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NORDISK ARKITEKTURFORSKNING
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INNOVATIONS IN MEASURING DENSITY: FROM AREA AND LOCATION DENSITY TO ACCESSIBLE AND PERCEIVED DENSITY

META BERGHAUSER PONT AND LARS MARCUS

Abstract

Although density has been an important concept for urban design and planning ever since the 19th century, it is an imprecise concept with varying definitions and measurements. This is annoying as the concept is central to strategies for sustainable urban development which have gained wide support since the 1990s. This paper gives a brief review of the most frequently used urban density measures and their shortcomings. In this paper, we will further show that a multi-variable definition of density as proposed in the Spacemate method is needed to capture important morphological qualities that otherwise are lost in abstract numbers. The paper also addresses the Modifiable Area Unit Problem inherent to all measures of urban density, and proposes to solve this by introducing accessibility in the density measure. Defining distance is obviously a critical part of the accessibility measure and it is therefore proposed to use the axial map developed in space syntax, to measure distance. The axial map is a geometric representation of urban space based on graph theory, constructed from the point of view of a cognitive subject, i.e. an experiencing and acting human being. By doing so this paper arrives at a measure of accessible density that even can be understood as a measure of perceived density.

Keywords:
urban density, morphology,
accessible density, space syntax,
perceived density

Introduction

The concept of density is important for urban design and planning, but the definitions and the use of the concept has varied greatly through modern history. At the beginning of the twentieth century, Raymond Unwin claimed that nothing was to be gained from overcrowding in cities; he proposed a standard density of 30 dwellings per hectare *maximum*[1] (Unwin, 1912). Fifty years later, Jane Jacobs suggested that a *minimum* of 250 dwellings per hectare[2] was a necessary condition for a vital and participatory city life (Jacobs, 1961). Today high densities are often seen as prerequisites for economic growth and sustainable urban development (e.g. Hall, 1999; Florida, 2005; Jenks, Burton and Williams, 1996; Lozano, 2007; Newman and Kenworthy, 1999). Various strategies for sustainable urban development have increasingly fused under the heading smart growth in which density plays an important role (Frumkin, Frank and Jackson, 2004) and have as such gained wide support, not least by the United Nations[3], as the viable way forward. A review of research regarding smart growth published since 1985 reveals how *density*, or its counterpart sprawl, are highly imprecise concepts and, moreover, that the way they are measured is decidedly inconsistent and almost by rule varies from paper to paper (Colding, et al., in press). The confusion around such an important concept is disturbing and we therefore find an urgent need to re-address the issue of measuring urban density with a focus on its usability for urban design and planning.

In the following we will briefly review the most frequently used urban density measures and their shortcomings and then show that a multivariable definition of density is needed to capture important morphological qualities that otherwise are lost in abstract numbers. Further, we will address the Modifiable Area Unit Problem inherent to all measures of urban density, by introducing accessibility in the density measure. Defining distance is obviously a critical part of the accessibility measure and we propose to use the axial map developed in space syntax, to measure distance. The axial map is a geometric representation of urban space based on graph theory, constructed from the point of view of a cognitive subject, i.e. an experiencing and acting human being. The following research question has been in focus in this study: How can density be measured in order to capture density and urban form from the perspective of a subject moving through urban space?

Measured density, physical density and perceived density

Urban density usually refers to measures of how much of some entity is within a fixed amount of space (e.g. mass per volume, mass over a (two dimensional) area, mass over a (one dimensional) line). In urban planning and design it mostly describes the relationship between a neighbourhood (the denominator) and the number of dwellings or floorspace in

1 Unwin mentions 12 dwellings per acre which corresponds to approximately 30 houses per hectare.

2 Jane Jacobs mentions 100 dwellings per acre which corresponds to approximately 250 houses per hectare.

3 In 1992, a comprehensive plan of action was adopted by more than 178 Governments at the United Nations Conference on Environment and Development (UNCED) held in Rio de Janerio, Brazil, 3 to 14 June 1992. (http://sustainabledevelopment.un.org/). [accessed 5 April 2013].

that neighbourhood (the numerator). The numerator (A) is the number above and the denominator (B) is the number below the line in a vulgar fraction for density (D):

$$D = \frac{A}{B} \qquad (1)$$

This is what Alexander (1993) in a review of density measures describes as the measured density and should be distinguished from notions such as physical and perceived density (figure 1). Physical density includes, according to Alexander, design aspects (e.g. character of buildings and lighting levels) and issues of land-use (e.g. presence of shops, pubs). Perceived density also incorporates individual cognitive and socio-cultural factors (Rapoport, 1975).

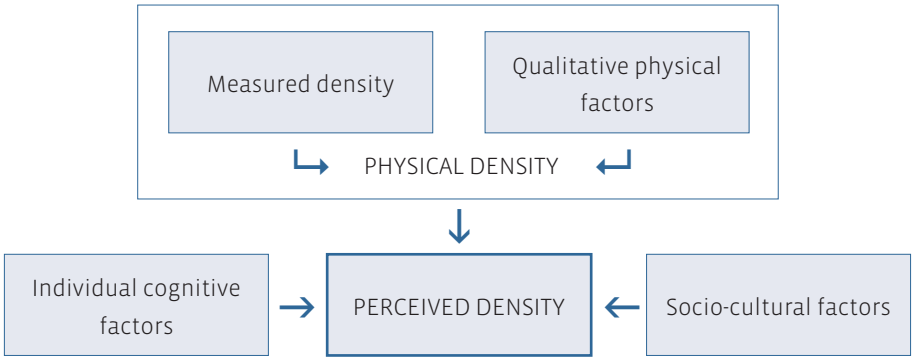

Figure 1
Measured density, physical density and perceived density (Alexander, 1993, p. 183).

