

## four strategic densification scenarios for two modernist suburbs in Stockholm

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### Abstract

*One of the biggest challenges for future urban design is to cope with suburbia and sprawl. This paper investigates how sprawl can be compacted in terms of spatial morphology. New 'user-related' location density measures, like spaciousness and compactness, are introduced that integrate floor area, axially of pedestrian network, and public open space. These and 'administrative' area density measures are applied to two modernist suburbs in Stockholm, Björkhagen and Rågsved (1946-1957), and four strategic densification scenarios: 'New urbanism', 'New regularism', 'New conservatism', and 'New modernism'. The results show that the suburbs can increase by 100% in Floor Area Ratio in the first two and but only 20-40% in the other two. Floor area accessibility, however, is influenced by network accessibility more than plot density. Public open space is needed to uphold spaciousness and compactness. To conclude, tree-like morphologies seem rational in peripheral low density suburbs with a lot of public open space, but when densified the grid becomes more necessary to uphold compactness. Even though densification by 'New urbanism' or 'New regularism' in modernist suburbia is improbable due to political reality, they point out possible ways to compact more efficiently modernist sprawl as well as the need for further research.*

## 1. Introduction

One of the biggest challenges for future urban planning and design is how to cope with sprawl, or more specifically, with the suburbia that has been built over the last century (See GUST 2000, Xaveer De Geyter 2002, COST 2005, EEA 2006). Many planners and designers are now asking this question – How can suburbia be densified and what is the role of public open space? Contemporary European and American cities consist of 5-50% public open space, often with a large share of public parks, nature areas, and green belts (Peterson 2002, SCB 2002, Oh & Jeong 2007). This comprises huge amounts of potential development and value for the building and real estate industry, which subsequently could make a major contribution to urban growth. Normally, open space is scarcer in dense central areas, yet highly urbanized areas like Manhattan in New York and the inner city of Stockholm have 5-15% public open space. Why is this space not built up? So far, there is very little research in economic geography or urban morphology that explains this (COST 2005, 267-273).

In Sweden, suburban densification started seriously in the 1980s. It has been called “building the city inwards” or “city healing” where the former has been the paradigm for the City Plan of Stockholm since 1999. Many policies, such as Stockholm’s City Plan and the “Urban renaissance” program introduced in the U.K. (Rogers 2005), proposed to build on semi-central industrial land and save green space due to environmental concerns and Not-In-My-Backyard effects. In many big cities such as Stockholm, many of the brownfield developments have now been planned and built. However, they have all been criticized for being too dense, lacking green space, and often

not child friendly enough, especially since a lot more families than was expected have moved in (Miljöförvaltningen 2007). The Stockholm City Planning Authority has now, in the beginning of the 21st century, reached a point where it can no longer rely on the comfortable strategy of avoiding green space exploitation by building on brownfields and parking lots. The pressure on the inner rather dispersed “green” suburbs is too strong. The demand for new urban design strategies on how to deal with this is expressed in the current discourse among planners.

*“When we have developed Hammarby Sjöstad, Liljeholmen, Norra Station, Västra Kungsholmen and Värtan [semi central industrial areas], we will definitely look at the voids of suburbia, often the green spaces that separates our suburbs. [...] Today we want city life, that’s the mega trend. Hence we can densify and increase the density we got. But if we are going to develop these voids, how do we do it?” Bengt Andrén, head of suburban planning, Stockholm City (Berkefeldt et al 2007, author’s translation)*

Stockholm is not unique. Many big cities are facing great planning and design challenges when it comes to the densification of suburbia and its open spaces, i.e., ‘compact sprawl’.

## 2. Theory and methodology

The background described above has been outlined in dialogue with a reference group from the Stockholm City Planning Administration and the following study is based on a commission from the same authority to deepen the understanding of the concept of densification and to test suburban densification scenarios. Therefore, this study examines these issues and ideas central for urban design practice in Stockholm today. The theory and methodology used in the study is basically grounded in the research field of urban morphology. The scenario techniques used are developed within the field of contemporary future studies.

### 2.1. Research questions

The research questions that were formulated together with the reference group from the Stockholm City Planning Authority can be summarised as follows.

- How can modernist suburbia be densified?
- What are the critical measures of spatial morphology when it comes to suburban densification?
- Are there ways to overcome the apparent conflict between densification and the need for public open (green) space?

The first question is very general and refers to the historical urban designs and structures in modernist Stockholm today and what are possible and probable future forms of densification. The second question refers to how these new forms are identified, measured, and analysed in the contemporary city. The last question refers to one of the major tasks that face densification since it by conventional definition consumes is open space. In a previous study of ten city districts in Stockholm, Ståhle (2005, 2007) claimed that there could be “more green space in a denser city” because existing urban structures have both high density and high public open (green) space accessibility. An important aim of this study is to investigate to what degree this also would be true for different densification scenarios applied in one and the same area.

### 2.2. Spatial density measurements

In recent decades, there has been extensive research and development when it comes to measuring urban density development, especially in the fields of sprawl (Frenkel & Ashkenazi 2008) and walkability (Lee & Moudon 2006). Many of these indices have been proved to be useful tools for urban studies but limited as tools for an urban designer since few are specifically morphological and few address the detailed scale of urban district or neighbourhood.

It is of great importance to look at both ‘administrative’ and ‘user-related’ measures, in this study distinguished as *area density* and *location density*. What is fundamental to the approach of this study is a basic division between urban built-up areas and public open spaces.

### 2.2.1. Area density measures

The area based density measures are especially useful from the urban administrator (developer) point of view, or for an urban designer that needs to control the development of space. We use five area density measures: Floor Area Ratio (FAR), Share of Built Space (SBS), Share of Open Space (SOS), Open Space Ratio (OSR), and Spatial Compactness Ratio (SCR).

<b>FAR</b>	Floor area / Site area
<b>SBS</b>	Building footprint / Site area
<b>SOS</b>	Open space area / Site area
<b>OSR</b>	Open space area / Floor area
<b>SCR</b>	Open space area X Floor area / Site area <sup>2</sup> = SOS X FAR

FAR is the most basic and widespread spatial density measure used in urban morphology, development, management, planning, and design. It can be used for estimating the amount of floor area, apartments, development costs, etc. For the analysis of density in regions, people/hectare is a more common measure among regional planners and geographers. The share of built space (SBS) on a site is often related to FAR, highlighting the relation to number of floors and OSR as shown in the left figure below. The OSR, introduced in the 1920s by Anton Hoenig, is a quantitative measure of spaciousness (Hoenig 1928). It is still used in New York City's zoning regulations to create open space (NYC 2008).

