The Spacemate:

Density and the Typomorphology of the Urban Fabric

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This article deals with current changes in the urban planning and design practice, and presents a tool based on the knowledge of the relation between physical density and urban form: The Spacemate.

In general, one can say that two tasks are central to urbanism: the programming of the city and its design. A strong emphasis on programming can be described as the doctrine of the statistically ordered city. Planning surveys, quantified uses, zoning and demographic predictions are central to such an approach. A focus on the design, on the other hand, can be described as the doctrine of the visually ordered city.

Over the past centuries, the focus between these two aspects has shifted. Before 1900, the preparation and division of the ground surface was at the core and a fixed image was not a main issue. Later, in for instance Berlage's Plan Zuid in Amsterdam at the beginning of the 20th century, the design was seen as a *Gesamtskunstwerk* where architecture and urban design should be totally integrated. In van Eesteren's scheme for a garden city expansion of Amsterdam (Algemene Uitbreidingsplan or AUP) from the 1930s, a functional and programmatic zoning plan was dominant (see figure 1).

These shifts in focus have continued, and it is a question whether this kind of detailed control of the urban design (be it programmatic or as final image) is appropriate for present design tasks. We work today in a situation where projects are of a large scale and have a very long time span. On top of this comes the privatization of development initiatives, an unpredictable future and an increase of complexity of programs. Examples that illustrate these new conditions in the Netherlands are the Westelijke Tuinsteden, IJburg and Zuidoostlob in Amsterdam and Stadshavens in Rotterdam. Those large scale transformations span over many decades and private investors gain influence at an early stage in the process. It is difficult today to imagine a grand design in the Netherlands with a detailed blueprint for a final image or program being executed in the same way as for instance Plan Zuid or the AUP.

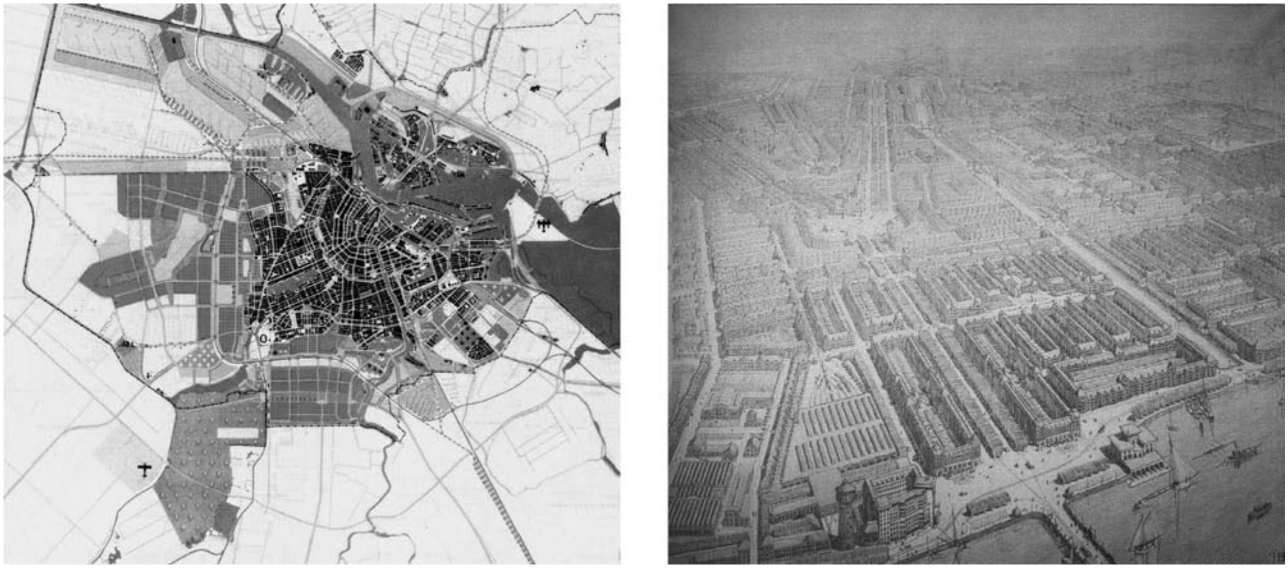


Figure 1. AUP and Plan Zuid.

What is needed in this new situation, according to some, are the knowledge and skills to design appropriate frameworks, or right conditions, for future developments which are not fixed in the long term. How can we make plans where main issues and qualities are taken care of, but that still leave enough freedom to incorporate changes during the process from design until realisation? And how can we then, at an early stage in the design process, still gain insight in the economic costs and benefits of a plan? Our research aims at developing an approach that can assist in these new urban challenges. But how can this be done? We claim that, by understanding the relation between quantitative and spatial properties, we are able to define programmatic demands and spatial ambitions simultaneously, without fixing a detailed program or a final image. We suggest that a design and planning instrument based on a combination of density concepts can help planners and designers understand the capacity of space and assist in designing appropriate conditions for largely unpredictable developments.

Density is a subject on which little fundamental research has been carried out. Built densities range from spacious rural settlements, through the low densities of the suburban sprawl, via the balanced urbanity of the 19th century expansions to the extremely dense down-towns of the world's metropolises. Measurement techniques used to describe these situations have differed over time and even at present there is much confusion as to which method should be used. Besides the need to clearly define a method, an investigation into the relation between density and built form might prove productive to both urbanism as an academic discipline and to the planning and designing practice. The Spacemate method described in this article provides a coherent measurement technique and reveals a linkage between densities and typologies of land development, urban environments, and non-built space.

The first part of this article positions the research in a morphological context and argues for a mathematical-analytical accent within this approach. It also sets out to explain the basic principles of measuring density using Spacemate. In this section, a series of variables is defined and the different scales of measurement (aggregations) are described. In addition, the Spacemate diagram is introduced. The second section covers the investigation of the relationship between density and spatial characteristics. It shows with examples how Spacemate can be used to classify different types of built environments. In the following two sections, we concentrate on densities on different levels of scale and network density as an important property of the built environment. In the final section of the article we introduce the concept of performance indicators and suggest possible applications of Spacemate as a control instrument and test framework for the planning and design practice. This final part describes the advantages of using density in urban design and spatial management during the early phases of the planning process. This can result in an increase of planning control on a high level of scale combined with a maximum degree of design freedom on a low level of scale.