Besides the uncritical use of these density notions, but maybe also due to this, scholars have argued that the use of density for anything but statistical purposes is questionable, as it is a too elastic concept that poorly reflects the spatial characteristics of an urban area, or, in other words, the urban form (see figure 2). Forsyth (2003) warns us to not confuse density with building type and assume, for example, that detached houses have a lower density than attached housing types. Because, as she writes: «*...while this is generally true it is not always the case. A high-rise tower with large units set on a park-like site may have a lower density than a set of detached houses on small lots*» (Forsyth, 2003, p. 4).

Density is also considered with suspicion because of the confusion regarding the area definition (Berghauser Pont and Haupt, 2010). Whether streets, a local square or park are included when density is measured obviously matters for the outcome. Both the issue of delimitation and the choice of scale arecentral to what in physical geography is described as the modifiable areal unit problem or MAUP (Openshaw and Taylor, 1979). We will later return to this, but firstly, we will introduce the multi-variable method to measure physical density, developed by Berghauser Pont and Haupt (2005; 2009; 2010), that effectively resolves the gap between measured density and urban form.

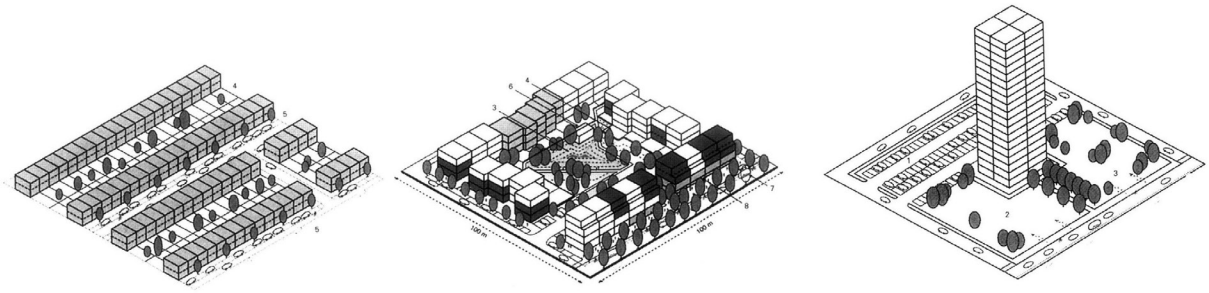

Figure 2
Three areas with the same density of 75 dwellings per hectare (Fernandez Per and Mozas, 2004, pp. 206–207).

Density and urban form

Berghauser Pont and Haupt (2005; 2009; 2010) developed a multi-variable method, Spacemate, to measure urban density including four variables: Floor Space Index (FSI), Ground Space Index (GSI), Open Space Ratio (OSR) and building height (L). FSI and GSI have been used in urban planning and design since the end of the 19th century with the extension plan for Barcelona by Ildefonso Cerdà (1860) as one of the earliest examples (Busquets, 2005; Rådberg, 1988; Alexander, 1993). FSI expresses the relation of the amount of built floor area to the area of the site and GSI expresses the relation between built and non-built land, often casually referred to as the built footprint or ground coverage.

Both FSI and GSI became more generally applied measures since they were included in the 1925 Building Ordinance of Berlin (see e.g. Rådberg, 1988). In 1944, the British Ministry of Health suggested using floor-space-index, or FSI, in areas dominated by commercial buildings and an international conference in Zurich in 1948 established this index as the common standard in Europe (Angenot, 1954). A comparable term for FSI used in New York City's Zoning Resolution is the Floor to Area Ratio (FAR), first incorporated into the New York City zoning ordinance in 1940 (Noble, et al., 1993). But before FAR was introduced as a separate measure, the built volume was the result of a limit on the coverage of lots by buildings (i.e. GSI) and building height regulations. The initial purpose of density regulations was to control the «*disadvantages of tall buildings, crowded together on land parcels too small, separated by streets too narrow*» (Noble, et al., 1993, p. 128). Jane Jacobs argued, in 1961, not to set limits on density but instead proposed minimum levels to force people out into the public streets and parks in support of a lively city (Jacobs, 1961). Jan Gehl used the same argument for a high GSI in his alternative plan for Ørestad Syd in Copenhagen[4].

Besides FSI (or FAR), GSI and building height, a fourth important density variable was introduced in the 1920s in Germany: Open Space Ratio (OSR), also referred to as spaciousness. This variable was used to avoid crowding without limiting FSI directly and by doing so guarantee a minimal amount of open space in relation to the total floor space in an area (Hoenig, 1928). This measure forces architects and developers to com-

4 Presentation of Jan Gehl's studies by Jan Christiansen, city architect of Copenhagen, at the conference Scale, Form and Process. Scales in Urban Landscapes, Aarhus School of Architecture, Department of Landscape and Urbanism, Aarhus, Denmark, 23-24 February 2006. It must be noted that Gehl group has no responsibility for the final planning of Örestad syd.

pensate a high FSI with more open space, resulting in higher buildings in a more spacious setting. Le Corbusier's alternative plan to the compact nineteenth-century city, *La Villa Radieuse*, is an extreme example of such an approach: a plan for a vertical garden city with plenty of open space, but with densities of up to 250 dwellings per hectare[5] (Berghauser Pont and Haupt, 2010).

5 Le Corbusier mentions a density of 1000 inhabitants per hectare which corresponds to 250 dwellings per hectare if we assume an occupancy rate of 4 persons per dwelling.