The SCR measure introduced in this paper describes the 'spatial compactness' of an area. This means an area is most compact when it has a lot of floor area and useful public open space. Unlike FAR, SCR adds useful open space to floor area. It differs from OSR in that it describes not the amount of open space per floor area but the product of interior and exterior space in a plot.

### 2.2.2. Eight location density measures

How densification affects lived and perceived urban space and how "urban" quality and intensity emerge can only be studied properly by location-based measures. We have chosen eight pedestrian-based location density measures that capture different dimensions of the intensity of urban life and environmental quality.

These measures are similar to the models developed in the field of walkability and in transportation research, which emphasizes land use and Euclidean distance (Cerverro & Kockelman 1997, Talen 2003, Lee & Moudon 2006); however, they address spatial morphology and cognitive topological distance (Hillier 1996, Ståhle et al. 2005). The eight location measures are described below.

*A. Axial line integration:* The space to move around in, in our case in the pedestrian network, is a space that connects people and attractions in cities. This network creates accessibility and distributes densities and open space to people. The 'axial line integration' measure, developed within space syntax research, captures the connectivity of the public street and pathway network represented by the least amount of axial lines that cover all its possible routes (Hillier & Hanson 1984). The measure captures the concentration of social and economical activities in cities (Hillier et al. 1993, Hillier 1996, Vaughn 2007). Hence, increased network accessibility affects the performance of density. In this study, we have chosen radius 6 integration since it has been proven to capture the spatial characteristic of urban and suburban areas in Stockholm (Ståhle et al. 2005).

*B. Entrance density:* This is a general measure used in urban morphology that captures the density of entrances along streets and pathways, here measured as number of entrances per 100 meters along axial lines. This measure is closely related to the intensity of activities in urban public space, since every entrance represents a possibility for the interior life of buildings to activate public space (Hillier 2004, Gehl et al. 2006). In terms of density, entrances connect the interior density in plots to the perceived and lived density in exterior public space.

*C. Floor area accessibility:* This measure calculates the accessibility to floor area within a certain distance. It can be seen as the location version of FAR. This analysis can be said to roughly

represent the potential local market or population within radius from a certain location and hence some kind of socio-economic potential and the conditions for the level of service (LOS). It is a measure that integrates network accessibility and plot density. We use radius 6 in axial steps since it has been proven to correlate to pedestrian flow in Stockholm's urban and suburban settings (Ståhle et al. 2005).

*D. Ambiterritory:* When cities are densified, territoriality becomes increasingly intensified. Modernist suburbs built as freestanding buildings in green space generally have a lot of open space that one can call 'ambiterritory', or no-man's-land, where private and public collide creating territorial ambivalence. Ambiterritory is here calculated by a 10-meter buffer around buildings that is not cancelled by a 10-meter buffer from a street, a pathway, or an entrance (Ståhle 2007). Increase in ambiterritory can generally be said to decrease useful public open space, which is important to densification analysis.

*E. Public open space proximity:* Proximity to public open (green) space is crucial to attractive housing and to urban density (COST 2005). Research shows that 300 meters is a limit for everyday green space use (Grahn & Stigsdotter 2003) and 1000 meters is a limit to recreational forests (Hörnsten & Fredman 2000). Other research shows that axial step distance – changes in direction – correlates with the actual and experienced visit frequency to green space (Ståhle 2005). In our study, we use walking network distance in meters and in axial steps.

*F. Public open space accessibility:* The accessibility to open space here means the sum of all public open space within reach. Public open space is multiplied with a qualitative factor of the direct use value from a 'sociotope map' (Ståhle 2006) and accessibility is limited by 1000-meter distance and open spaces are weighted according to axial step distance (Ståhle 2005). Accessibility to public green space is a major planning issue, especially in Nordic countries. In the suburbs, public open space basically equals public green space in terms of quantity.

*G. Location spaciousness:* This measure is calculated by dividing open space accessibility (E) with floor area accessibility (C). It can be seen as the location version of OSR. This aims to capture the spatial conditions for potential congestion in public open space that may encourage suburban sprawl.

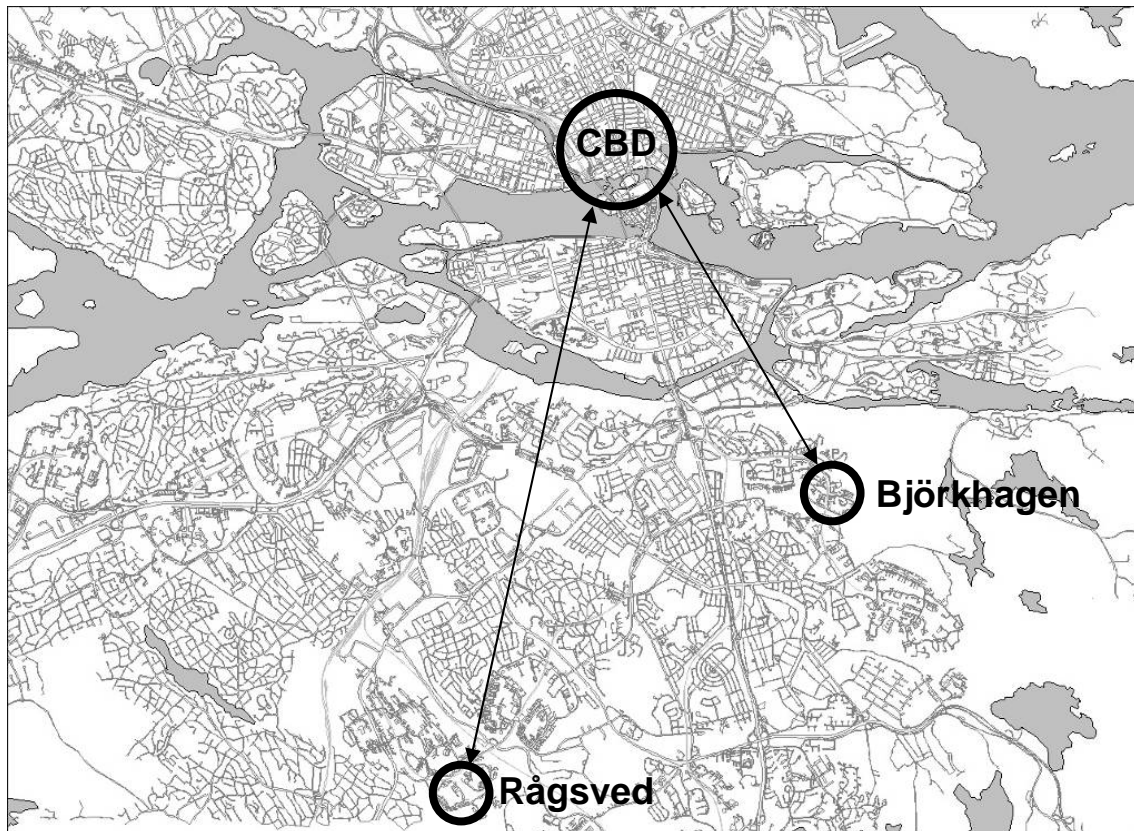
*H. Location compactness:* This measure, described as location SCR, is calculated by multiplying open space accessibility (E) and floor area accessibility (C). This measure aims to capture the spatial production of urban sprawl, i.e. inefficient non-compact spread-out morphology.