Background: typomorphology

Morphology means knowledge of form, in this case knowledge of urban form. Rowe (1978) describes the city using a figure-ground analysis and defines two extremely different urban figures: one dominated by mass and cut through by voids, the other an accumulation of solids in an endless floating void. In typomorphology, various classifications of buildings and open spaces are used to arrive at a more detailed description of urban form. Moudon (1994) discusses three schools of typomorphology (Italian, English and French), all with different origins and research focuses. However different their purposes and methods, morphological research in general has generated a useful body of definitions since the 1950s, as well as a common language for describing architectural and urban form. Morphological studies also have provided some key insights by focusing on the evolution of form (morphogenesis). Further, the expansion into different scale levels has helped to increase our understanding of the mutual dependence of architecture and urbanism.

However, in general, one can say that a quantitative analysis of the built form has not been applied thoroughly within morphology. This means that morphology as such has contributed little to understanding the relation between quantitative and spatial properties of urban areas.

An interesting example of quantitative analysis within the field of urbanism comes from the Centre for Land Use and Built Form Studies, which institute was established at the School of Architecture in Cambridge in 1963. Leslie Martin and Lionel March (1966) studied the relationship between, among other things, floor space, distribution of free space, and building height. In a way these studies relate to the work of Cerda in Spain (end of the 19th century) and Unwin in England (beginning of the 20th century). Unwin talks, for instance, about "the balance between area of plot, area of floor space and area of street". A more recent study that fits into this series comes from the University of Geneva (1986). In this study, a wide range of spatial properties were quantified, analysed, and related to each other. Most important in all these studies is the recognition of related factors: the land available, the built form placed on it, and the roads necessary to serve them.

We claim that quantitative analysis can help to expand the possibilities and the explanatory power of morphology. And we suggest that the mathematical-analytical approach, represented by Cerda, Unwin, and Martin and March, must be viewed not as a separate 'school' with little kinship with the detailed graphical mapping techniques of traditional morphology, but as an extension of the field of morphological research itself. The analytical techniques differ, but the research aims coincide: describing and explaining built form. We want to characterize our own approach as being positioned inside the morphological tradition, but with an accent closer to the mathematical-analytical tradition just mentioned.

Urban density

One way to analyse built form in its three-dimensional presence is to examine the density of the built environment. Before looking for hard and fast definitions of density, it is important to realise that this concept can be approached in various ways. The individual perception of density can differ completely from density in technical terms. These are different categories, and it should be clear that it is dangerous to use analyses in one category to draw conclusions in the other. The emphasis in our research is on the physical/spatial aspects of density. That is to say, it investigates the physical, measurable characteristics of built areas.

In the past, a number of indicators were defined and used for measuring physical density. These indicators take the form of quotients in which the denominator is the total area of land where the density is being measured, while the numerator can take a variety of forms: homes, inhabitants, rooms, total available floor area, total available built area. Angenot (1954) and Heimans (1965), two researchers at Delft University of Technology, present the most accepted methods that are of importance when determining density. Their retrospective goes back to the year 1912 when Unwin wrote of an upper density limit of 12 houses to the

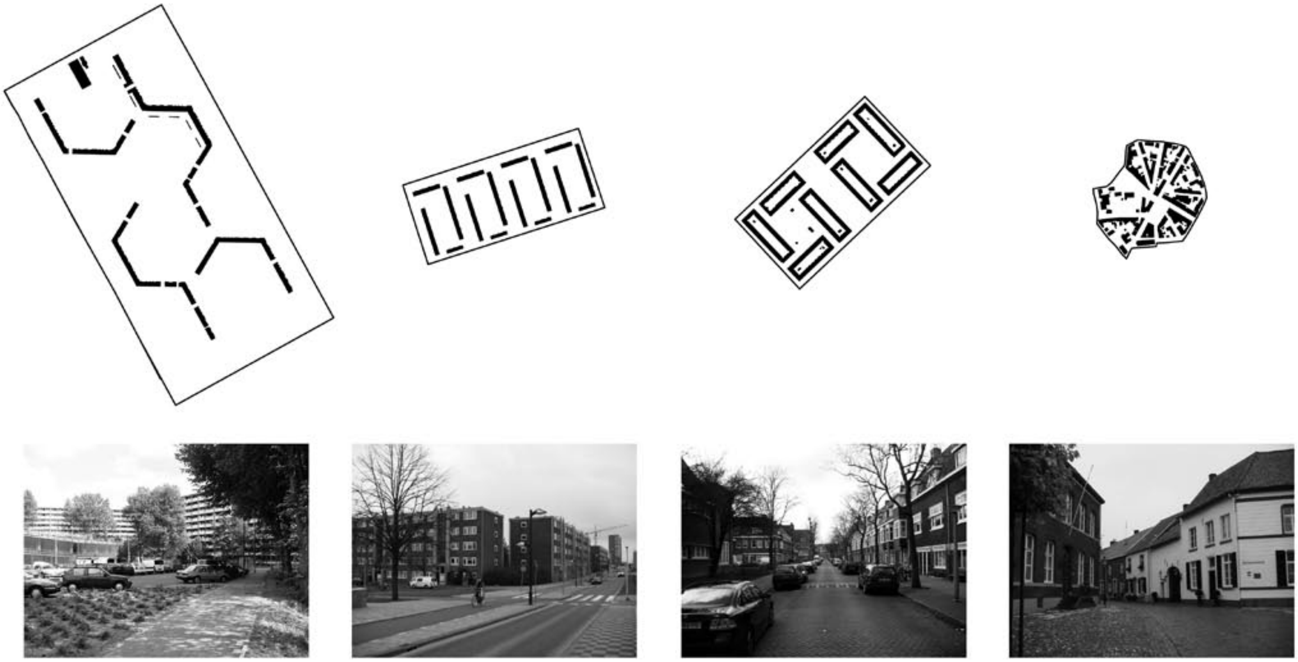


Figure 2. Examples with FSI app. 0.7

acre[1] (*Nothing Gained by Overcrowding*). Two decades later Wright suggested an ideal density of one house to the acre (*The Disappearing City*). In the Netherlands, the concept of density was used and prescribed in practice for the first time in 1934. Van Eesteren's scheme for a garden city expansion of Amsterdam (Algemene Uitbreidingsplan or AUP) was said to be based on pure scientific research and used density to define its environmental ambitions. Two recent Dutch publications by Urhahn (1994) and MVRDV (1998) deal with the subject in a less technical and more suggestive manner.

The most common variables to measure built density, such as houses per hectare or Floor Space Index (FSI) can not efficiently be used to describe spatial properties. Houses per hectare does not take other programs (such as offices, schools, and other amenities) into account and, due to different sizes of the dwelling units, is a very elastic variable. FSI (ratio of floor space and ground area) is more informative as it reflects the building intensity independently of the programmatic composition. But, as the examples in figure 2 show, it is still not precise enough to differentiate between different spatial layouts. The four examples all have a comparable FSI, however, they differ greatly in the distribution of built mass and open space.

