Measuring urban form

META BERGHAUSER PONT

For many, the notion of 'measuring urban form' will sound disturbing. Urban form is about visual images of cities, experiences, feelings, memories of place, thoughts and intellectual constructs anchored in the realm of the arts and the humanities. Anne Vernez Moudon however gives in the paper Urbanism by numbers (2009) a good argument to study the urban environment quantitatively as it offers urban designers the opportunity to practice their art with its due precision.

Urban density is one of the measures that is used frequently in urban design practice, but is also questioned by many as it relates poorly to urban form (Alexander 1993, Forsyth 2003). The use of a concept with such a large "warning disclaimer" is disturbing. The Spacematrix method has contributed to a clarification of the existing Babel-like confusion in the terminology currently being used by urban planners working with urban density. The most important contribution of the Spacematrix method is, besides a clear definition of density, that density can be related to urban form and other performances and that urban form is thus measurable.

Spacematrix

Spacematrix defines density as a multi variable phenomenon and makes a correlation between density and the built mass (urban form). Spacematrix uses the following measures: floor space index (FSI), ground space index (GSI), and network density (N). FSI reflects the building intensity independently of the programmatic composition; GSI, or coverage, demonstrates the relationship between built and non-built space; and the density of the network, N, refers to the concentration of networks in an area. Measures such as open space radio (OSR) or spaciousness, the average number of floors or layers (L) and the size of the urban blocks (W) can be derived from these three main measures. These three main measures are represented in a three-dimensional diagram, the Spacematrix (figure 1). Separate projections of the Spacematrix are in the present context necessary due to limitations in data management and representation (and thus communication) of the results (see for instance the FSI-GSI plane in figure 3).

Figure 2 shows three examples on how different an area can look like with one and the same density of 75 dwelling per hectare. When applying Spacematrix for describing the density of these three examples we get a more accurate description. In all cases the FSI is the same (based on mono-functional areas and 100 m2
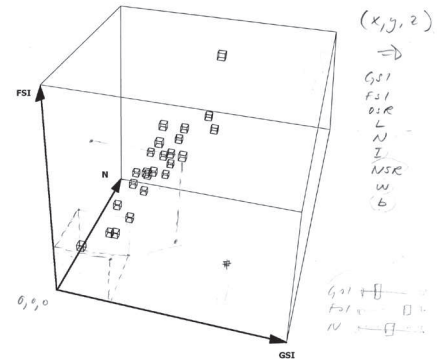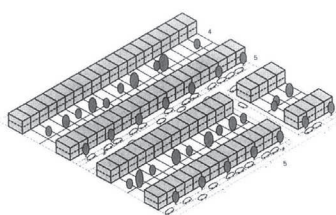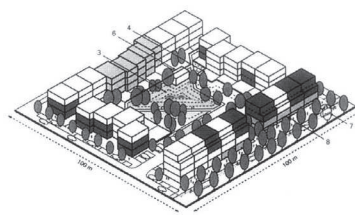

Figure 1. Spacematrix with floor space index (FSI) on the y-axis, ground space index (GSI) on the x-axis, and network density (N) on the z-axis (Berghauser Pont and Haupt 2010).
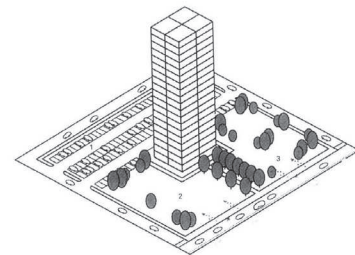

Figure 2. Three different types of urban areas with 75 dwellings per hectare (from left to right, 1-3, see position in Spacematrix in Figure 3).

1

2

3

per dwelling), but the GSI in the left case is relatively high. In the middle case, GSI is medium, whereas in the right case the GSI is low (Berghauser Pont, Haupt 2010).

Figure 3 shows the position of the three examples in the FSI-GSI plane of the Spacematrix diagram. Besides FSI on the y-axis and GSI on the x-axis, the measures OSR and L are included as gradients that fan out over the diagram. OSR describes the spaciousness (or pressure on the non-built space), and L represents the average number of storeys. Although the examples have one and the same FSI, their position in the Spacematrix is different due to the differences in GSI, OSR and L.