Each of these density measures is applied to the existing situation in the study areas and to the four designed scenarios. All analyses are made using the GIS-software MapInfo. A is done with the application Confeego (<http://www.spacesyntax.net/software>). C, E, F, G, and H were done with the application The Place Syntax Tool (Ståhle et al. 2005, <http://www.arch.kth.se/sad>).

### **2.3. Study areas**

Two study areas were selected in dialogue with the planners from the Stockholm City Planning Administration. There were two main criteria for choosing the study areas. First, they had to be interesting for future long-term densification, but not in an active planning state at the moment. Second, the areas had to be divided into two sub-areas: one sub-area representing densification within a built-up district in the small open spaces between buildings and the other sub-area representing densification of the large open spaces in-between districts.

The two study areas represent the narrow time span of a decade (1946-1957) in Swedish post war modernism, yet they are morphologically quite different. In the Stockholm City Plan from 1999, Björkhagen is categorized as a "thin-slab-suburb" (*Smalhusstad*) and Rågsved as a "city-satellite" (*ABC-stad*).



**Figure**

*CBD in Stockholm inner city and the study areas in the southern suburbs.*

**Björkhagen and Nytorpsgårde**

The in-district built-up sub-area, the Björkhagen sub-area, has FAR 0.38 and OSR 1.06. The in-between sub-area basically consists of the large public green area called Nytorpsgårde, facing three other districts, Hammarbyhöjden, Kärrtorp, and Dalen.

**Rågsved and Rågsveds friområde**

The in-district built-up sub-area, the Rågsved sub-area, has FAR 0.43 and OSR 0.76. The in-between sub-area consists of the large public green area called Rågsveds friområde, facing one other district, Fagersjö, to the east.

**2.4. Scenarios**

How then can modernist suburbia be densified? In other words, what are the possible densification scenarios? What is needed is an explorative approach to densification, similar to what Börjesson et al. (2006, 728) call *strategic scenarios*. The aim of strategic scenarios is to describe a range of possible consequences of strategic decisions, in our case different densification strategies. The goals are not absolute but target variables, such as the area and location density measures, are used to evaluate different strategies.

The selection of strategic scenarios is decided by what is considered as possible futures, in our case possible densification strategies. Since municipal planning has so far been rather strong in Sweden and in Stockholm, urban development has been quite predictable, following certain design doctrines. From the 1980s, planning has been increasingly market-oriented, an approach that has made design more diverse. In this early stage of the 21st century we can clearly see some dominating urban design trends in Stockholm. For example, there is one leaning towards conservation and another driven by the market, an economist trend.

How can we then translate these trends into morphological terms? A rather simplified but still fundamental way of defining conservationist densification would be to say that it tries to mimic existing building types, to keep new development within existing building height, and to use existent street systems. In the 1940s, modernist suburbia would mean constructing mostly thin lamella buildings. An economist densification strategy, on the other hand, would be to follow the existing building typology but raise the building height to increase floor area ratio, but still keeping within the existent street systems because new streets mean additional development cost. This design strategy could be labelled 'New modernism' since it is conventionally rational and tends to produce point buildings housing, such as a Le Corbusiean "city of towers" (Hall 1988). These two strategies are the most common in the current suburban densification incrementalism that is taking place in Stockholm today.

An internationally strong urban design trend, maybe the major counter reaction to modernism, is 'New urbanism'. This design doctrine has been gradually developing since the 1980s due to the demand both for higher development densities and the renaissance of urban lifestyles. 'New urbanism' has emphasized the street, which was erased by modernist traffic planning, as well as adapting to the local scale (Jacobs 1961). Hence, a crude definition of a 'New urbanism' densification strategy could be that it tries to add new development that preserves established building height and is also open for an extended street network, favouring a more block-like building typology. Following our simple but fundamental search for possible densification strategies, what remains is one where both building height and street networks are increased. This kind of urban design doctrine could be called 'New regularism', referring to the planning schemes of late 19<sup>th</sup> century. This approach combined densification with upgrading of public space including not only streets and squares but also parks and green areas. This strategy is not often used in suburban densification today, mainly due to the big supply of (public) open space and expected high development costs. However, new large-scale developments such as Hammarby sjöstad and NW Kungsholmen in Stockholm can be considered regularist-like in many ways.

Although our study is mainly strategic, exploring densification, it has apparent normative connotations since the densification strategies can be used as planning goals. Börjesson et al. (2006) defines this as *normative preserving scenarios*, where the task is to find out how a certain target can be efficiently met. From the municipal planner's point of view, it is important that densification supports "sustainable development" and that the lack of housing is solved. This will allow the scenarios to be used to study which design strategy is preferable given these planning goals. Since the core aim of our study is to evaluate experimental densification by spatial density measures, these measures do not directly address these goals. Rather, the results are used to discuss the role of spatial morphology and design in densification planning.

#### 2.4.1. Urban design of scenarios

The identification of the densification strategies, as well as their rather simplified urban design definitions, were first formulated in a workshop at the Spatial Analysis and Design research group at The Royal Institute of Technology and then acknowledged by the reference group from the Stockholm City Planning Administration as accurate, providing interesting generalizations of the current urban design trends in Stockholm.