The formulas to calculate FSI and GSI are variations on (1) and are calculated as follows:

$$FSI_x = \frac{F_x}{A_x} \qquad (2) \qquad \text{and}$$

$$GSI_x = \frac{B_x}{A_x} \qquad (3) \qquad \text{where}$$

F = gross floor area (m^2)
B = footprint (m^2)
A = area of site (m^2)
$_x$ = scale level (e.g. parcel/lot, urban block/island, neighbourhood)
FSI and GSI use the unit m^2/m^2

The formulas to calculate OSR and building height (L) can be derived from (2) and (3) as follows:

$$OSR_x = \frac{1 - GSI_x}{FSI_x} \qquad (4) \qquad \text{and}$$

$$L_x = \frac{FSI_x}{GSI_x} \qquad (5)$$

Berghauser Pont and Haupt (2009; 2010) have shown that expressing density with only one of these variables is not enough to make a distinction between areas with various spatial characteristics (i.e. different morphological types) as those shown in figure 2. Only by expressing urban density through a composite of variables, FSI, GSI, OSR and L, can these various morphological types be distinguished numerically. Each spatial solution, high and spacious or low and compact, results in a unique combination of the density variables and thus has a unique position in the Spacemate diagram they developed (figure 3). FSI on the y-axis gives an indication of the built intensity in an area and GSI on the x-axis reflects the ground coverage, or compactness, of the development. The OSR and L are gradients that fan out over the diagram. Earlier research by Berghauser Pont and Haupt (2009; 2010) shows that morphological types cluster in different positions in the Spacemate diagram. The examples within the cluster marked with G in figure 3 have, for instance, both a high FSI and GSI and mostly contain mid-rise buildings (three to seven storeys) dominated by perimeter blocks. Examples with both low FSI and GSI (cluster marked *A*)

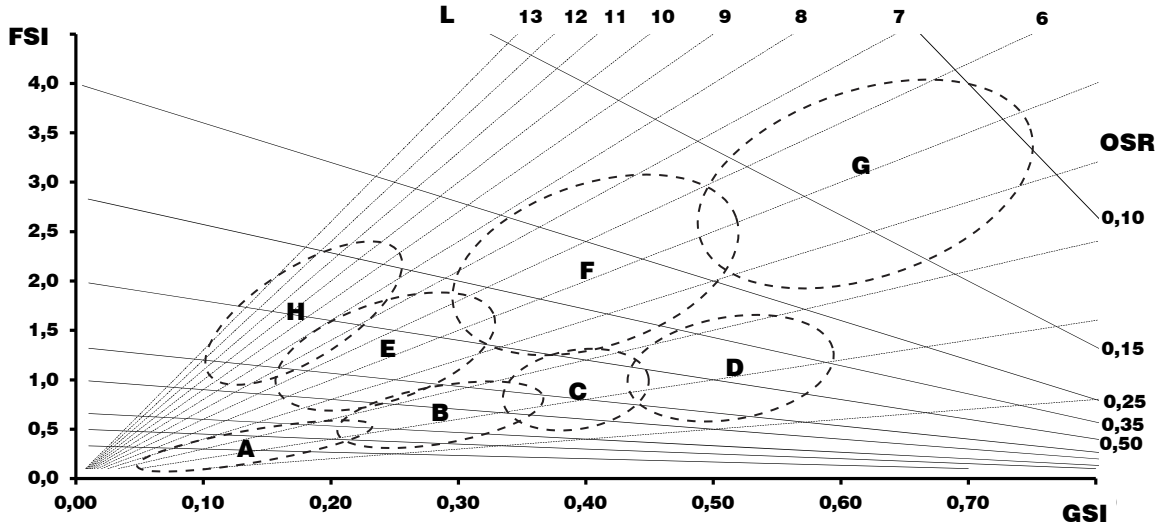

Figure 3
Clustering of the different morphological types in the Spacemate measured at the scale of the island (excluding streets). A = low-rise pavilion type; B = low-rise street type; C = low-rise hybrid type; D = low-rise court type; E = mid-rise street type; F = mid-rise hybrid type; G = mid-rise court type; H = high-rise street type (Berghauser Pont and Haupt, 2010, p. 182).

consist of low-rise detached houses with large gardens. Examples in between these two can be described as more linear developments such as row houses up to three storeys (cluster *B*), slabs of three to seven storeys (cluster *E*) or slabs higher than seven storeys (cluster *H*).

Berghauser Pont and Haupt (2009; 2010) arrived at their findings empirically and Steadman (2013) shows that also on a more theoretical level, the clustering of types holds. For this purpose he uses three schematic building types used by Martin and March (1972) in their systematic research on the relation between density and urban form (figure 4): the «pavilion» type that corresponds with the detached housing type mentioned earlier, the «street» type (e.g. row houses, slabs) and the «court» type (i.e. perimeter block). By fixing building depth, *d*, and cut-off angle, α (10 meter respectively 27˚), and varying the number of storeys (L), GSI, OSR and FSI can be calculated. The results can be plotted in the Spacemate diagram and describe three thresholds for the pavilion type, street type, and court type (figure 4). The clustering of the actual samples as proposed by Berghauser Pont and Haupt (2009; 2010) approximate for the most part the thresholds found for Martin and March's schematic types. These thresholds would of course move up or down for different building depths and «cut-off angles» between opposing facades[6], and this fact explains the difference between the plotted density of the schematic types and the clustering of empirical samples. Conclusively we can say that by using at least two of the four density measures that are part of the Spacemate method, we can successfully relate density to urban form (for a more comprehensive discussion of the Spacemate method and Steadman's test with Martin and March's types, see Berghauser Pont and Haupt (2009; 2010) and Steadman (2013)).

