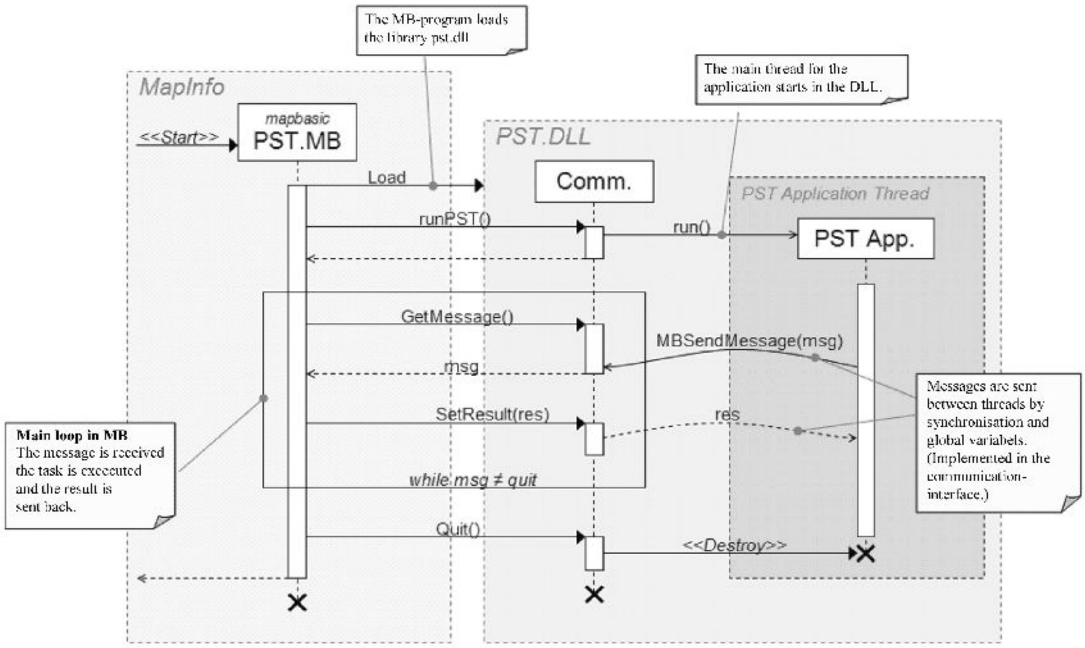

Figure 4. Software structure of the Place Syntax Tool.

The GUI has two main windows. In the first window all tables are selected: input place data (plots or address points) and output place data (where the results will be distributed: plots or address points), axial lines and ‘unlinks’ (points where crossing axial lines do not connect), links (e.g. address points which link plots to closest axial line).

[8] Gustav Algotsson, Martin Fitger, John Jansson, Ranin Jouda, Björn Lalin, Göran Lindmark, Linus Löfström, Max Thoursie, and Hanna Wijkström.
[9] http://www.mapinfo.com/

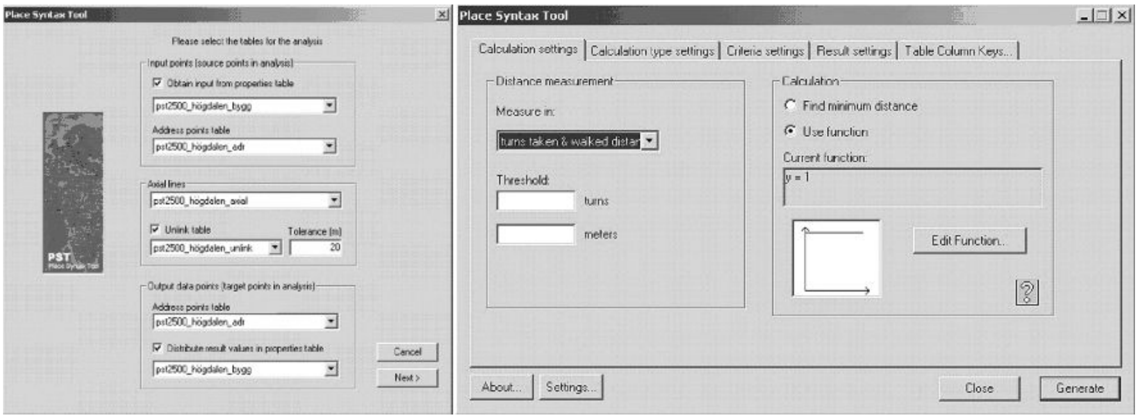

Figure 5. Window 1 (left) and window 2 (right) in the Place Syntax Tool.