1. *'New urbanism'*: This scenario investigates the effects of an urban design strategy that allows for extension of the street network, but keeps new buildings under the established building height, which is 3.2 floors in Björkhagen, and 3.8 in Rågsved, and also following 'New urbanism' design principles of closed blocks that measures about 60 X 100 meters. Building width is about 12 meters and street width about 15 meters.

2. *'New regularism'*: This scenario investigates the effects of an urban design strategy that allows for extension of the street network and increases the building height by 50%, which means 4.8 floors in Björkhagen and 5.6 floors in Rågsved, but also preserves and enhances some parks. The street and block structure is the same as in the new urbanism scenario.



**Figure: New Urbanism**

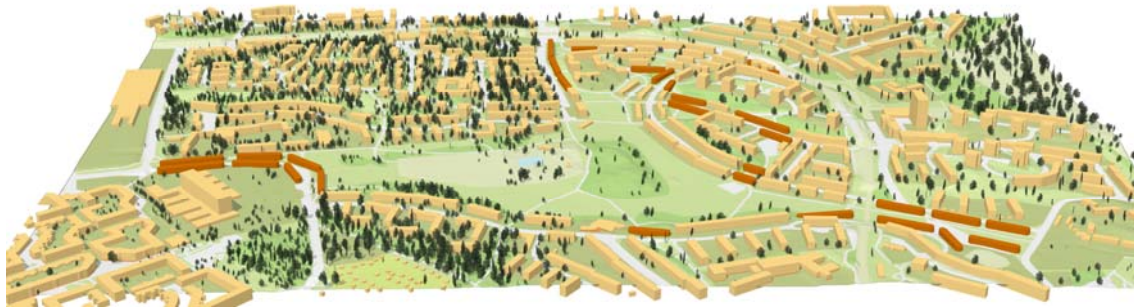
The 'New urbanism' densification scenarios for Björkhagen-Nytorpsgårde and Rågsved-Rågsveds frområde study areas. 3D-illustration of Björkhagen-Nytorpsgårde by Stockholms Stadsbyggnads-kontor, Stadsmättningsavdelningen, Mats Lilja, July 2008.



**Figure: New Regularism**

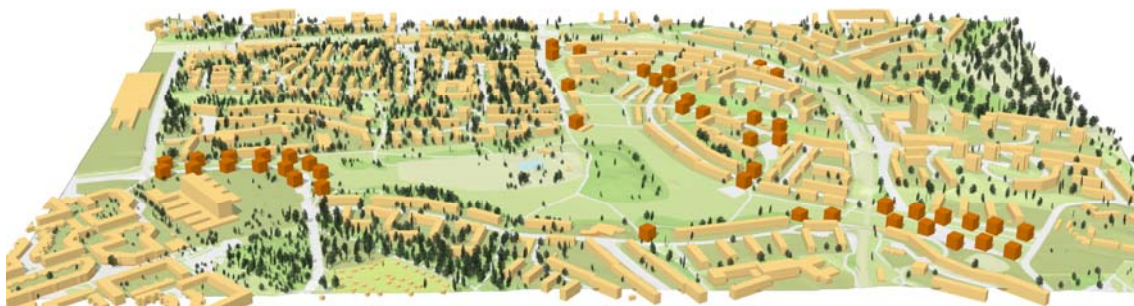
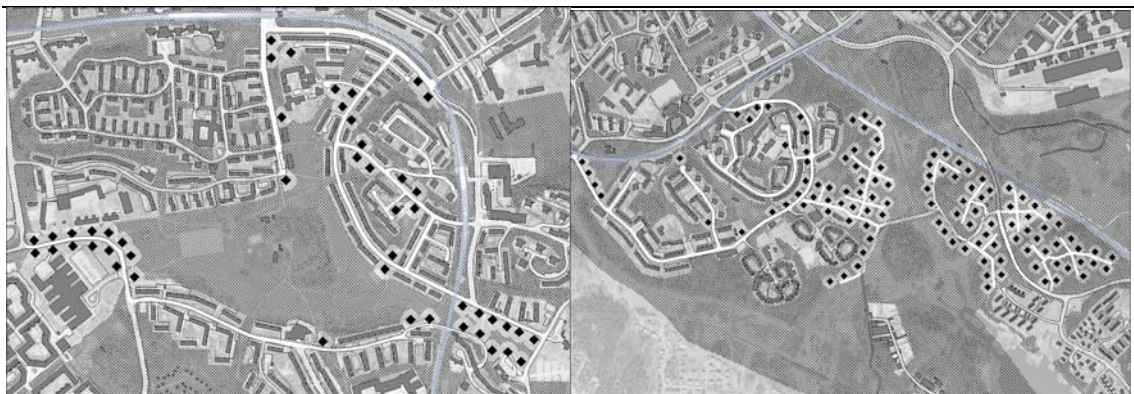
The 'New regularism' densification scenarios for Björkhagen-Nytorpsgårde and Rågsved-Rågsveds frområde study areas. 3D-illustration of Björkhagen-Nytorpsgårde by Stockholms Stadsbyggnads-kontor, Stadsmättningsavdelningen, Mats Lilja, July 2008.

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**Figure: New Conservatism**

The 'New conservatism' densification scenarios for Björkhagen-Nytorpsgårde and Rågsved-Rågsveds friområde study areas. 3D-illustration of Björkhagen-Nytorpsgårde by Stockholms Stadsbyggnadskontor, Stadsmättningsavdelningen, Mats Lilja, July 2008.



**Figure: New Modernism**

The 'New modernism' densification scenarios for Björkhagen-Nytorpsgårde and Rågsved-Rågsveds friområde study areas. 3D-illustration of Björkhagen-Nytorpsgårde by Stockholms Stadsbyggnadskontor, Stadsmättningsavdelningen, Mats Lilja, July 2008.

3. 'New conservatism': This scenario investigates the effects of an urban design strategy that preserves the street network as well as the building height. The typology used is lamella buildings with a width about 12 meters and a length of 50-100 meters and placed within a distance of 20 meters of each other along existing streets. In Nytorpsgårde and Rågsveds friområde, where there



are no existing streets, the street network is designed according to the conventional tree-like structure of the existing sub-areas. In Rågsveds friområde, new buildings are placed according to the latest new development in Rågsved.

4. *'New modernism'*: This scenario investigates the effects of an urban design strategy that allows for a preserved street network, but increases the building height by 100% to 6.4 floors in Björkhagen and 7.5 floors in Rågsved. Point buildings with a width of about 20 meters wide are placed within a distance of about 30 meters of each other along existing streets. The dimensions of new streets in *Nytorpsgårde* and *Rågsveds friområde* are the same as in the *'New conservatism'* strategy.