6 The cut-off angle is the angle between the ground and a line joining the base of one façade to the roofline of the façade opposite.

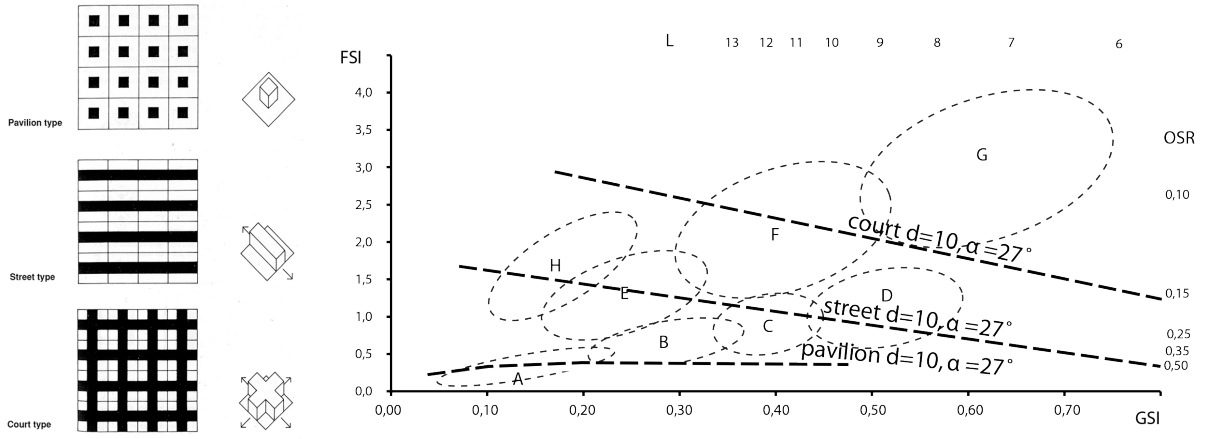

Figure 4
«Pavilion», «street» and «court» type as defined by Martin and March (1972, p. 36) plotted in the Spacemate diagram (Steadman, 2013, p. 12).

The modifiable areal unit problem (MAUP)

The definition of the neighbourhoods in the study of Berghauser Pont and Haupt is subject to a comprehensive problem inherent to all measures of urban density and many other geographic descriptions: the modifiable areal unit problem (MAUP). There are two issues of concern related to MAUP: the scale (or aggregation) effect and the zonation effect (Openshaw and Taylor, 1979). The scale effect is attributed to variation in numerical results owing strictly to the number of areal units used in the analysis of a given area. The zonation effect is attributed to changes in numerical results owing strictly to the manner in which the areas are defined, or in other words, how the area boundary is drawn. The schemes (a), (b) and (c) in figure 5 demonstrate the effects of scale: in (a) the area is sub-divided in 16 units, in (b) in eight units and in (c) only four units. The mean value of the overall density, $\overline{X}$, does not change with an increase of scale, but the variance, δ^2, declines. By comparing (d), (e) and (f) one can see that even when the number of zones (i.e. sub-areas) is held constant (i.e. four sub-areas), the mean and the variance are affected according to the zoning system chosen (Jelinski and Wu, 1996).

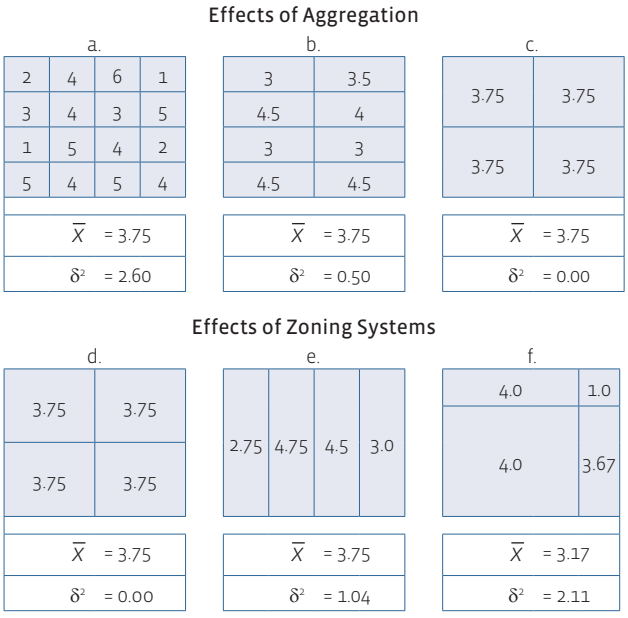

Figure 5
Effects of scale and zonation on the mean value ($\overline{X}$) and variance (δ^2) (interpretation of Jelinski and Wu, 1996, in Dark and Bram, 2007, p. 473).

The larger the area of aggregation and the greater the diversity in the aggregated parts, the more variation is lost in the calculation and the more abstract and less relevant the result is for urban design (Jong and van der Voordt, 2002). Moreover, area statistics at any scale are by nature abstractions in the sense that they are not based in the cognitive experience of cities. Such abstract measures are highly useful for particular purposes, for instance, the calculation of public maintenance costs of streets and green areas in different city districts. But we increasingly face demands where we need to reach beyond such abstract area statistics and instead develop more user-related measurements that to a far higher degree include location characteristics and the concrete experiences of users (Cervero and Kockelman, 1997; Lee and Moudon, 2006; Ståhle, 2008). Ståhle therefore discusses area measures contra location measures in his study on density. Area and location measures differ especially in their way of defining the area boundaries and thus deals especially with the zoning effects discussed earlier. Area measures are often based on administrative boundaries (e.g. cadastral boundaries, census areas) or projected boundaries (e.g. an arbitrary grid of pixels or circles) and typically concern representations of conceived space, which traditionally also dominates geographic descriptions. Location measures on the other hand, include the user's perspective and define the boundaries via the position of a location in the city and what is possible to «reach» from there at different radii where the chosen radius relates back to the earlier discussion on scale effects (see figure 6).