To demonstrate how these four plans can be differentiated from each other, three more variables have to be introduced that are useful when describing built space: Ground Space Index (GSI), Open Space Ratio (OSR) and Layer (L). The first, GSI, describes the amount of built ground in an area. The OSR describes the intensity of use of the non-built ground. Unwin explained this variable as follows: if the population of all the buildings in an area goes out at a given moment, how much room would there be for them in the streets and other non-built ground? The last variable, L, indicates the average number of floors in an area.

The four variables are calculated using the same series of data – gross floor area, built area and plan area – and are thus mathematically related. When working with FSI, GSI, OSR and L, it is important to agree how to calculate the underlying values of gross floor area, built area and plan area. It is not possible to discuss the definitions of these values in detail here (for more information on these issues, see Berghauser Pont and Haupt, 2004).

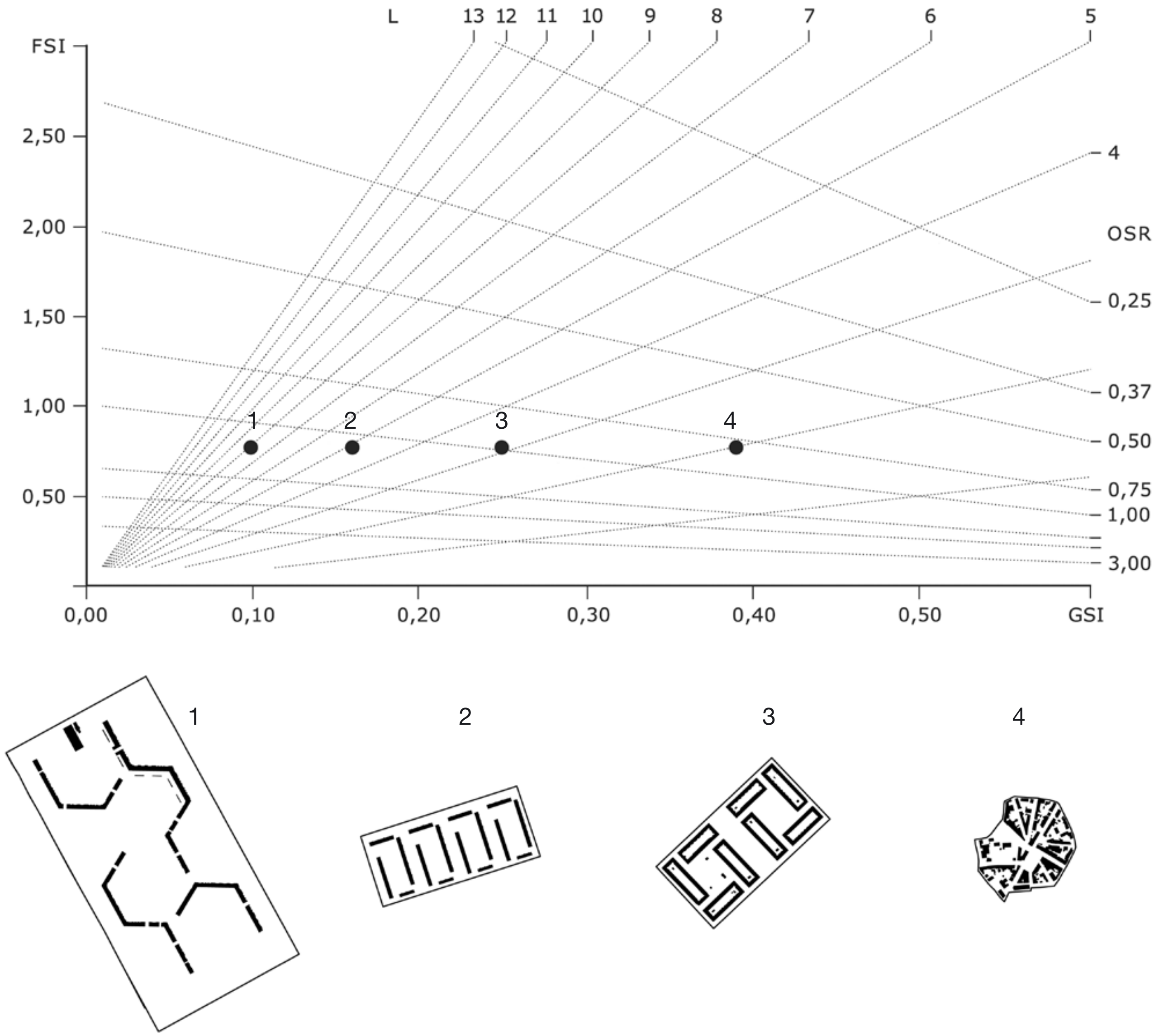
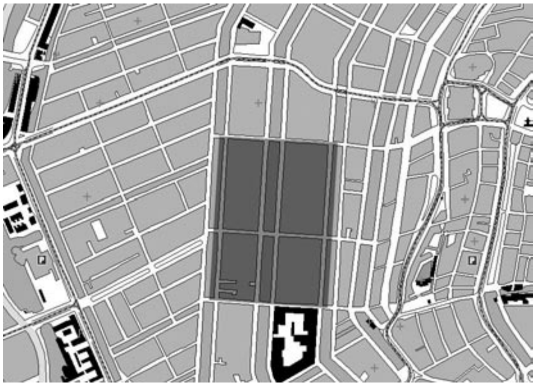


Figure 3. Four examples in the Spacemate.

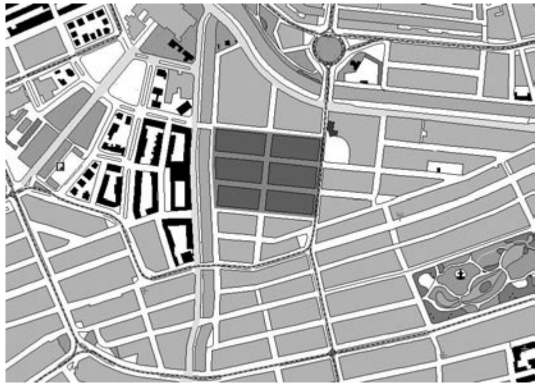
Spacemate

We suggest that if density is defined not only as intensity (FSI), but as a combination of intensity, compactness (GSI), height (L), and pressure on non-built space (OSR), it can be used to differentiate between urban form in a more efficient way. To assess all four variables simultaneously, we have developed a diagram, the Spacemate. The FSI on the y axis gives an indication of the intensity in an area and the GSI on the x axis reflects its compactness. The OSR and L are gradients that fan out across the diagram. Combining these four variables gives every project a unique 'spatial fingerprint'. The four examples used before can now be seen to occupy different positions in the Spacemate (see figure 3).