### 3. Results

The four 'administrative' area density measures and the eight 'user-related' location density measures were applied to the existing situation (0) and the four densification scenarios (1, 2, 3, and 4) in the four sub-areas. Although the result patterns are significant, it is important to have in mind that we are dealing with two thoroughly planned modernist areas with an unusual amount of internal and external public green space in a European and in a North American suburban context.

#### 3.1. Area density statistics

The area density results are rather self-evident from the administrative point of view given the definitions of the different scenarios.

The greatest increase in FAR is created by scenarios 1 and 2 (90-104 %), and the least increase is created by 3 (27-32 %). Although the number of apartments and residents could double with scenarios 1 and 2, the area density in the districts would be just half of inner city Stockholm.

'New urbanism' essentially erases all municipal open space in the built-up sub-areas. 'New regularism' more than halves municipal open space. Scenarios 3 and 4 save municipal open space. This means that the design strategies that add new streets and choose block shapes clearly encourages higher area densities and housing production but erase open space. The cost of public open space will decrease as indicated in the OSR; however, the need for enhancement park design and maintenance due to increased wear and tear is then not accounted for.

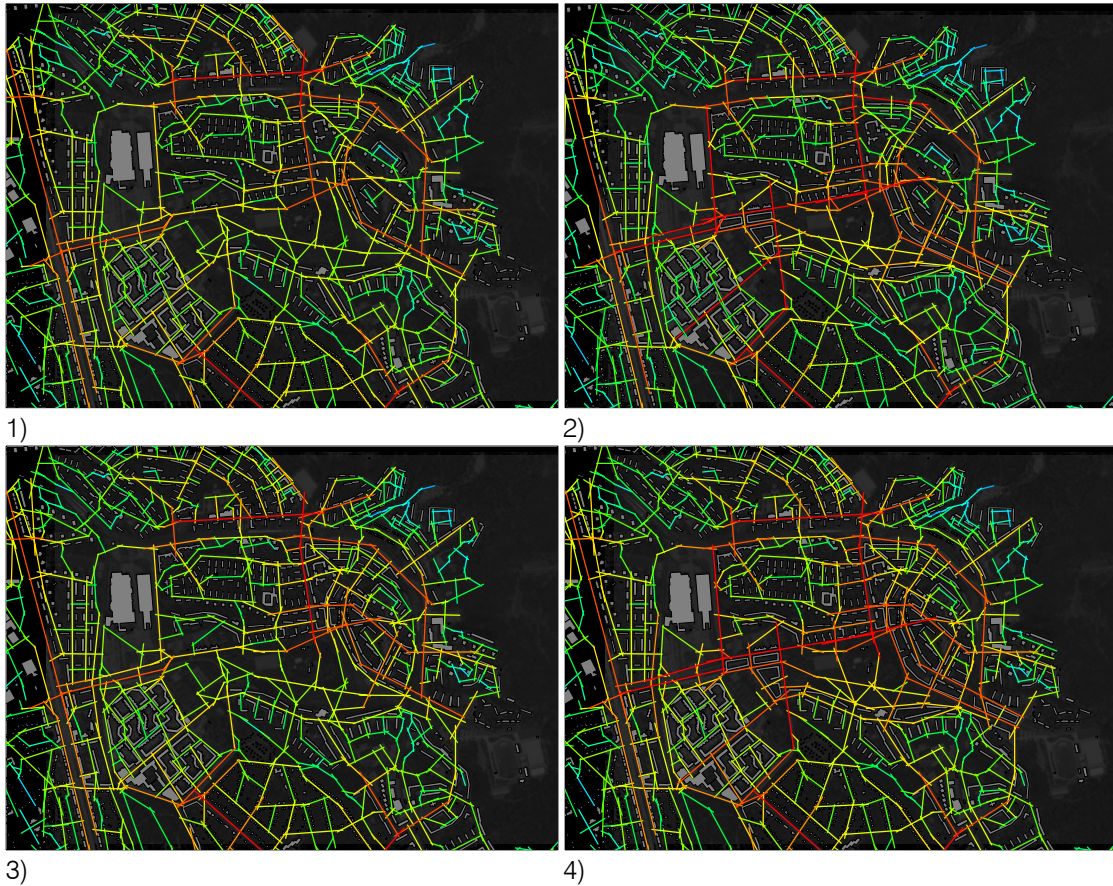
OSR decreases in all scenarios, especially in 1. When it comes to SCR, it roughly follows the same line of decrease although 2 upholds a significant amount of SCR compared to 1. In administrative terms, this would mean that compactness measured in SCR is difficult to uphold when densifying these type of modernist structures that are quite well planned with an OSR of about 1.0. The results for the location density measures, however, are rather different and in many ways contradictory.

#### 3.2. Location density statistics

We now move to density measurements that start from locations and accessibilities. The results from the location density measures are presented as averages for all axial line (A, B) or address points (C, E, F, G, H) within the sub-areas, except 'ambiterritory' (D), which is measured by percentage of the sub-area.

##### A) Axial line integration

The axial line integration analyses show how surrounding spatial morphologies affect the network accessibility within the sub-areas. To start, Björkhagen is from the beginning much more integrated into its surroundings than Rågsved. This means that Björkhagen is more affected by surrounding networks and densities. An in-between grid at Nytorpsgårde connecting Björkhagen increases axial line integration significantly more than making an internal grid within Björkhagen. In Rågsved, the case is the opposite. Rågsved is too segregated to be connected by Rågsveds friområde. Instead, spatial integration is increased by an internal grid. Naturally, integration is the highest in all sub-areas when there is a well-connected street grid in all sub-areas.



**Figure: Axial Integration**

*Axial line integration (radius 6) for 1) the existing street-pathway network, 2) an increased grid (as in scenario 1 and 2) only in-between districts sub-area, 3) an increased grid only in-district sub-area, and 4) an increased grid in both, for the four sub-areas.*

Since many of the following analyses are based on the axial line as a distance measurement, the axial line integration analysis indicates and explains many of these results. In fact, from the user point of view, a location can be densified only by making better connections to surrounding settlements.

