Street Network Inter-Accessibility and Urban Sustainability. Measuring Urban Compactness with Various Spatial Analyses Tools

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Key words: urban compactness, space syntax, safety, sustainable mobility means, building-street interfaces

SUMMARY

This contribution demonstrates how the use of the space syntax method and urban micro scale tools can be used to identify and describe the spatial features of a sustainable city. As turned out, the spatial structure of the mobility network and the spatial relationship between buildings and streets influence several aspects related to compact and sustainable cities, such as vital urban centres, street life diversity, street safety, walkability, and the degree of the use of sustainable mobility means.

This broad subject will be approached in the following way: Firstly, the term sustainability and urban sustainability requires some explanatory remarks. Secondly, urban compactness and its impact on urban sustainability will be taken into consideration. A short discussion of some writings on compact city are elaborated. Finally, urban compactness will be reconsidered in spatial configurative terms through the use of space syntax and the urban micro scale tools.

As argued, sustainable urban design relies on spatial inter-accessibility on all levels. Accessibility depends on compactness. Hence, urban compactness and thus accessibility can best be approached from a spatial topological point of view, since compactness is a topological term. Examples from car based cities and pedestrian and public transport based cities will be used throughout the paper. As it turns out, achieving well-functioning compact cities enhancing sustainable mobility means and safe streets for walking depend on the following complex set of sufficient conditions: spatially integrated street network on all scale levels, short urban blocks and streets constituted by buildings with windows and doors on ground floor level.

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1. CONDITIONS FOR URBAN SUSTAINABILITY

This contribution attempts to answer the question in what ways a spatial configurational approach of built environments contributes to our understanding of urban sustainability. This broad subject will be approached in the following way: Firstly, the term urban sustainability requires some explanatory remarks. Secondly, urban compactness and its impact on urban sustainability will be taken into consideration. Short discussion on current writings are discussed here. Finally, compactness will be reconsidered in spatial configurational terms. The difference between *necessary* and *sufficient* conditions will pertain to each of these sections

Moreover, all subsequent considerations will present themselves from a so to speak holistic perspective. For an understanding of the complexity of human beings and their behaviour in cities is at stake at least on the following levels: Rationales for human behaviour can be given in terms of travel time efficiency. i.e. for choosing the shortest or fastest routes with the most efficient travel means for carrying out daily activities. Rationales for human behaviour can be given equally in terms of economic activities, i.e. with regard to profit maximising in the way shop owners choose the most optimal location for reaching potential customers. Rationales for human behaviour can be given equally in terms of social activities and values. In the present context, it is about the human rationale behind choosing where to live, work and to carry out their various necessary, optional and social activities. Conversely, the nature and form of a built environment can encourage or put limitations on humans' social and economic behaviour.

2. DEFINITION OF URBAN SUSTAINABILITY: THE CITY AS AN OBJECT OR A PROCESS?

The subject of sustainability introduced itself for good reasons. Christian Patermann, the director of the Environmental and Sustainable Development research programme, notices that during the 20th century cities tended to put economic expansion on their agenda. They did so at the cost of social well-being and environmental equilibrium. The social effects are for instance placelessness, exclusion, insecurity, criminality, and loss of cultural identity. The environmental effects are among others bad air quality, pollution, and low-density urban sprawl. Furthermore, the effects of traffic congestion and deteriorating infrastructure and built environments have affected the locations of economic activities (Patermann 2002, p.1).

The Brundland report of 1987 and the 1992 Earth Summit in Rio de Janeiro rightly predicted that in the beginning of this century more than 50% of the world's population will live in

urban areas. During the last decades, increased energy use for transportation in urban areas contributed to the greenhouse effect and climate change. In these contexts, the concept of a sustainable development came on the agenda and turned into a fashion word of the 1990's.