Figure 4. Four examples



1. the Grachtengordel



2. De Pijp

3. Betondorp

4. Osdorp

Four examples

Four areas of Amsterdam – the Grachtengordel, De Pijp, Betondorp and a part of Osdorp (Zuidwest Kwadrant) – will serve to further illustrate the described method. The Grachtengordel (1613) and De Pijp (1875) are examples of orthogonal fabrics with traditional building blocks. The Grachtengordel was developed as an extension of the medieval city which had become overcrowded due to the economic growth at the end of the 16th century. The urban fabric has an orthogonal and rational layout of streets, canals and blocks and is not based on the underlying landscape or the adjacent older fabric. De Pijp, on the other hand, was shaped by the existing landscape which has resulted in a smaller grain without canals. Both urban extensions consist of traditional closed (perimeter) blocks composed of a great many individual lots. In the case of the Grachtengordel, these lots were developed individually, while in De Pijp building developers sought to pack as many dwelling units as possible into relatively small blocks. However, the densities of the Grachtengordel and De Pijp differ little when it comes to GSI and FSI. Both have an FSI of approximately 2.0 and, with almost 50% of the fabric built upon, a GSI of 0.5.

The third example, Betondorp ('Concrete Village'), was developed at the beginning of the 1920s when the housing shortage in Amsterdam was on the increase. Betondorp is the outcome of a competition organised by the City of Amsterdam for prefabricated working-class housing in the rural area of Watergraafsmeer. The density of this low-rise development is much lower than that of the two examples from the inner city. Its FSI of 0.64 is less than a third of the intensity of the Grachtengordel and De Pijp, and only 30% of the fabric is built upon.

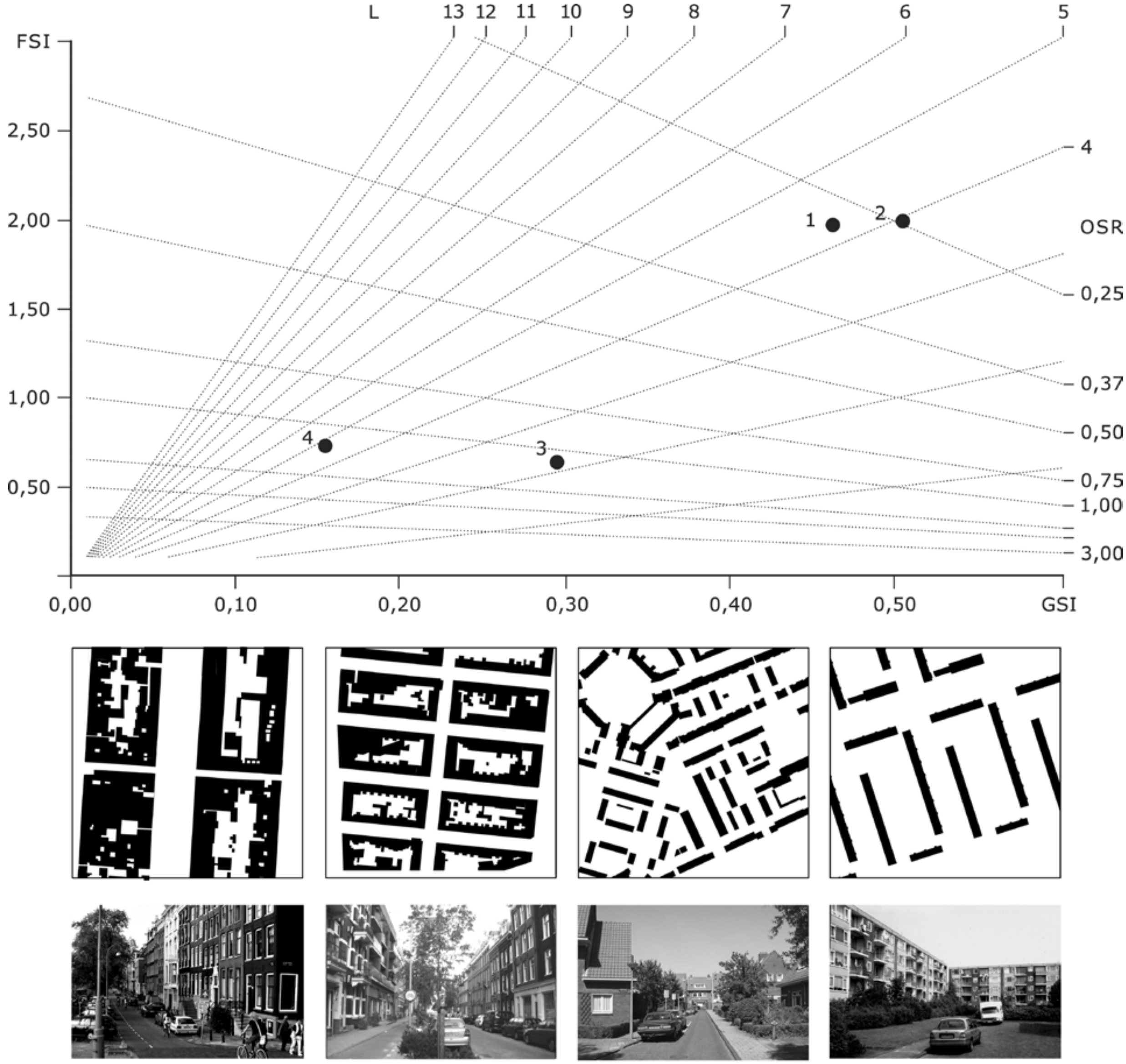


Figure 5. Four examples positioned in the Spacemate.

After the Second World War, when Amsterdam was again confronted with a huge housing shortage, the 'Western garden suburbs' (Westelijke Tuinsteden) were developed on the basis of Van Eesteren's AUP. The traditional building block was transformed into a half-open block where the inner courts became part of the public realm. This ideologically influenced way of building a garden city with lots of light, air and green space resulted in low densities. The FSI of Zuidwest Kwadrant in Osdorp (one of the Western garden suburbs) is 0.80 and thus comparable to Betondorp, but the GSI is much lower. Only 15% of the fabric is built upon. Due to these differences in density (FSI and GSI), the OSR differs too. Pressure on the non-built areas is four times as great in the Grachtengordel and De Pijp as in Betondorp and Osdorp.