The diagram in figure 4 shows, based on empirical samples from various locations in the Netherlands, and Berlin (Germany) and Barcelona (Spain), where different types of urban environments are located in the Spacematrix. The environments with both a high FSI and GSI are areas with mid-rise buildings dominated by perimeter blocks. These areas are marked as a circle with the letter "E". Conversely, urban areas with both low FSI and GSI (marked as a circle named "A") tend to consist of low rise single houses with large gardens. Areas with a high FSI but low GSI tend to be areas with high-rise buildings sur-

rounded by large open spaces (marked as a circle named "F"). In particular post-war housing areas inspired by Le Corbusier's La Ville Radieuse design principles belong to this category. Conversely, urban areas with a high GSI but low FSI (marked as a circle named "C") tend to be low rise row houses with small gardens, but also industrial areas cluster here. The multi-variable definition of density makes it thus possible to quantitatively describe the different urban environments.

These types of urban environment do not have rigid borders, but slowly transform from one to another. What is most important to understand is that the conditions set by density very much influence the performance of a built environment. It is suggested that performance-based descriptions of urban fabrics could become more important than the traditional image- or activity-based descriptions. Instead of naming low-rise block types or high-rise strip types, the fabric type could be described and prescribed solely by its Spacematrix density and the performance characteristics embedded in this density. Performances that are discussed in the book Spacematrix. Space, Density and Urban (Berghauser Pont and Haupt 2010) are parking, daylight access and urbanity.
Many more performances of urban fabrics could and should be researched and related to density in the same manner, contributing to a better underpinning of urban plans and designs.

Instead of creating images, urban professionals will then be more involved with defining the conditions under which specific qualities are most likely to be realized. In the Harvard Design Magazine reader Urban Planning Today such a conditional approach to planning is described when it defines the future role of governments as establishing intelligent and flexible guidelines, or incentives (Saunders 2006). These guidelines should not prescribe solutions or particular built forms, but should define principles or performance criteria that leave the designer free to be creative in solving design problems (Punter 2007).

The performance of the built landscape
There is among many researchers and professionals a consensus that compact settlements are more sustainable than sprawl, and that denser cities, be it with high rise or with compact mid-rise solutions, will somehow halt an unsustainable increase of consumption of transport, energy and resources (Newman and Kenworthy 1999; Jenks 2000).

Newman and Kenworthy demonstrated that in low-density cities in North America energy consumption per inhabitant for transport is far higher than the same energy
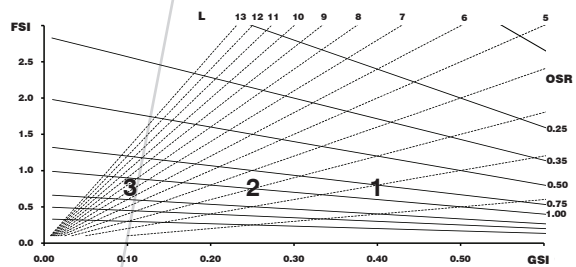

Figure 3. The relationship between GSI, FSI, OSR and L in Spacematrix (positions 1-3 refer to Figure 2) (Berghauser Pont and Haupt 2010).

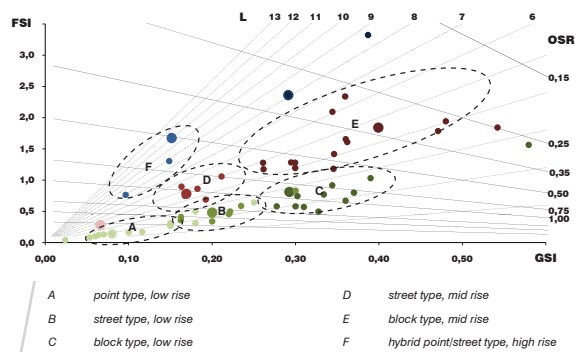| A | point type, low rise | D | street type, mid rise |
| B | street type, low rise | E | block type, mid rise |
| C | block type, low rise | F | hybrid point/street type, high rise |

Figure 4. The various types of urban areas (scale: urban fabric) in the FSI-GSI plane of the Spacematrix (Berghauser Pont and Haupt 2010).

used by Europeans, and even more so when compared to very high-density cities in Japan (see figure 5). North Americans are almost totally dependent on the private car, while the Japanese in general cluster in higher densities and are able to sustain a more efficient public transport network.