The second window is for selecting type of analysis and consists of five pages. In the 'Calculation type setting' page you can choose to calculate from all places or just from a single place. In the 'Criteria settings' page the column for desirable place data is selected. Here you can choose multiple columns. Data can also be normalized and given a relative weight. In the 'Result settings' page you choose how results are displayed, in a table or on a coloured map in MapInfo. Here there is also a critical section where you on the one hand decide how data on input place data are distributed to the address points, divided with the amount of address points or the full value to all. Similar to that, the output place data has to be determined, whether they are to collect the mean, max or min of the result values at the address points (that is if you do not choose to display them on the address points). In the 'Table Column Keys' page you select the key columns that connect, e.g. address points and plots.

9. Empirical test: set-up

The first thing we wanted to examine was if accessibility to population or built floor area, measured metrically or with axial lines, would correlate with observed pedestrian movement and if so how it would compare with the integration analysis. The two urban areas already presented, Södermalm and Högdalen, were once again used.[10] They are delimited for maximum convexity and so that their size is 100 hectares each. Axial maps with buffer zones were constructed for the two areas where the deformed grid of Södermalm turned out to have a mean axial line length of 221 meters and consist of 131 axial lines, while the interrupted grid of Högdalen had a mean axial line length of 100 meters and consisted of 435 axial lines. Observations of pedestrian flows were conducted at 28 gates in Södermalm and 41 gates in Högdalen during two days (one rainy and one sunny), at five different times during both days, each lasting five minutes. In this way each gate was observed 50 minutes in total.[11]

Four types of accessibility analyses with ten different radii (d_{ij}) were executed with PST: accessibility to population[12] measured with axial lines, floor area with axial lines, population with walk distance, population with bird's distance.[13] The analyses where also tested with two different radii of the buffer area: 700 meter and 2500 meter (both birds' distance). The latter was based on the general rule of approximately 30 minutes walk distance[14] around a study area, often used within space syntax. Correlations between the observed flow (logarithmic) and the

[10] See also statistics on Stockholm, see http://www.stockholm.se/usk. Go to ”In English” > ”Data Guide”.

[11] The observations in Södermalm roughly corresponded with earlier studies by Marcus (2000).

[12] Population is here calculated as the sum of population in housing and work places.

[13] GIS-statistics on floor area, night and day population are from 2003 and come from the Stockholm Office of Research and Statistics (http://www.stockholm.se/usk). Geodata of address points and plot regions comes from the Stockholm City Planning Office.

[14] i.e. a walking speed of 5 km/h.

accessibility analyses using PST, as well as integration analyses using Webmap, were then compared.

10. Empirical test: findings

The main findings in our empirical test are basically of four types.

1) Buffer zones. To begin with, our test of different buffer zones surprisingly shows that buffer radius does not seem to have a major impact on values and correlations.

		Buffer zone 700 meter	Buffer zone 2500 meter
Söder-malm	SS integration r-3	0,6458	0,6462
	SS integration r-n	0,6812	0,6858
	PST population r-3	0,6811	0,6823
	PST population r-10	0,5804	0,5857
Hög-dalen	SS integration r-3	0,1424	0,0948
	SS integration r-n	0,1594	0,2467
	PST population r-3	0,2589	0,2598
	PST population r-10	0,2392	0,1938

Table. R2-value for different buffer zones around study areas Södermalm and Högdalen.

This finding can however be questioned because of the segregated spatial structures of both study areas. Södermalm is basically an island and Högdalen is a quite homogenous city district surrounded by road barriers in a very heterogeneous suburban landscape. On the other hand, the Södermalm area should be affected by its buffer because of the low mean depth, and Högdalen because of the extremely different space structure in the buffer zone. The above findings nevertheless indicate that buffer zones can for practical reasons, at least in Stockholm, be constraint to at least 1000 meters. The major comparisons and findings below are however made with the 2500 meter buffer zone, to secure any global effect.