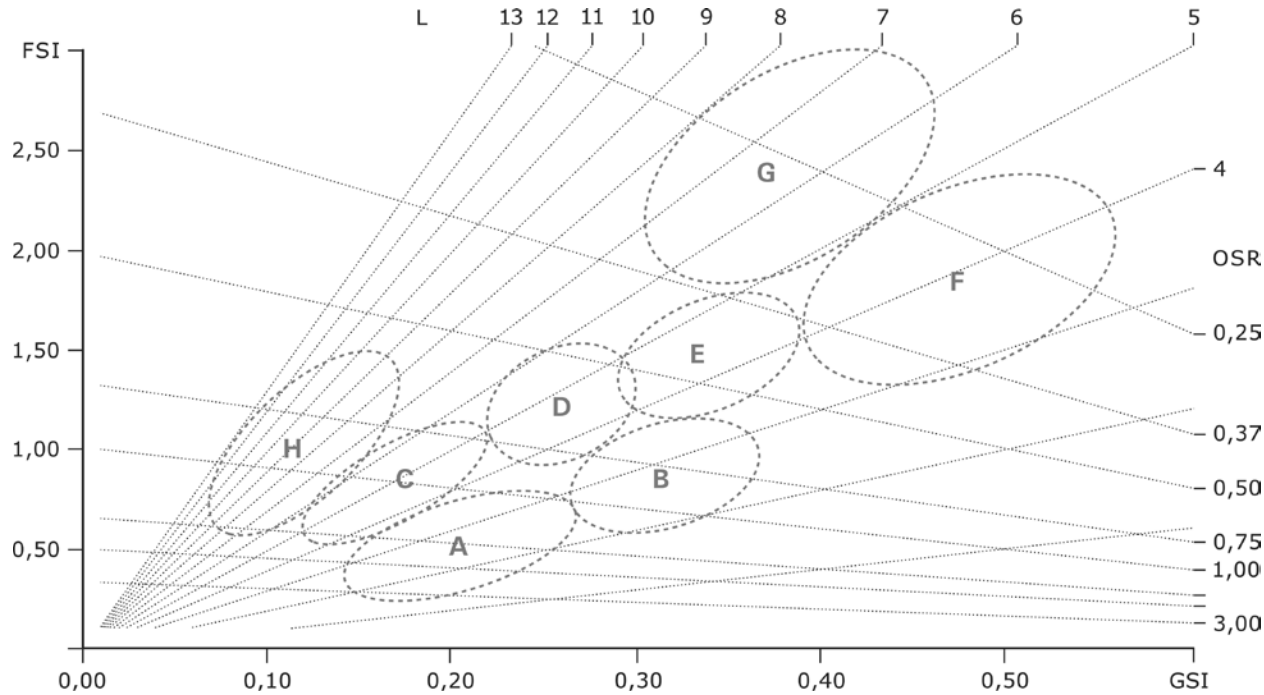


Figure 6. Land development typologies:

A. Low-rise spacious strip developments blocks
B. Low-rise compact strip developments blocks
C. Mid-rise open building blocks
D. Mid-rise spacious building blocks
E. Mid-rise compact building
F. Mid-rise closed building
G. Mid-rise super blocks
H. High-rise developments

Typologies

In order to investigate the degree to which a relationship exists between the variables and the various building typologies, we selected 50 Dutch residential areas that clearly differ in terms of the degree of urbanisation and the type of land development. The typologies we selected and analysed can be categorised as low-rise (2–4 floors), mid-rise (3–6 and 5–8 floors) and high-rise (> 7 floors).

Low-rise typologies are subdivided into areas featuring strip developments in either a 'spacious' or a 'compact' setting. These typologies are common in the suburban neighbourhoods of the 1990s, but also in post-war neighbourhoods and neighbourhoods from the 19th and early 20th centuries. The mid-rise buildings are subdivided into areas containing open, spacious, closed and compact building blocks. The open block is typical of the post-war period, while the closed and compact blocks are typical of pre-war cities. In the last ten years compact building blocks have become popular once more. Due to their larger scale in terms of size and height (5–8 floors), they are referred to as super blocks. High-rise buildings can be subdivided into strip developments and tower blocks. Both have a very spacious urban layout.

When grouping the different residential areas in the Spacemate chart, it is evident that clusters are formed that display similarities in terms of spatial structure. Thus, all the high-rise areas are gathered together in one zone in the diagram. This is also true of areas where closed building blocks, strips of low-rise developments or super blocks predominate.

The interaction between the variables appears to be more significant than their absolute values; a high-rise area can have the same FSI as an area with closed building blocks.

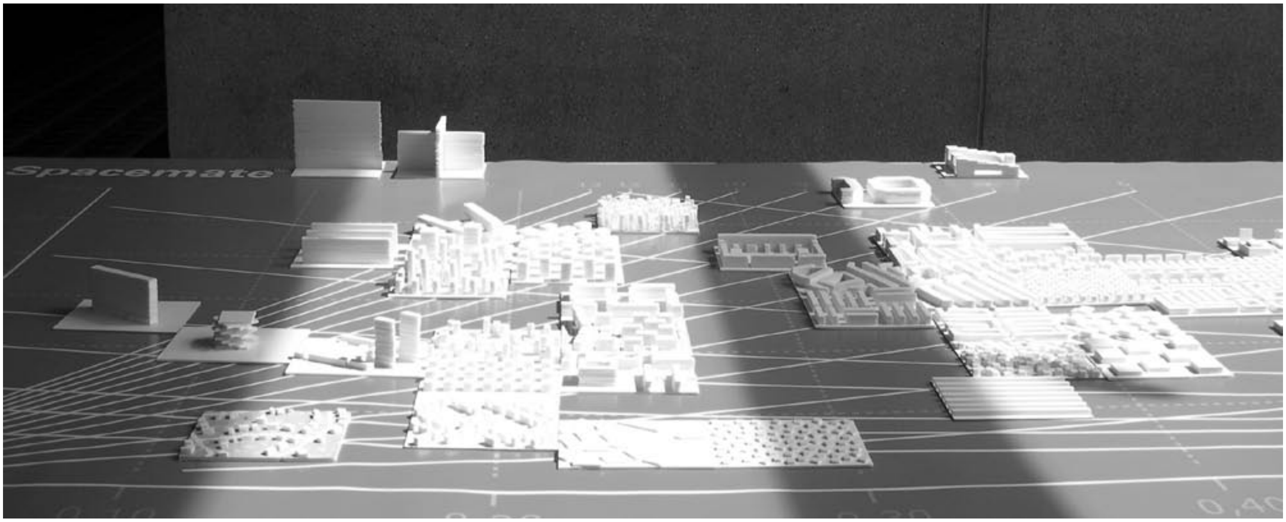


Figure 7. Student models positioned on a Spacemate chart for the exhibition ´Dwelling on Density´, 2004.