Measurement	Description	Size	Space	Perspective	World	View	Value
Area	Geographic, typo-morphological	Area (surface, volume)	Abstract (conceived) space	Administrative (developer, manager)	System	Top-down	Exchange value
Location	Spatial, structure-morphological	Accessibility (radius, distance)	User's (lived or perceived) space	User-related (residents, businesses)	Life-world	Bottom-up	Use Value

Figure 6
Social, economic, spatial, and scientific distinctions between area and location measures and its representations in urban morphology (Ståhle, 2008, p. 42).

Location density (A_i) is thus defined via accessibility which is a widely used measure in spatial analysis. In general terms, it is related to the notions of nearness, proximity of one place, *i*, to other places, *j*, and opportunity for interaction (Weibull, 1980). Formally, the measure can be defined as:

$$A_i = \Sigma f(W_j d_{ij}) \qquad (6)$$ where

W_j= index of attraction of *j*
d_{ij}= measure of distance or travel time of moving from *i* to *j*

Defining how to measure distance (d_{ij}) is obviously a critical part of the accessibility measure. The most common distance units used in accessibility research are metric travel distance, travel time, and travel cost. But it is precisely concerning such measurements of distance that problems have been encountered in spatial analysis when moving from the more abstract level of geography and traffic planning to the detailed level of architecture and urban design: «*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, Claramunt and Batty, 1999, p. 128). An alternative approach can be found in space syntax with a central role for what is called the axial map (Hillier and Hanson, 1984). The axial map is made up of the least amount of straight lines that cover all accessible urban space in the area of analysis, where each straight line (here called axial line) in the map represents an urban space that is possible to visually overlook and physically access (Hillier and Hanson, 1984). The important argument for the axial line is that if a straight line (i.e. a street) is crooked, we do not add significantly to the distance measured by a ruler, but we add greatly to what we here interpret as the cognitive distance (Golledge and Stimson, 1997, p. 261). Or, in Hillier's words: «*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, 2003, pp. 06–3). Consequently, the axial line can be regarded as a kind of distance measure based in human cognition, since it is putting «*data about a person's cognitive environment into the analytical framework*» (Kwan, 2000, pp. 86–87).

As a matter of fact, we seem able to set up an almost symmetrical problem here. On the one hand, we have spatial analysis in general, where there are problems in dealing with the smaller scale of urban settings because of a lack of adequate descriptions of spatial form. On the other hand, we have space syntax, which has problems in predicting movement in certain areas because of a lack of adequate descriptions of attractions – keeping in mind that such predictions are not the primary aim in space syntax. Thus, it seems natural to try the cognitively defined spatial units used in space syntax as a measurement of distance in accessibility analysis. On the one hand, it would make it possible to «load» geographical data concerning «supply» and «demand» for improved predictions of pedestrian movement in space syntax, when this is the aim. On the other hand, and more interestingly, it would mean integrating representations of the cognitive environment into general accessibility analysis. It is precisely such an approach that has driven the development of the (PST) at KTH, school of Architecture, and is used for the tests presented later in this paper[7].

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.

The method to arrive at a measure of accessible density

In developing a location measure of density, Ståhle (2008) uses what is known as the contour measure (Geurs and Ritsema van Eck, 2001). This makes it apparent how the concept of location density actually is a misleading term since it only involves the numerator A of the density fraction A/B. The contour measure indicates the number of opportunities, or attractions, accessible within a given travel time or travel distance. Hence, the accessibility increases if more attractions, such as people or amount of floor space, can be reached within such spatial or temporal limits. In short, we can either increase accessibility by reducing the distance to the studied attractions or by adding such attractions inside the given spatial limit (i.e. distance threshold).

The general shift from area based to location based measures can be illustrated by the example in figure 7. Here we can see how the same geographical data can generate dramatically different spatial distributions depending on how it is measured. In this case the data concerns floor area distributed on parcels. In the image to the left the data is represented as area based density, that is, as floor area per parcel area (FSI), and in the image to the right it is represented as location based density, which as we have mentioned rather should be understood as a form of accessible attraction. The difference is dramatic and helps us realize, on the one hand, how both measures can be useful and, on the other hand, the first typically represents conceived space, while the second clearly comes closer to what we have called perceived space.

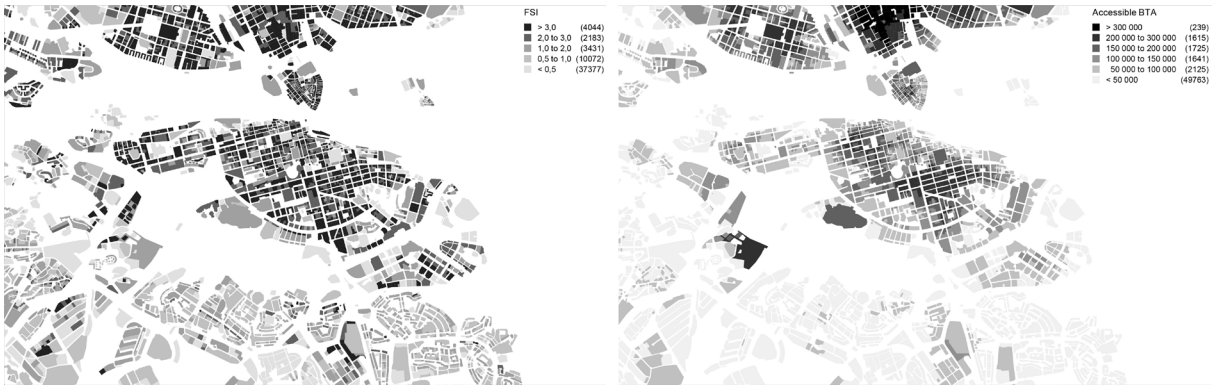

Figure 7
Density measured with the area density measure (left) and with the location-density measure (right).