However, denser urban environments do not automatically mean less transport and energy consumption. Distances between homes and places of work, regulations and fiscal policies probably have far greater impacts on car use than the mere physical layout of cities and regions (Neuman 2005). If the argument is turned around, though, one has to admit that dense settlements are a necessary prerequisite if we are to aspire to a radical cut in car and lorry transportation. Only dense settlements offer feasible circumstances for the large investments needed for a more energy-efficient and environmentally responsible movement of goods and people. Such settlements are also the only environments that can be successful when it comes to healthy and sustainable modes of transportation, such as walking and cycling.
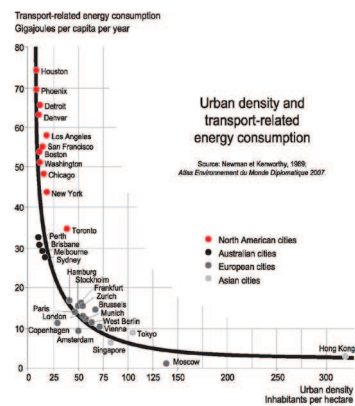

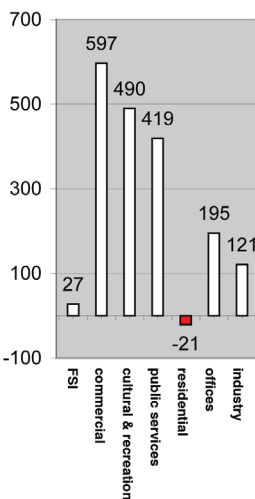Figure 5. Urban density and transport-related energy consumption.

Figure 6. Difference between density of blocks, mixed-use to mono-functional (Berghauser Pont and Mashhoodi 2011).

Figure 7. Accessible areas of a block are unique. They cover 500, 1000, 2500, and 5000m distance from the block and are dependent on network configuration (Berghauser Pont and Mashhoodi 2011).

Based on these findings, we can conclude that FSI plays a distinctive role in predicting energy consumption related to transport. In what sense the other density measures are of importance, and thus urban form on the micro scale, is unknown. In other words, does it matter whether density is realized through

1) **high and spacious developments versus**
2) **low and compact developments with similar high densities.**

Walkability research done by Moudon et al. (2006) shows that besides residential density, also block size, presence of proximate grocery stores, restaurants, and retail facilities are strongly associated with walkability. The findings of this research show that quantitative thresholds, in this case to support walkable neighborhoods, need to be defined with great precision: blocks should be smaller

than 2,4 ha, residential density should be more than 54 units per hectare, and distance to the closest grocery store should be less than 440 meter. The finding that less than 440 meter could "make or break" an environmental support to walking was maybe the most powerful lesson that arose from these quantitative analyses.

Based on results of a study in Rotterdam by Berghauser Pont and Mashhoodi (2011) concerning mixed-use environments, we can conclude that FSI in mixed blocks is significantly higher than in mono-functional blocks. The FSI is 27% higher in the mixed blocks than in the mono-functional blocks.

When considering all the mixed blocks the share of floor area used for commercial services such as shops and restaurants show the highest difference with the mono-functional blocks, followed by the share of cultural function, social services, offices and industries. In other

words, the service function and especially the commercial functions dominate the mixed blocks. The share of work is less spectacular as can be seen in figure 6. The share of housing reduces significantly in the mixed blocks. A mixed block has 21% less gross floor area for housing than a mono-functional block. This is not so strange as the other functions need more space in order to make the blocks mixed.

What is also found is that this reduction of residential floor area within a block is compensated for by an increase of residential density in the proximity of the block in question. This can be studied by measuring the accessible residential density. Accessible density (Ståhle 2008) takes into account both the gross floor space of an area (for instance the urban block) and the accessible floor area within a certain radius (see figure 7).

By doing so, the density of a low dense block can increase in case it is embedded in a high dense context. Or vice versa, a high dense block can have a very low accessible density if it is extremely segregated from its context. Comparison between mixed-use and mono-functional blocks shows that mixed-use blocks have a higher accessible density in all the radii and land use classes (Berghauser Pont and Mashhoodi 2011). The difference is more distinctive in lower radii. In walking distance the accessible commercial service density is 77% higher in mixed-use blocks than in mono-functional blocks. Within biking distance, the presence of work is the most distinctive, where it differs 39% between mixed-use and mono-functional blocks. As general conclusion, mixed-use blocks are more likely when the FSI of the block is higher and the block is located in an area with greater provision of different land use classes.