**B) Entrance density**

If an increasing amount of entrances along the everyday paths means higher intensity of activities in public space, and therefore in a sense higher density, 1 would be most activating and 4 the least since point buildings only means one entrance per building. The average entrance density in the inner city and in the detached housing areas in Stockholm is 4-6 per 100 meter, which is about the level reached in Björkhagen with 1 and 2. Björkhagen is consistently higher because it has a more street orientated building structure. A major conclusion is that outward facing blocks do the best work to increase density in the sense measured here.

**C) Floor area accessibility**

The peripheral location of Rågsved becomes even more evident with this measure. In the existing situation, floor area accessibility is a third of Björkhagen. Interestingly, Nytorpsgårde has slightly higher floor area accessibility than the built up Björkhagen. This would mean that there could be a higher socio-economic potential in the in-between park than in the built up area. This relation is the opposite in Rågsved because Rågsveds friområde is not really connecting to any settlement. These relations stay unchanged in the scenarios, indicating that it is difficult to change the basic relations between district centre and periphery in the suburbs although it is possible to raise spatial potential generally. Scenario 1 and 2 in Rågsved and Rågsveds friområde raises floor area accessibility up to the level of the existing Björkhagen. The same densification strategies, however, double floor area accessibility in Björkhagen and 3 and 4 change floor area accessibility only marginally.

#### **D) Ambiterritory**

Due to the open modernist morphology of slabs and point buildings in Björkhagen and Rågsved, a lot of ambiterritory, or no-man's-land, is created where there is no clear definition of public and private space. As much as 10% of open space can be said to be difficult to use due to territorial confusion. However, when a street grid is introduced and buildings are organized in more enclosed blocks, as in 1 and 2, ambiterritory is basically erased. On the other hand, 3 and 4 increases ambiterritory. One can say that densification erases bits of public open space from the citizens, but can be used to also 'give back' space by making clearer distinctions between private and public space. In 1 and 2, there are the many small stretches of green space that embeds buildings, roads, and walkways creating a lush green setting, a quality that is well-known and highly appreciated by residents. It is without doubt that 1 and 2 will change the landscape character, especially in terms of territoriality.

#### **E) Public open space proximity**

Although densification is quite extensive (in 1 public open space is completely erased in-district) public open space proximity does not exceed 300 meters. In 3 and 4, changes are marginal. The most intriguing thing is that a few carefully placed parks in 3 make a great difference, keeping the proximity in spite of the densification. The axial results look similar to the metric. The increased street grid cannot help densification in 1 since there is a great shortage of public open space in district. In addition, existing urban structure and topography restricts the possibilities to make more direct connections. Nonetheless, Nytorpsgårde gains from the increased street grid. This clearly indicates that there are no direct relations between densification and change in open space access from the user's points of view.

#### **F) Public open space accessibility**

Although Björkhagen and Rågsved are surrounded by large nature areas, Björkhagen reaches almost double on this measure. The major reason for this is that Nytorpsgårde is a large park with many use values. Usually parks score higher than nature in number of use values. Then looking at 1 it does not decrease public open space accessibility in Björkhagen since the street network is radically improved. In Björkhagen, 2 even raises the values by 5% since some parks are saved and improved by one or two use values. Since accessibility is not improved and some public open space is erased by densification in the other two scenarios, the values decrease by 10-13%. In Rågsved, the values decrease about 30% in all scenarios but scenario 2, where the decrease is only 7%.

#### **G) Location spaciousness**

It is evident that location spaciousness decreases in all scenarios. By increasing both building mass and network accessibility, as in 1 and 2, spaciousness is radically decreased. The value is slightly over 0.5; the location OSR in the inner city is still about half of this level. Rågsved seems to be a little more sensitive to densification since spaciousness decreases relatively more here. This can possibly be explained by the lower public open space accessibility. Björkhagen would then have a greater resilience to potential congestion since it has a lot of surrounding public open space to benefit from.

#### **H) Location compactness**

The figures show clearly that densification does not generally increase compactness. In 3 and 4 in Rågsved, compactness actually decreases due to the loss of public open space. In Björkhagen, 3 and 4 compactness basically stays unchanged. However, in 1 and especially in 2 compactness increases significantly in both study areas, which in reality means a radical change in settlement character.

### **3.3. Sub-area FAR related to location measures**

In the study, there are some particularly interesting non-correlations that contradict common sense about how densification affects perceived and lived (user-related) density.

The relation between sub-area FAR and floor area accessibility reveals some correlation in every scenario, but no evident correlation was noted between the different scenarios. The major reason is the impact of street and pathway network accessibility (axial line integration) as well as in the entrance locality.

In Björkhagen, there is an almost inverse relationship between sub-area FAR and public open space accessibility. Hence we can confirm earlier studies that claimed there could be “more green space [from the user point of view] in a denser city [from an administrator point of view]” (Ståhle 2005). There is no evident relationship between an increase in FAR, the loss of public open space, and public open space accessibility. It all has to do with how public open spaces are designed and located within the street-pathway system in relation to where people live.

Interesting patterns emerge when we look at the relation between sub-area FAR and location OSR. It seems that there is some sort of location OSR limit to area FAR levels, given the possible scenarios. This could explain why it is rational to build tree-like segregated structures at certain densities in suburbia. For example, Rågsved is relatively spacious compared to its FAR although not very resilient to densification.

The relation between location SCR and area FAR is quite clear. An increase in area FAR and increased network accessibility creates the highest raise in compactness. The increased network accessibility also means that in-district and surrounding public open space becomes more accessible, raising compactness even more, moving to the upper right in the scattergram. We claim that sprawl-like densification is a move to the right or even the lower right.

### **3.4. Relations between location measures**

If we look at the relationships between different location measures, we can explain the importance of accessibility. Correlations were calculated for all sub-areas, which means that they are not really related in reality since they have different contexts. Yet it is interesting to see if there is some relationship between areas.

Area-level densification means less public open space, a well-known limitation to urban designers. However, our results show some contradictory correlation ( $R^2=0.5526$ ): higher floor area accessibility means higher public space accessibility. This is, of course, a result of axial line network accessibility that by its connectivity has increased compactness. Naturally there is a strong correlation between axial line integration (radius 6) and location SCR,  $R^2=0.8341$ . One can say that an integrated street and pathway system brings buildings and public open spaces together, making them accessible to each other.

The relationship between axial line integration (radius 6) and location OSR reveals the specific roles of street and pathway network. The correlation ( $R^2=-0.4619$ ) indicates, as expected, that by increasing the accessibility spaciousness will decrease. There seems to be a limit to spaciousness when it comes to axial line integration. Very high network accessibility can increase risk of spatial congestion, which once again can explain why tree-like morphologies in suburbia can be rational where there is a lot of public open space.