To transform Ståhle's location measure of density into a measure of accessible density we need to involve the denominator (B). Instead of an administrative or projected boundary as was used in the work of Berghauser Pont and Haupt described earlier, (B) is now defined via the accessibility measure. The attraction in this case is the parcel area reached within a fixed distance.

We have now arrived at a method to measure accessible density that can be consistently and continuously calculated at different scales (e.g. parcel, block, etc.) using distance thresholds to define the scale of reach (e.g. 500 meter, 3 axial steps, etc.). By making the calculations for each parcel separately, differences between them are not lost. In other words, each parcel is loaded with the data of its own unique set of parcels within the fixed distance threshold.

Accessible density in Stockholm – testing the developed method

In the following, we will test the method to measure accessible density in the city of Stockholm, Sweden and compare the results with the Spacemate method to measure area density. Six areas will be discussed that represent a variety of morphological types.[8] The results of the density calculations are plotted in the Spacemate diagram shown in figure 8 and photos and maps of the examples are shown in figure 9. The six examples chosen represent the following morphological types:

- The mid-rise court type (cluster G), represented with two examples: one of the older parts of Södermalm (position 1 in figure 8) and a recent development in Hammarby Sjöstad (position 2).
- The high-rise street and pavilion type: an area with slabs on Södermalm (3) and towers in Johanneshov, located south of Södermalm (4).
- The low-rise pavilion and court type: a villa area in Essingen (5) and an area with perimeter blocks in Skarpnäck (6).

8 Many more examples are measured, but for reasons of readability only six are presented in this paper.

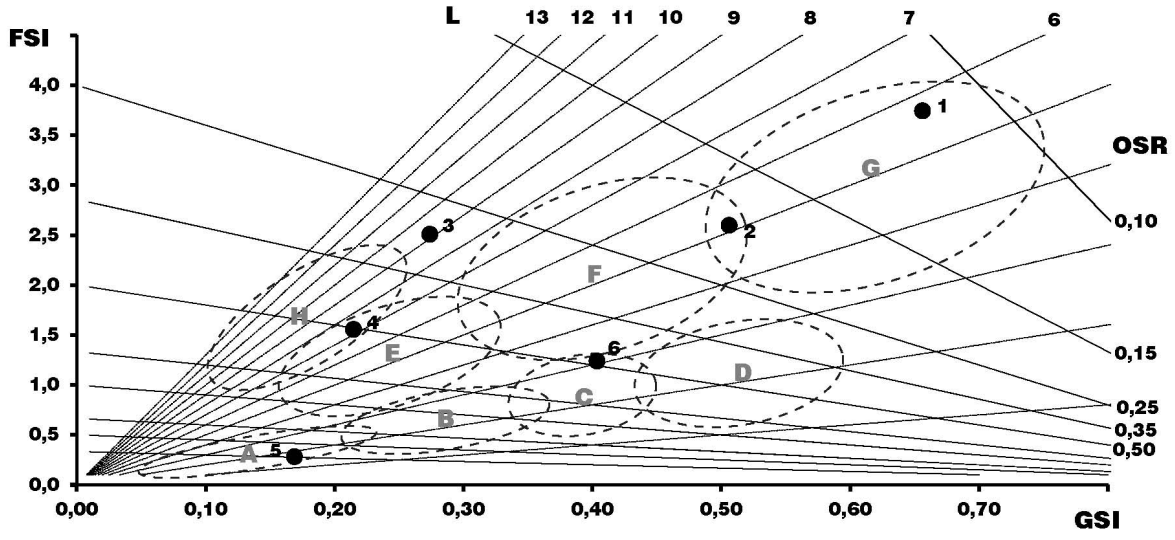

Figure 8
The area density measured at lot level for six areas in Stockholm plotted in the Spacemate diagram.