2) Pedestrian movement prediction. We can conclude that PST, when calculating accessibility to population or floor area measured with axial lines, predicts pedestrian movement at the same level as an integration analysis in the ‘deformed grid’ of Södermalm, but, more interestingly, considerably better than integration analysis in the ‘interrupted grid’ of Högdalen. The apparent reason is that PST captures the heterogeneous distribution of population densities in and around Högdalen (Fig 3). Even though the correlations are lower in Högdalen all over the line than in Södermalm, the R^2-value 0,4417 for PST (axial, pop, radius-6) must be considered fair. The variations in correlation using the different measurements are however interesting in themselves, and probably tell us something fundamental about the planning paradigms used in the two areas.

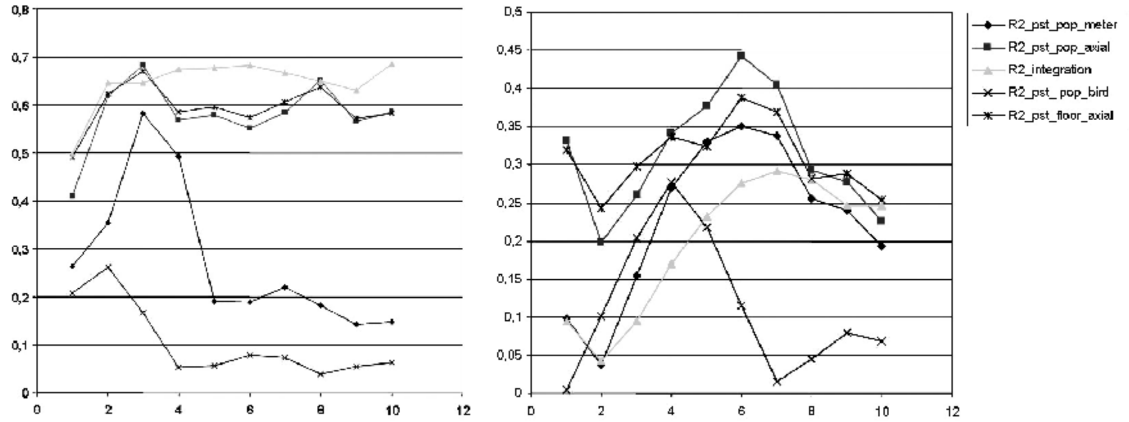

Figure 6. R^2-correlations for different radius of Space syntax integration-axial line (10=n), Place syntax floor area-axial line, Place syntax population-axial line, Place syntax population-walk distance (*100), Place syntax population-bird's distance (*100).

Furthermore, since calculations with PST are based on absolute numbers of population a coefficient can be derived by dividing the observed movement-values with the place syntax value. This 'movement production coefficient' can then be used to predict movement in places not observed, in absolute numbers, not only relatively as in the integration analysis. Taking the measures with the best correlations, the axial population configuration r3-coefficient for Södermalm is 0,013 and the axial population configuration r6-coefficient for Högdalen is 0,026.

3) Distance measures. We can conclude and confirm that the axial line is superior to any metric distance measure, walk or bird's distance, especially in the 'deformed grid' of Södermalm, where most trips are likely 3 axial line steps.[15] When comparing the two areas in terms of different radii it is very clear that they have different correlation peaks, and hence great differences in pedestrian movements. At Högdalen it seems that most trips are 6 axial lines or 600 meters. I.e. most trips are probably generally shorter in Södermalm.

Figure 7. Map of accessibility to population r-3 Södermalm-area (0-60 000 persons) and r-6 for the Högdalen-area (0-11 000 persons). Maps are not comparable in terms of colour. (Darker higher' configurative' population)

4) Density configurations. Comparisons of space syntax and place syntax make it possible to analyse the connections between spatial configuration and spatial distribution of densities. For

[15] Note that metric walk distance correlates considerably well for r-300 meter in *Södermalm*, the drop between 400 and 500 is intriguing.

example the low mean depth in Södermalm makes the correlations good for all radii > 2 using integration analysis. The same is true for the place syntax analysis, both when calculated for population and floor area, though with small peaks at r-3 and r-8. The latter can of course lead to speculations. People (housing) live and move locally and businesses move and attract globally. This does seem likely to be the case but it has to be further investigated.