Finally, the relationship between location SCR and location OSR, represented by the L-shaped result pattern in the diagram, tells us that there seems to be a limit to how great spaciousness can be created in very compact urban environments. And reversely, low compactness has low risk for congestion: it needs little public open space to feel spacious.

## **4. Discussion and conclusions**

In the paper, we have tried to identify and measure urban density, densification, compactness, spaciousness and sprawl in morphological terms so that it can be useful for the urban designer. Most important, it has presented new location density measures that integrate floor area, axiality of street and pathway network, and the use value of public open space.

In conclusion, from our study the relationship between densification, compactness, and spaciousness can in spatial terms be described as follows. Essentially densification does not change compactness since it also decreases public open space. However, compactness can be increased by raising building height, improving public open space, and increasing the accessibility of the street and pathway network. Second, densification normally decreases spaciousness since

public open space is erased and floor area is added. However, spaciousness can be increased (or at least minimized) by improving public open space and increasing accessibility to areas with higher spaciousness since increased accessibility of the street and pathway network tends to even out spaciousness between areas.

We have found that these new measures allow us to make a straightforward user-related morphological definition of sprawl-like development, starting from a basic division of built space and open space. Since all urban development, if there is no tearing down, is densification, one cannot not generally say that densification is the opposite of sprawl. We do suggest separating the morphological nature of sprawl and the morphological causes of sprawl. A simple proposal for a definition of the nature of sprawl is urban development that decreases compactness, in our terms the product of floor area accessibility and public open space-accessibility. Compactness, or location SCR, can thus identify sprawl-like development, but it does not explain why it occurs.

A cause of sprawl, we propose, can instead be identified by the measurement of spaciousness or location OSR. If a new urban development decreases spaciousness, it raises the risk that people will move to less congested areas. This explains why it is used in Manhattan to create public open space (NYC 2008). Spaciousness also explains the vast low-density detached housing suburbs that are sprawling into the green edge of the city. It is more than just the fact that people have their own gardens; a small public green area here can feel like a large forest since there are so few real and potential visitors in it. The real estate market can also be freer since there is little risk of creating the congestion that people moved from in the inner city. However, the experience of congestion is culturally defined. The tolerance to congestion is different in Sweden than it is, for example, in India. There are also sub-cultural differences. Families tend to move away from congestion while youth tend to move towards it.

We can now define many things as sprawl-like that are not usually labelled this way. For example, one can claim that developing detached housing in Central Park in New York 1) is urban sprawl since it decreases compactness and 2) will probably cause suburban sprawl since it may create congestion that will lead to residential flight to spacious settlements in the city fringe. This is, of course, an extreme example to make a point.

Clearly, 'New conservatism' and 'New modernism' densification strategies are sprawl-like since they do not really increase location compactness in the current context. Do any of the scenarios risk congestion that can lead to residential flight and sprawl somewhere else? The short answer is, probably no. The most extreme densification scenario 'New urbanism' in Björkhagen still has about the double spaciousness of the inner city since Björkhagen is set in extremely green surroundings. We can also conclude that a well connected street and pathway grid can lead to unnecessary congestion if there is a lot of public open space; that is, tree-like morphologies such as the green modernist suburbs can combine compactness and spaciousness. However, when these areas are densified and public open space become scarce, increased network accessibility is needed to uphold public open space accessibility, a situation that can lead to congestion. This is a true densification paradox that urban planners and designers face.

If we look at the social, economical, ecological, and spatial challenges facing future cities, the picture can hardly be broken down to a set of particularities. The city is a complex system that integrates things and creates synergies by external effects. If the costs of sprawl grow, as Burchell et al. (1998) and Haughey (2005) argue, the current sprawl-like densification of Stockholm is creating obstacles for future development towards compactness and spaciousness. Many people talk about sustainable development. We claim that for a city to survive in the long term, it must find a balance between congestion and sprawl, spaciousness and compactness. If energy and transportation costs increase post peak-oil, which seems to be likely, we will become more dependent on walking, bicycling, and public transportation. This, as well as many other infrastructural investments, will demand a higher compactness that can be created by taller buildings, higher quality public open space, and a more efficient street and pathway network. It is possible that future urban economies will not be able to afford the transportation costs of sprawl and more compact cities will increase its competitiveness. A spatially compact city should hence be more equitable

and resilient to change in this respect, since many compact urban areas already today stand up to the competition against more sprawling cities. This is a vast growing field of research that only has begun to be explored by urban analysts and urban morphologists.