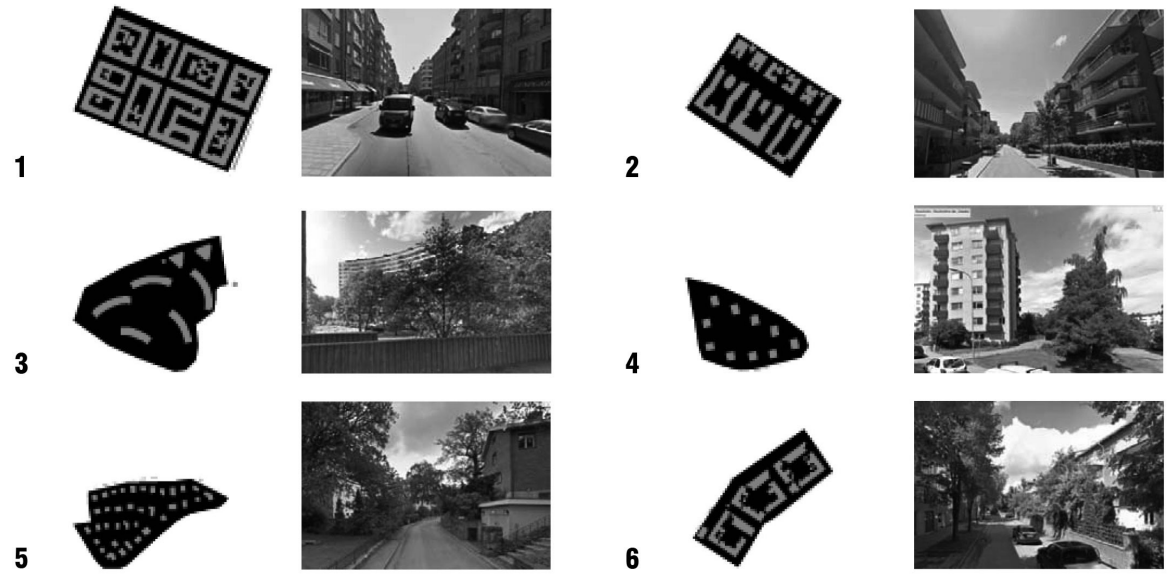

Figure 9
Plan and photo of the six areas in Stockholm. 1 = Sturegatan, Östermalm; 2 = Hammarby Allee, Hammarby Sjöstad; 3 = Sockerbruksgatan, Södermalm; 4 = Arkadvägen, Johanneshov; 5 = Eremitvägen, Essingen; 6 = Pilotgatan, Skarpnäck.

The accessible density of the six samples in Stockholm is measured for five different distance radii, increasing with increments of one axial step, and plotted in the Spacemate diagram (figure 10). When including parcels further away from the parcel of origin in the density calculations, the result is in some cases identical from the initial density calculated for the parcel of origin alone. In these examples (e.g. 2, 5 and 6) the dots plotted in the Spacemate diagram do not change position much and indicate homogeneity. For other examples, the opposite can be observed. Here, the dots plotted in the diagram move position when the distance threshold changes. In other words, the density of the parcel of origin is distinctly different from its context, indicating heterogeneity (e.g. example 3 and 4).

After testing various radii in many more areas than the six presented here, it is shown that in Stockholm the different morphological types can still be distinguished in the Spacemate when density is measured as accessible density with a radius of three axial steps and with an additional metric distance threshold to reduce the impact of long axial lines (500 meter). The result of this specific accessible density is presented in figure 11. When compared with figure 8 where the area density was represented the results are slightly different, but the relation between density and morphological types is still valid.

By this we have arrived at strong indications in the case of Stockholm that it is possible to develop a measure of density that, first, gets around MAUP by using accessible density measures instead of area measures, second, measures perceived density rather than conceived density by including cognitive distance in the measure and, third, retaining a strong relation between measures of density and morphological types.

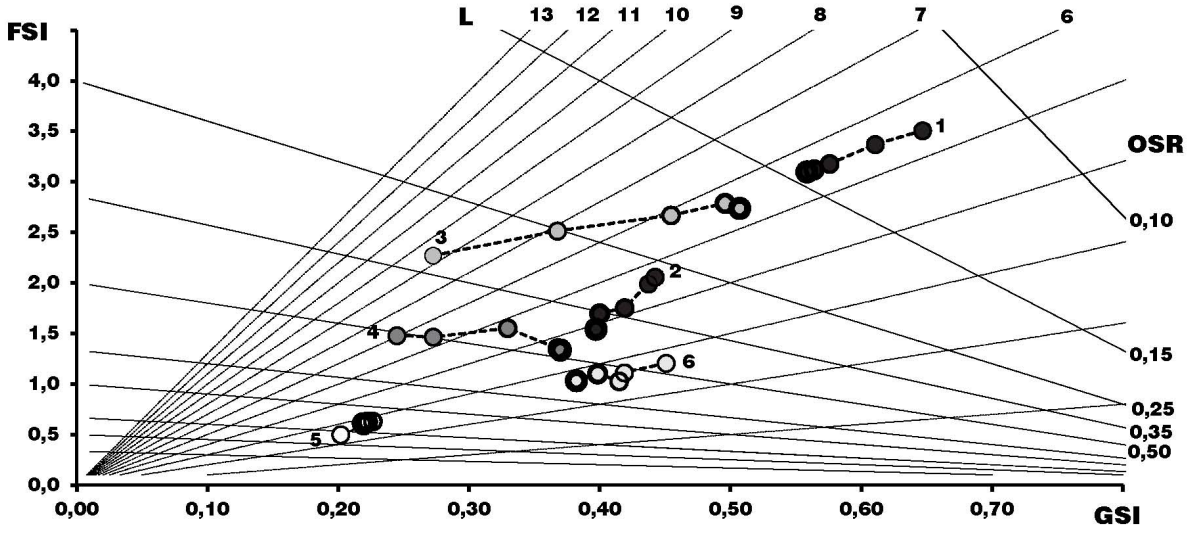

Figure 10
Net accessible density of six areas in Stockholm plotted in the Spacemate diagram from distance of one to five axial steps (numbers indicate the «start» position with a distance of one axial step).