There are numerous definitions of the term "sustainable development". According to the 1992 Earth Summit in Rio de Janeiro, "sustainable development" is defined as a "development which meets present needs without compromising the ability of future generations to achieve their needs and aspirations" (Jenks 1996, p. 233). A major problem in defining sustainability in this manner results from the term's normative as well as descriptive aspects. From a normative point of view, questions of the following kind seem appropriate: Should something be sustainable and what should be done to guarantee its sustainability? In this case the intentions are to assess a certain goal in terms of sustainability. The descriptive aspects of sustainability, however, concern what actually *is* sustainable. If intentions of future generations are taken into account at present, it is difficult to guarantee to what extent it will be sustainable in the future. Accessing whether scientists or politicians propose a normative or descriptive understanding of sustainability is difficult. For the suggestion of the Brundtland Report concerns present as well as future needs, hence not just descriptive, but likewise normative matters.

At the millennium, various strategies and proposals on how to achieve a sustainable city came on the agenda. But what is then a sustainable city? Is it an object or a process? Sustainable, the quoted definitions, tell that a city is not an object but a development or process. That will say a development influenced by or consisting in human interaction. Urban sustainability is a particular case of sustainability. If sustainability is about processes, then the term 'sustainable urban development' is more appropriate than a 'sustainable city'. Conversely, the concept 'sustainable city' or the more recently used 'the compact city' is about the physical aspect of built environments. Here the city is treated as an object. A clear distinction between the city as a transformation process and an object is lacking in many recent writings about sustainable built environments. Moreover, the distinction between what is a sustainable city and what should be a sustainable city is not always clear.

Thus, urban sustainability has to concern continuous transformation processes of economies and cultures where their impacts on the environment - either built or natural - can be understood as a product or an object. And can the impacts on the object encourage a certain kind of behaviour, both socially and economically? At least descriptive approach to urban sustainability is a two-sided topic, where the aim is to understand the impacts of social and economic activities on the built environment, and conversely in which rationales for human behaviour can be given equally in terms of way the built environment conditions - be it necessarily or sufficiently - a certain kind of economic and social behaviour. In whatever way urban sustainability can be understood, these processes have to be taken into consideration.

3. THE COMPACT CITY AND DENSITY PROBLEM

There are numerous writings on urban areas and their sustainable development. Most of them set out as a criticism on Le Corbusier's Radiant City model, Ebernezer Howard's Garden city

model, Frank Lloyd Wright's individualistic dwelling model and general post war planning. These kinds of anti-urban city models and planning are recognised to contribute to separation of functions and simplification of urban areas. What all these authors search for is an understanding of the compact city model, which is recognised to encourage sustainable ways of living and low energy use for transportation (Jenks 1996, Rogers 1999, Calthorpe 1996). Generally speaking, urban sustainability is thus accounted for in terms of compactness. In one way or another a city's compactness is taken to condition a sustainable urban development. In essence, this contribution is intended to render this thesis somewhat more precise. At least the following features are recognised from recent writings to be essential to compact cities:

Physical aspects: High density of the built mass in central areas and sub-centres, pedestrian friendly streets, and clear demarcation on what is public and private space.
Functional aspects: Dense location and mixed use of dwellings, work, services, retail and shops in urban areas, short movement routes between facilities, pedestrian friendly, dense concentration of people, and an intensifying of human activities in the urban centres.
Social aspects: Low criminality, mixture of people of different class and race, healthy and good dwelling areas, safe streets, possibilities for social contact between inhabitants and visitors.
Economic aspects: Vital centres and sub-centres and a mixture of small and large enterprises in urban areas.
Environmental aspects: Reduction of energy use, new development on recycled land, and reduction of low-density urban sprawl in the countryside.
Political aspects: The ways in which governments on the local, regional and national level should act or not in order to encourage sustainable development rather than the opposite.

Is then the compact city a product of urban sustainability? Or is urban sustainability possible in terms of compactness? Initially, compactness is a topological term. In a very loose and scientific way of speaking compact is what is closely and firmly united, pressed together, dense, fine grained and packed into small space. In addition to quantitative aspects, the qualitative, economical and aesthetic aspects of the term are thus mentioned. Even in the light of these preliminary suggestions at least two hypotheses may be proposed:

A: An urban development is not sustainable unless the city in question is compact. Thus, compactness of urban environments is a *necessary* condition for the sustainability of their development.