The high-rise area is in fact built in a much less compact manner and so has a lower GSI. In Spacemate, the position occupied by the high-rise areas is different to that occupied by the closed blocks.

In addition to the various land development typologies, aspects such as urbanisation, open space typology, granularity and functional blending can also be related to positions and clusters in Spacemate. This is an initial step towards quantifying the spatial characteristics of urban areas. The figure-ground analysis is hereby enriched with the third dimension and abstracted by quantifying the drawing. At the same time, the productivity (and resolution) of density as a concept for distinguishing between different urban typologies has been increased by integrating the figure-ground analysis in the form of the GSI.

Aggregation model and 'tare space'

So far, we have concentrated on the built floor area and the associated non-built area. The non-built area has not yet been further analysed. Interesting aspects of these non-built areas are the amount of public versus private ground, the amount of infrastructure, water and green space. Another limitation in the examples discussed here is their primary focus on the scale of the urban fabric. The results of this scale are important, but the relationship between different scales (aggregations) is also of great importance to designers and planners.

Though the effect of a certain density at one scale on the densities at other scales is of great importance to designers and planners, this has not been adequately researched. By using the Spacemate method at all scales – from building to district or city – we hope to lay bare the logic of the surplus or 'tare space' which is added or subtracted when there is a switch of scale. The aggregations used in the Spacemate project are as follows:

- **Building**. The plan area is the same as the built area. The borders of the built area are defined by the edges of the building footprint.
- **Lot**. The plan area is the sum of built areas and non-built private areas (tare space) such as gardens and private parking lots. In some cases the lot contains built areas only and thus corresponds with the entity of the building; no tare space is added. The lot is defined by the legal boundaries specified in the cadastral map.
- **Island**. In most cases the island will simply be a collection of lots. Sometimes, however, it will also contain public areas (tare space) such as playing fields, public car parks and green space. An island is limited by the borders of the transport infrastructure surrounding it. In places where no relevant transport infrastructure is present, a border is constructed between the lots and green areas or water.

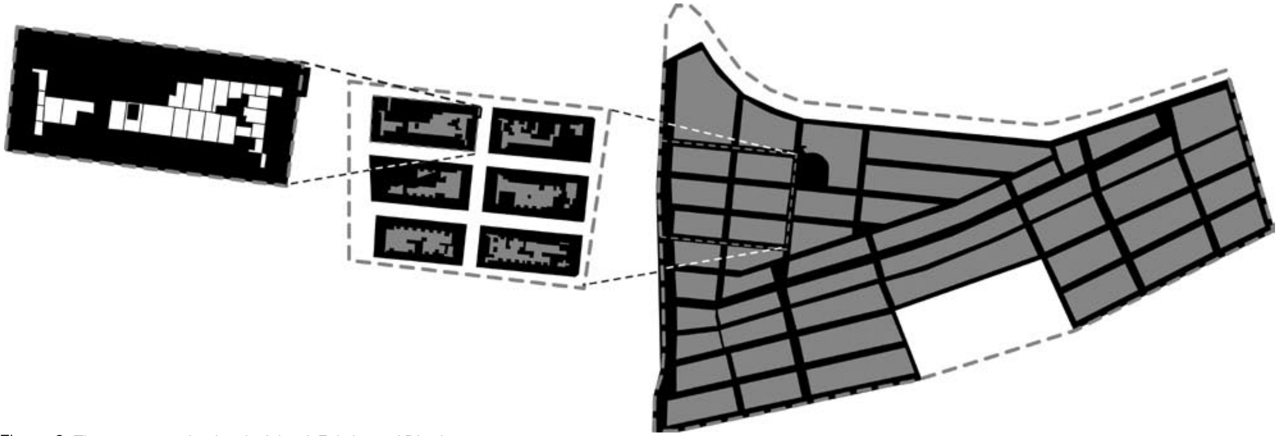


Figure 8. Three aggregation levels: Island, Fabric, and District.

- **Fabric**. The fabric consists of a collection of islands and the transport infrastructure surrounding these islands (tare space). The urban fabric is limited by borders drawn centrally along transport corridors relevant to the scale of measurement. In places where no relevant transport infrastructure is present, a border is constructed between the lots and green areas or water.
- **District**. This entity is composed of a collection of fabrics and large-scale non-built areas (tare space) not included in the fabric itself, such as parks, water and larger transport infrastructure.

Recent studies show that the added tare space differs greatly at the scale of the fabric. This space consists exclusively of infrastructure. A systematic inquiry into the relationship between the distribution of tare space at different scales and urban typologies could reveal insights that might be of great value for planners and designers.

Four examples

The four examples used above – the Grachtengordel, De Pijp, Betondorp and Osdorp – can also serve to describe the differences in building densities between the scales of island, fabric and district. The Grachtengordel and De Pijp show great similarities at the scales of island and fabric. In the Grachtengordel, 27% of the island consists of tare space (non-built private) whilst in De Pijp this figure is 25%. At the fabric scale, 37% of the Grachtengordel and 33% of De Pijp consists of tare space (network). At the scale of the district, however, the areas show a clear difference. Only 4% of the Grachtengordel district is tare space. In the case of De Pijp, the district tare space is 16%. This is due to the fact that in the Grachtengordel almost the entire public area consists of streets and canals, whilst in De Pijp 35% of the public area is a park (Sarphatipark). In other words, in the Grachtengordel the public area is evenly spread out over the district and in De Pijp a part of this public area is concentrated in the Sarphatipark. The other two examples show a different logic. Betondorp and Osdorp are comparable at the island scale, where respectively 59% and 63% consists of tare space. At the scale of the fabric, however, they show a slight difference. In Betondorp 29% of the fabric is needed for infrastructure, compared with 39% in Osdorp. The same thing happens at district level; less non-built space is added in Betondorp (district tare space 7%) than in Osdorp (18%). Thus, starting with the same amount of non-built space at island level, differences occur at the higher levels due to the amount of infrastructure and the added large-scale open areas (green space).