11. Place syntax: a discussion

We believe that the place syntax approach could be further generalised and contribute to other fields of spatial analysis, and also be useful to urban planning and design practice. These new realms of geographic accessibility analyses with axial lines are however so diverse that only empirical investigation will show their usefulness. To begin with we could anyway make some rough categories of Place syntax analyses.[16]

a) Between all places: This means calculating how many places there are within a specific radius from all places[17]. It could for example be 'configurative constitution', i.e. the number of entrances, or 'plot configuration', which would be the number or the total size of "accessible" plots/properties. The latter could, as discussed by Marcus (2000), say something about diversity of events and occupation in urban areas.

b) From all places to an attraction: This means calculating the number or the sum of the value of a specific attraction within a specific radius from all places. This implies a 'supply' or LOS (Level Of Service). It could be for example the number of shops, or the amount of green space. To combine these two would be a simple measure of urban attraction.

c) Between same attractions: This means calculating the number or the sum of the value of a specific attraction within a specific radius from the attraction. This could be a measure of ´clustering´ of attractions or possible competition/corporation between businesses.

d) Between different places/attractions: This means calculating the number or the sum of the value of a specific attraction within a specific radius from another attraction. This can be for example used for linking households and jobs, people's accessibility to work etc.

e) Place population: This means calculating the number of people within a specific radius from all places. This can, as shown in this paper, be used for pedestrian movement prediction. As shown, population can be exchanged with amounts of floor area, for this purpose.

f) Attraction population: This means calculating the number of people within a specific radius from an attraction. Prime urban examples are of course the number of possible customers to a shop or visitors to a park.

[16] See also the posters "Park Syntax" and "Plot Syntax" presented at this symposium, where the application of the tool is further investigated and tested.

[17] 'all places' practically means in GIS all address points or property regions within the study area.

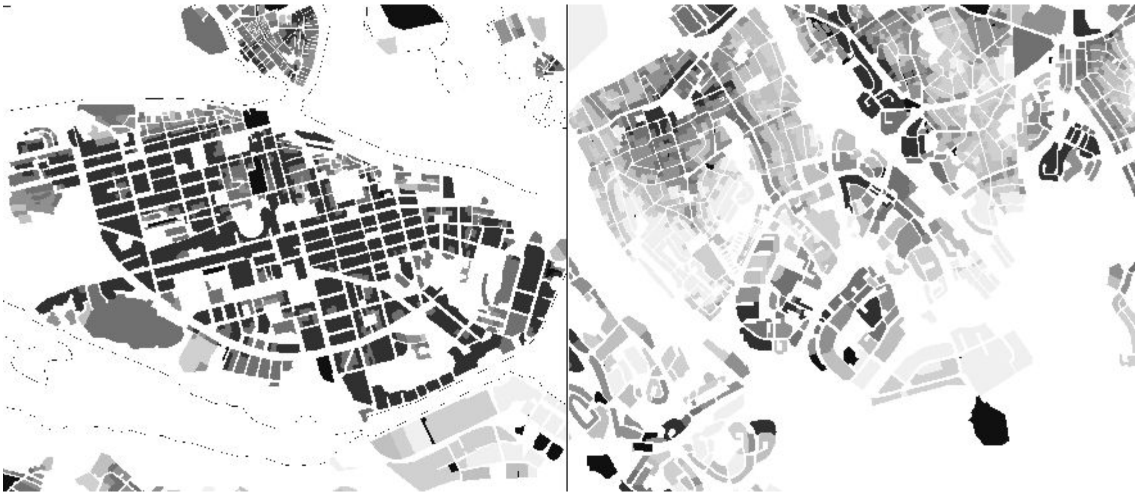

Figure 8. Closest food store within axial lines. Maps are comparable in terms of colour. (Darker is shorter distance)

As with all analyses of accessibility and configuration there are complex of qualitative factors that are difficult to take into account as put forth by Kwan et al (2003) among others. There is also what Michael Batty defines as "the primal and dual problem of graphs" (2003a), that conventional spatial analysis gives precedence to points or areas, and space and place syntax emphasizes lines. From this one can also draw the conclusion that the experiential or the cognitive point of view has not won much acclaim within spatial analysis, that is that one deal with system descriptions rather than life-world descriptions and that it is the former that dominates the foundations of urban design and planning practice. A switch in geographic accessibility analysis from points to lines might then imply more than it at first seems, namely design resting on knowledge derived from the point of view of the people designed for rather than from the bureaucracies of planning and design.

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