A recently developed block in Rotterdam has a relative high FSI and is planned with a mixed program, but is located in a walkable neighbourhood (radius 500 meter) dominated by housing (figure 8 & 9). It is therefore questionable whether this planned mix will on the long run survive as not all conditions are optimal for a mixed-use block.

Conclusion and discussion
Measuring urban form is to many designers frightening, but could - as is shown here - be of great value to better underpin design decisions. The complexity of designing cities makes that we will never find (and we do not want to find it, do we?) the formula for the best city, but we can understand the performance of the city better based on quantitative analysis. The most important conclusion is the need for precision and accuracy in dimensioning the physical neighbourhoods. In addition, the knowledge how a local change in urban form has effects on the city as a whole, and vice versa. Based on this knowledge we can guide the future city with smart urban rules prescribing performances instead of form. ▄▄▄▄▄

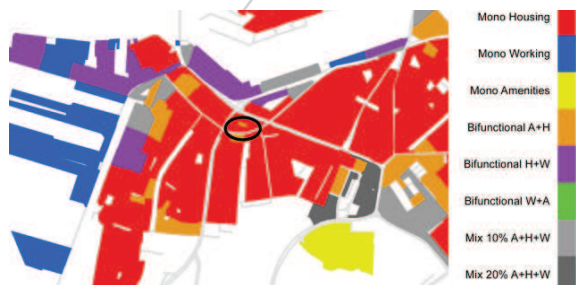Figure 8. Mixed-use block (Wolphaertsbocht) measured on block level (Mashhoodi 2011).

Figure 9. The same block is mono-functional measured on the scale of a walking neighbourhood of radius 500 meter (Mashhoodi 2011).

Alexander, E. R. (1993), Density Measures: A Review and Analysis, in: Journal of Architecture and Planning Research 10(3), pp. 181-202

Berghauser Pont, M. Y., Haupt, P (2010) SPACEMATRIX, Space, Density and Urban Form. Rotterdam, NAi Publishers.

Berghauser Pont and Mashhoodi (2011), Studying land-use distribution and mixed-use patterns in relation to density, accessibility and urban form, ISUF conference 2011, Montreal, August 26th -29th 2011 (forthcoming).

Forsyth, R. (2003) Measuring Density: Working Definitions for Residential Density and Building Density, in: Density Brief, 8 2003, Design Center for American Urban Landscape, University of Minoesota.

Jenks, M. (2000), The acceptability of urban intensification, In: Williams, K., E. Burton, et al., Eds. (2000), Achieving sustainable urban form. London, E & FN Spon.

Mashhoodi, B. (2011), Bio-inspired Design Support for Enhanced Mixed-use Potential. Understanding the relation between urban form and mixed-use development by means of bio-inspired computation, first year PhD presentation TU Delft.

Moudon Vernez, A. et al., (2006), Operational Definitions of Walkable Neighborhood: Theoretical and Empirical Insights, Journal of Physical Activity and Health 2006, 3, Suppl 1, S99-S117, © 2006 Human Kinetics, Inc.

Moudon Vernez, A., Lee C.(2009), Urbanism by numbers. A quantitative approach to urban form. in: Making the metropolitan landscape: Standing firm on the middle ground. Ed. by Jacquline Tatom, Jennifer Stauber, New York, Routledge: 57-77

Neuman, M. (2005), 'The Compact City Fallacy', in: Journal of Planning Education and Research 25, 11-26.

Newman, P. and J. Kenworthy (1999), Sustainability and cities: overcoming automobile dependence, Washington, Island Press.

Punter, J., 2007. Design guidelines in American cities: conclusions. In: M. Larice & E. Macdonald, eds. 2007. The urban design reader. Oxon: Routledge. pp. 500-516. Original text from 1997.

Saunders, W.S., 2006. Cappuccino urbanism, and beyond. Harvard Design Magazine, fall 2006 / winter 2007, p. 3.

Ståhle, A. (2008) Compact Sprawl: Exploring Public Open Space and Contradictions in Urban Density, Stockholm; KTH.