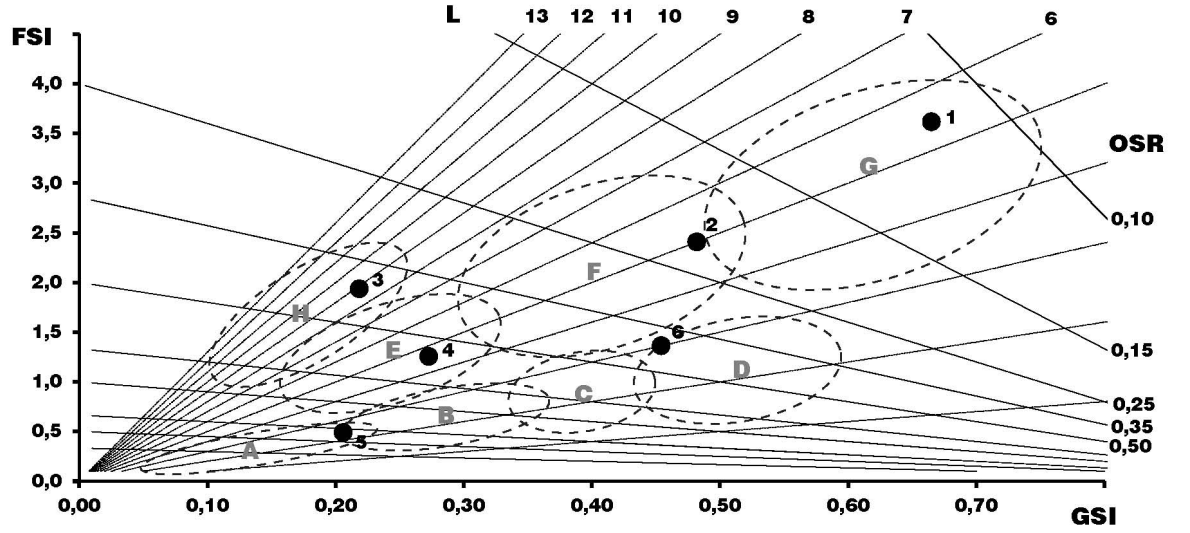

Figure 11
The accessible density of six areas in Stockholm plotted in the Spacemate diagram with a distance threshold of three axial steps and 500 meter.

We can now use this measure to map the accessible density for a whole city or, as we show here, a larger city district such as Södermalm in Stockholm. In figure 12 the accessible density (FSI and GSI) are shown and we clearly see clusters with similar FSI respectively GSI values. In combination these capture the variation of morphological types as is discussed extensively and shown in the various Spacemate diagrams (e.g. figure 11). In figure 13 a map of Södermalm with three of these types is shown in which the types mentioned in the legend are the same as the clusters G, B and E in the Spacemate diagram in figure 11. We have now discussed and presented area density (see left image in figure 7) that typically represents conceived space, accessible density (see figure 12) that clearly comes closer to what we have called perceived space with accessible FSI representing perceived intensity and accessible GSI perceived compactness. The map in figure 13 shows the result of the multi-variable accessible density which even represents the morphological type perceived when moving from an address, in either direction, but within the defined distance threshold.

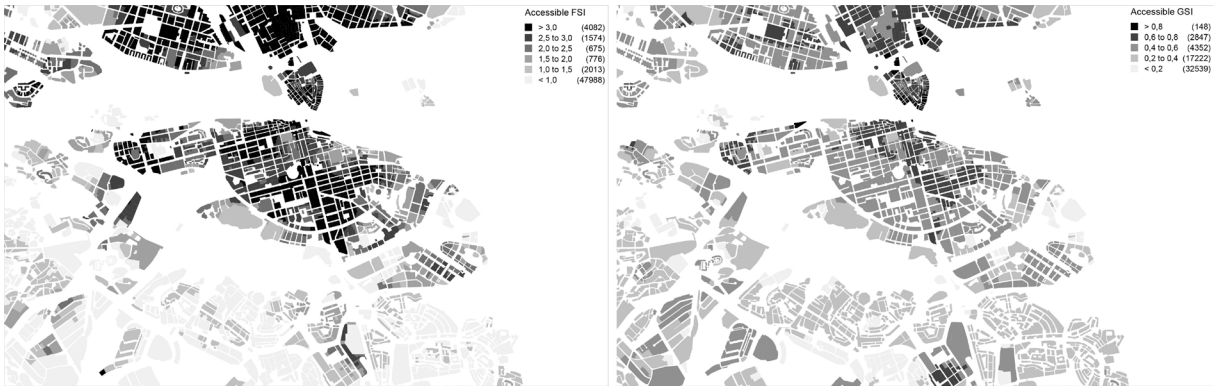

Figure 12
Accessible FSI (left) and accessible GSI (right) in Södermalm, Stockholm. Accessible density is measured with a distance threshold of three axial steps and 500 meter.

Figure 13
Three of the clusters with morphological types shown in the Spacemate diagram (see figure 11) mapped in Södermalm: cluster G, cluster B and cluster E.

Conclusion

The combination of four density variables to measure density as developed in the Spacemate method makes it possible to capture urban form in numbers. Adding accessibility measures to the equation and using the axial line to measure distance, we have shown, allows to measure what can be called a *perceived* density. This is of course limited to a measurement of perceived density, as for its *interpretation* in concrete cases we naturally might want to include individual and cultural factors. While acknowledging this, the *measurement* presented in this paper is aiming to capture in a generalised form the cognitive experience of a subject moving through urban space and the associated experience of its variations in density and corresponding variations in urban form.

Further, MAUP is partly solved, as we do not have to work with aggregated data or preselected boundaries and scales. Instead, we use the distance threshold variable to define both boundary and scale. What we have done is, following Openshaw (1984), to make the choice for aggregation which is subjective and adjustable anyway, part of the research question. Dark and Bram (2007) describe this as a new methodology that «*defies the normal science paradigm by including a hypothesis in the data set-up design of the spatial analysis project*».

There are many interesting follow up research questions of which we want to mention three. The first is to continue working with the changes

in density when increasing the distance threshold, as is shown in figure 10. A measure of homogeneity (or heterogeneity) could be developed. Further, more research is needed to find out whether the same distance thresholds that are used in Stockholm are valid in other contexts to capture urban form effectively. And thirdly, the proposed accessible density measure can be used in studies on the performance of urban form.

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