Network density

Although the Spacemate method increases insight into the logic of urban form by using a set of quantifiable variables to describe the built environment, the form remains abstract and lacks scale. Aspects such as the distribution of the footprint and the size and shape of the grain of the fabric

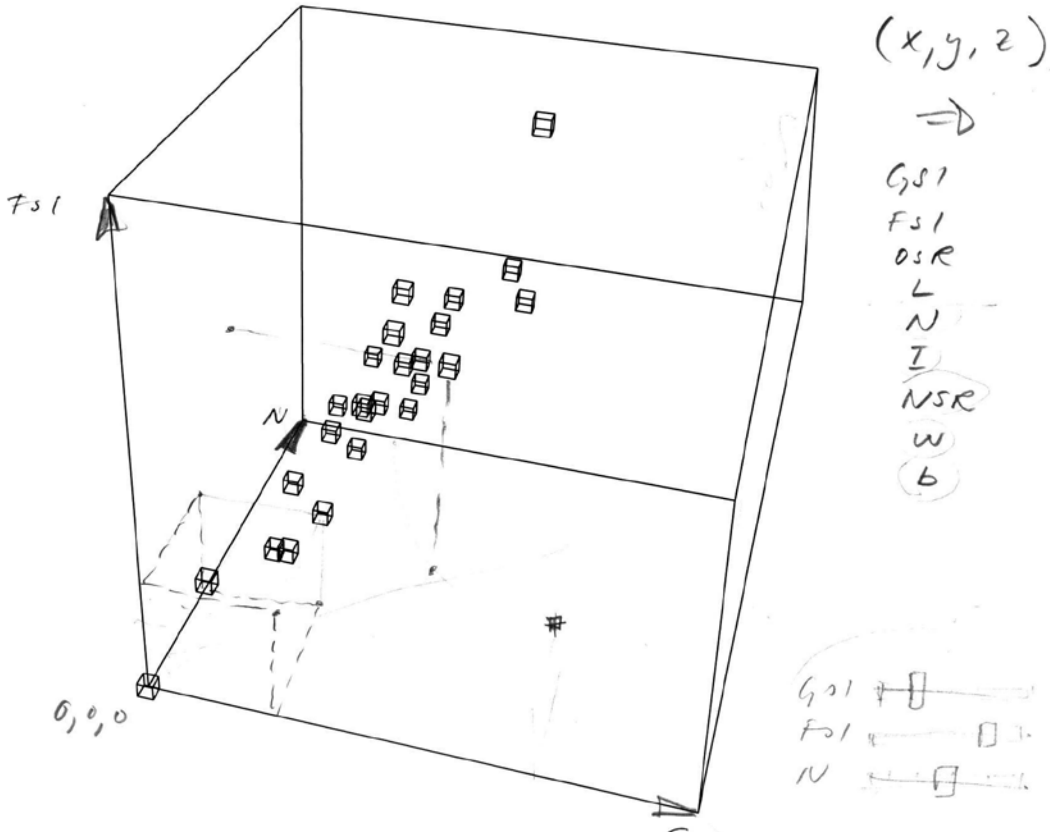


Figure 9. SpaceMatrix

remain unknown. Studying the relationship between networks and the various forms of built environments might make these more explicit. In order to measure network density we need to define the term ‘network’. In this case, network is primarily defined as infrastructure with a certain structural robustness. In most cases this will amount to motorised infrastructure with a width larger than a certain measure. This will for instance exclude a small path winding through a park. Further study will include formulating the most productive and relevant definitions of network.

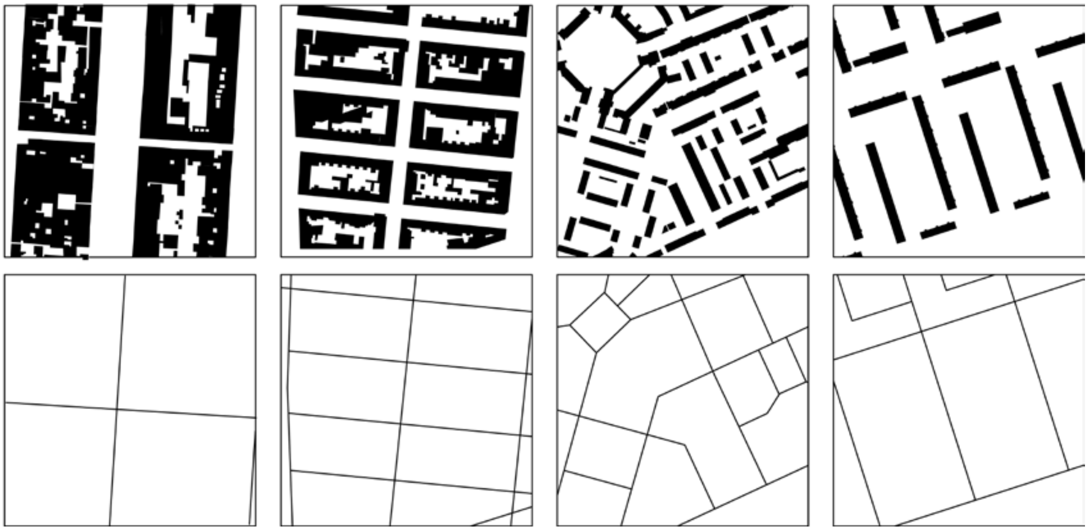
The length of the network is used to determine the network density (N). This network density can then be used to calculate:

- The average distance from street to street (fabric width/grain size);
- The porosity of the fabric (width of open space);
- The street profile.

The new variable N not only contains quantitative information but also gives an indication of the dimensions of the urban form. This was not possible using only the FSI, GSI, OSR and L, as these variables are dimensionless. Thus, by adding the variable N to Spacemate, the ‘spatial fingerprint’ of an area becomes more precise. A three-dimensional extension of Spacemate – the SpaceMatrix – visualises this spatial fingerprint with three coordinates: the FSI on the y axis gives an indication of the intensity in an area, the GSI on the x axis reflects the compactness of the buildings and the N on the z axis introduces the network density.

Combining the research on network density with the aggregation model may lead to new conclusions concerning typologies. It is important to note that the network density described above only can be applied at the scale of the urban fabric. Network density must be seen as a specific case of a more general ‘transitional density’ which can be

Figure 10. Figure-ground and network analysis of four examples.



1. the Grachtengordel 2. De Pijp 3. Betondorp 4. Osdorp

defined on all levels of scale. In the case of the island entity, a density of lot divisions describes (indirectly) the average size of the lots composing this island. At a higher scale, the density of borders or transitions between different fabrics describes the size of these fabrics and thereby also gives an indication of the heterogeneity of a district.