## References

- Alexander C., Ishikawa, S., Silverstein, M., 1977, *A pattern language: towns, buildings, construction*, Oxford, New York.
- Andersson, M 1998, *Stockholm's annual rings: a glimpse into the development of the city*, Stockholmia, Stockholm.
- Berkefeldt, K, Schröder, M, Andrén, B, Andersson, M, Strömbäck, E, Egerö, U, Isaksson, K, Gunnarsson Östling, U, Orrskog, L, Högström, E & Bradley, K 2007, 'Stadens mellanrum', *RUM*, no. 12/07.
- Batty, M 2008, 'The Size, Scale, and Shape of Cities', *Science*, vol. 319, 769–771.
- Burchell RW, Shad NA, Listokin D, Phillips H, Downs A, Seskin S, Davis J, Moore T, Helton D & Gall M, 1998, *The cost of sprawl-revisited*, Report 39, Transit Cooperative Research Program (TCRP) Transportation Research Board, National Research Council, Washington DC, 83-125.
- Börjesson, L, Höjer, M, Dreborg, K-H, Ekvall, T & Finnveden, G, 2006, 'Scenario types and techniques: Towards a user's guide', *Futures*, vol. 38, no. 7, 723-739.
- Cervero, R, Kockelman, K 1997, 'Travel demand and the 3Ds: Density, diversity, and design', *Transportation Research Part D: Transport and Environment*, vol. 2, Issue 3, 199-219.
- COST, 2005, *Green structure and urban planning: Final report*, COST Action C11, Office for Official Publications of the European Communities, Luxembourg.
- Cox, W 2006, *War on the Dream: How Anti-Sprawl Policy Threatens the Quality of Life*, I Universe.com
- Duany, A & Talen, E 2002, 'Transect planning', *Journal of the American Planning Association*, vol. 68, no.3, 245-266.
- EEA, 2006, *Urban sprawl in Europe: The ignored challenge*, EEA Report No 10/2006, European Environment Agency, Copenhagen.
- Ewing, R 1994, 'Characteristics, causes, and effects of sprawl: a literature review', *Environmental and Urban Issues*, vol.21, 1-15.
- Florgård, C & Forsberg, O 2006, 'Residents' use of remnant natural vegetation in the residential area of Järvafältet, Stockholm', *Urban Forestry & Urban Greening*, vol. 5, iss. 2, no. 15, 83-92.
- Frenkel, A & Ashkenazi, M 2008, 'Measuring urban sprawl', *Environment and Planning, B: Planning and Design*, vol. 35, 56-79.
- Gehl, J, Johansen Kaefer, L & Reigstad, S 2006, 'Close encounters with buildings', *Urban Design International*, vol. 11, 29-47.
- Gordon, P & Richardson, HW 1997, 'Are Compact Cities a Desirable Planning Goal?', *Journal of the American Planning Association*, vol. 63, no. 1, 95-106.
- Grahn, P & Stigsdotter, U 2003, 'Landscape planning and stress', *Urban Forestry & Urban Greening*, vol. 2, pp 1-18.
- GUST (ed), 2002, *Post Ex Sub Dis: Urban Fragmentations and Constructions*, 010 Publishers, Rotterdam.
- Hall, P 1988, *Cities of tomorrow: an intellectual history of urban planning and design in the twentieth century*, Blackwell, London.
- Haughey, RM 2005, *Higher-density Development: Myth and Fact*, Urban Land Institute, Washington DC.
- Haupt, P 2006, *Spacemate: The Spacial Logic of Urban Density*, Delft University Press, Delft
- Hillier, B & Hanson J 1984, *The social logic of space*, Cambridge University Press, London.
- Hillier, B, Penn, A, Hanson, J, Grajewski T & Xu J 1993., 'Natural movement: or, configuration and attraction in urban pedestrian movement', *Environment and Planning B: Planning and Design* vol. 20, 29-66.
- Hillier, B 1996, *Space is the machine*, Cambridge Univ. Press, Cambridge.
- Hillier, B 2004, 'Can streets be made safe?', *Urban Design International*, vol. 9. 31-45.
- Hoenig, A 1928, 'Baudichte und Weiträumigkeit', *Die Baugilde*, no. 10, 713-715.
- Höjer, M & Mattson, L-G 2000, 'Determinism and backcasting in future studies', *Futures* vol. 32, 613-634.

- Jacobs, J 1961, *The death and life of great American cities*, Random house, New York.
- Klasander, A-J 2003, 'Suburban navigation: structural coherence and visual appearance in urban design', Ph D thesis, Chalmers tekniska högskola, Göteborg.
- Krier-Kohl Architects, 2003, *Town spaces: Contemporary interpretations in traditional urbanism*, Birkhäuser-Publishers for Architecture, Basel.
- Lee C, Moudon, AV 2006, 'The 3Ds + R: Quantifying land use and urban form correlates of walking', *Transportation Research Part D*, vol. 11, 204–215.
- Marcus, L 2000, 'Architectural knowledge and Urban Form: The functional Performance of Arcitectural Urbanity', Ph D Thesis, Arkitekturskolan KTH, Stockholm.
- Miljöförvaltningen, 2006, *Barns tillgång till lekrområden* [Childrens accessibility to play areas], Spacescape AB, Stockholm.
- NYC, 2008, *Zoning, Department of City Planning*, retrieved feb 2008, <http://www.nyc.gov/html/dcp/html/subcats/zoning.shtml>
- Oh, K & Jeong, S 2007, 'Assessing the spatial distribution of urban parks using GIS', *Landscape and Urban Planning*, vol. 82, 25–32.
- Openshaw, S 1984, *The Modifiable Area Unit Problem*, Geo Books, Norwich.
- Peterson, A 2002, 'Building the Urban Landscape: Political approaches to City Park' Distribution, Doctoral Dissertation, Graduate School of Arts and Sciences of Washington University in St Louis, St Louis.
- Rogers, R 2005, *Towards a Strong Urban Renaissance: An independent report by members of the Urban Task Force chaired by Lord Rogers of Riverside*, Urban Task Force Publication, London.
- Rådberg, J 1988, *Doktrin och täthet i svenskt stadsbyggande 1875-1975*, Statens råd för byggnadsforskning, Stockholm.
- Saglie, I-L 1998, *Density and town planning: implementing a densification policy*, NIBR:s PLUSS-series, 4-98, Norsk institutt for by- och regionforskning, Oslo.
- SCB, 2002, *Grönrområden, grönytor och hårdgjorda ytor i tätorter: Studier utförda av SCB på uppdrag av Boverket*, SCB, Stockholm.
- Stockholms stad, 1983, *Handlingsprogram för upprustning av den äldre ytterstaden*, Kommunstyrelsens planeringsutredning, Utl. 1983:65 RI, Stockholm.
- Stockholms stad, 2002, *Stockholms sociotopkarta*, retrieved Feb. 2008, <http://www.stockholm.se/Extern/Templates/Page.aspx?id=99580>
- Ståhle, A, Marcus, L & Karlström, A 2005, 'Place Syntax: Geographic accessibility with axial lines in GIS', *proceedings in 5 th. Space Syntax Symposium*, Delft, 13-17 June.
- Ståhle, A, 2005. *Mer park i tätare stad: Teoretiska och empiriska undersökningar av stadsplaneringens mått på friytetillgång*, Licentiate thesis, Arkitekturskolan KTH, Stockholm.
- Ståhle, A, 2006, 'Sociotope mapping: exploring public open space and its multiple use values in urban and landscape planning practice', *Nordic Journal of Architectural Research*, vol. 19, no. 4, 59-71.
- Ståhle, A, 2007, 'Ambiterritory: No-man's-land in post-war morphologies, confusing users and complicating maintenance', *Proceedings in 6 th. Space Syntax Symposium*, Istanbul, 12-15 June.
- Talen, E 2003, 'Measuring urbanism: Issues in smart growth research', *Journal of Urban Design*, vol. 8, no. 3, 195-215.
- Vaughan, L 2007, 'The spatial syntax of urban segregation', *Progress in Planning*, no.67 (3). Special Issue edited by Laura Vaughan. ISSN 03059006, Elsevier, Oxford.
- Xaveer De Geyter Architects, 2002, *After-sprawl: research for the contemporary city*, Nai, Rotterdam.