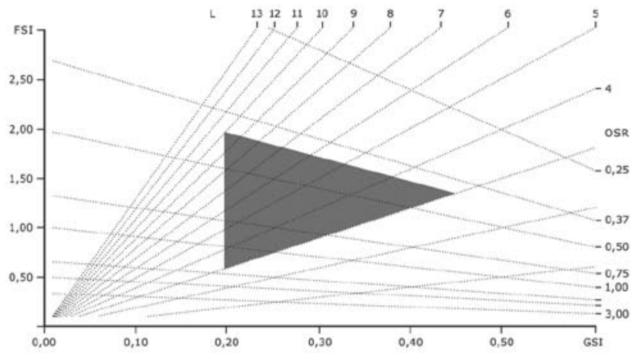
Four examples

To illustrate network density in relation to building density we return to our four examples: the Grachtengordel, De Pijp, Betondorp and Osdorp. By measuring the length of the network within the urban fabric of the selected examples, we are able to describe the density of this network, the grain of the fabric and the street profile. It should be noted that the following theoretical values for grain and profile width are derived solely from the network density.

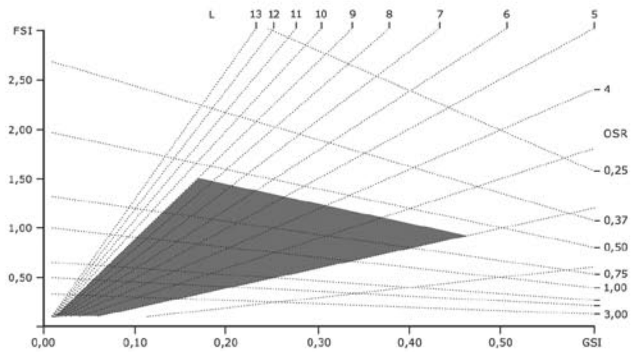
The Grachtengordel has the lowest network density, 110 m/ha, due to the large scale of the building blocks. This means that for every hectare of the plan area, there are 110 metres of network. As a result, the grain of the fabric is quite wide, 182 metres, and the average street profile is 38 metres. If we compare this to De Pijp, which has almost the same building density, we see a big difference. Here, the network density is more than double that of the Grachtengordel (230 m/ha) and the grain of the fabric is half the width (87 metres). The average street profile is only 16 metres. This shows that although the building densities are comparable and the building typologies belong to one family, little is said about another important characteristic of the urban fabric, size. By using the network density in addition to the building density, new families of different urban patterns can be identified. The third example, Betondorp, has almost the same network density and fabric grain width as De Pijp. From the perspective of network density, they resemble each other, while they differ in building density. The fourth example, Osdorp, has a network density lower than that of Betondorp and De Pijp but higher than the Grachtengordel. The fabric grain width is 113 metres.

Performance indicators

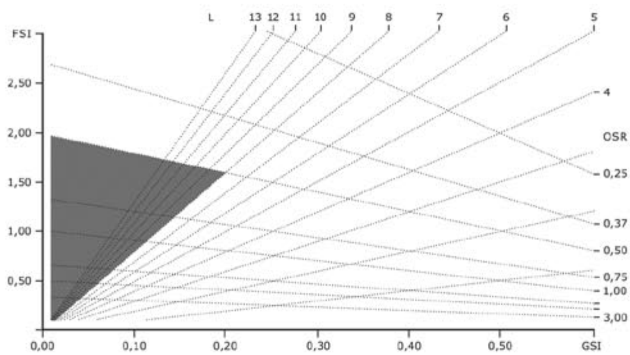
In addition to describing fundamental properties of built space such as the ones sketched above, Spacemate can also be used to investigate and describe the "behaviour", or the performance, of certain factors under different density conditions. Examples of such properties are private exterior space, urbanity, programmatic blending, parking, light access, accessibility, energy consumption, pollution and water management. The behaviour of these properties can be described by *performance indicators*. These performance indicators can produce important information about which



Urban



Suburban



Highrise

Figure 11. Urban environments defined in the Spacemate. Used as guidelines for transformations of the Westelijke Tuinsteden in Amsterdam.

problems and possibilities can be expected for different densities (positions in the Spacemate). Every performance indicator can be viewed as a descriptive layer that, when combined with the others, can be used to clarify different qualitative aspects of urban environments, as well as identifying conflicting programs.

By understanding the logic of these issues and their relation to density, the design task can be formulated more precisely and difficulties, or inconsistencies, can be spotted at an early stage in the design process. For instance, at which combinations of intensity, compactness and network density does it become necessary to look for built solutions for parking? Up to which densities can single-family housing with ground access be realised? And what potential do different densities have for urbanity and functional blending?

Conclusions

As we have seen above, it is not only the FSI that matters when it comes to urban density. The three other variables of Spacemate (GSI, OSR and L) are just as important in describing built density. In addition, network density is important to describe the built environment.

At an early stage in the development of a plan (for example when drawing up a list of requirements), Spacemate can help clarify the relationship between the spatial objectives and the development program. Depending on the stated starting point in a planning process (program, public space, building type), the diagram can be utilised in different ways. By setting out upper or lower limits, zones in the diagram can be delineated.

In summary, Spacemate has a number of qualities that can aid the design practice:

- Spacemate sets out a clear relationship between measurement units and graphic representation.
- Agreements made on the basis of Spacemate have an objective character.
- Spacemate increases control opportunities at a high level of scale and design freedom at a low level.

The quantifiable information embedded in density concepts has proven helpful in describing certain primary aspects of spatial form. This can be used in developing an instrument for planning (programming) and design (form).

	Grachtengordel	De Pijp	Betondorp	Osdorp
FSI	1,98	2,01	0,64	0,80
GSI	0,46	0,50	0,29	0,17
OSR	0,27	0,25	1,11	1,04
L	4,30	4,02	2,21	4,71
tare island (gardens) (%)	27	25	59	63
tare fabric (network) (%)	37	33	29	39
tare district (parks) (%)	4	16	7	18
N (m/ha)	110	230	250	150
grain fabric (m)	182	87	80	133
street profile (m)	38	16	13	29

Figure 12: Data of the four examples.

By understanding the relation between quantity and form, the design task can be formulated more precisely. Densities can be used to define conditions under which formal ambitions can be realised. Densities can also be put to work in assessing the qualitative consequences of such factors as parking, accessibility, street profiles, and dwelling type. By making relations explicit, difficulties and inconsistencies can be spotted at an early stage, thus improving the design process.

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Illustrations

Figure 1: *Algemeen Uitbreidingsplan van Amsterdam*, 1934 and Gemeentearchief Amsterdam.

All other illustrations have been produced by the authors.

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Notes

1. 1 acre = 0,4 hectare (app.)