B: Compactness guarantees sustainability. It is a *sufficient* condition for sustainability.

Is then urban compactness a sufficient condition or a necessary condition for sustainability? Or is it neither - nor? So far, it seems difficult to make statements on urban sustainability, because a concise definition of urban compactness is missing. Presumably urban compactness can contribute to a certain kind of sustainable human behaviour but in what way depends on what is meant by compactness. Here a short briefing of some of the recent writings on urban compactness might be helpful.

Jane Jacobs' book *Life and death of great American cities* introduces new ways of understanding cities in terms of the social behaviour in the city, economic behaviour of cities, generally speaking the way in which cities are used and function. Her main message is that life on streets makes the city lively. A well-used city and diversity in cities gives safe streets (Jacobs 2000, p. 44). She suggests the following suggestions for enhancing lively and safe cities: short urban blocks, high mixture of various urban functions, eyes on the streets from adjacent buildings, and safe sidewalks. Her conclusions are based on observations in well-functioning traditional urban areas. Jacobs' account of urban compactness illustrates methods in the qualitative social science. She does not rely on quantitative measures falsifying or confirming her observations. Her work consists in descriptions of essentials spatial features. She offers some normative directions as to how things should be to ensure liveable cities.

A different kind of approach is offered by Christopher Alexander's article *A city is not a tree*. It is a criticism of the modern planned structure of cities. Alexander discusses the structure of information processing of human beings in society. He does not set out from observations, but proposes a formal approach. Alexander tries to give an explanation as to why many cities do not fulfil the social task for which they were designed. As regards their inner organisation, natural cities have the form of a *semi-lattice*, whereas artificial ones have a *tree structure*. According to Alexander, a city with a tree structure is divided into different zones. Each zone has a set of functions not relating to other zones (Alexander 1966, p. 51). For Alexander organising cities in the form of trees is a means to simplify the spatial organisation of the complex environment. Cities with a Semi-lattice structure usually dispose of a complex transportation network. The different zones are overlapping each other and well integrated with one another. According to Alexander, this structure improves a city's economic development, its safety and its liveliness.

Through Alexander's work urban compactness can be understood in terms of the complexity of the transportation network and the intertwined functions of the semi-lattice structured cites. However, consequences as regards further improvements of urban compactness are not discussed in his writings.

While the previous writings were concerned with social, economic and communicative aspects of the compact city, environmental issues and sustainability were explicitly taken into consideration in more recent writings. Richard Rogers' approach to urban sustainability is reinterpreting and reinventing the dense city model. It is defined to consists of anti-zoning, increase of energy efficiency, consuming fewer resources, produce less pollution and avoiding sprawling over the countryside (Rogers 1997, p. 33).

Like Jane Jacobs, Rogers discusses the compact and well-connected city. In a sense, he takes up principles introduced by Jane Jacobs. Rogers makes proposals on how a compact city *should* be designed. He obviously does not specify *how* such a design is brought about, but set forth normative statements on how things should be done to achieve a compact urban form. A comprehensive understanding of the economic and social behaviour of a compact city's inhabitants and visitors is missing in Rogers' books. As future human beings will have their

own values and intentions it is in principle difficult to guess or even know what their future will be.

Like Jacobs' writings, Peter Calthorpe's book *The next American Metropolis* emphasises the role of the pedestrian and the mixed usage of urban space in neighbourhood areas. His concept of the pedestrian pocket accounts for the idea of an opportunity for walking distances for all kinds of people to all activities from home. Therefore, he introduces the *Transit Oriented Development* concept in a word "TOD". Calthorpe explains TOD as follows: "moderate and high density housing, along with public uses, jobs, retail and services are concentrated in mixed-use developments at strategic points, along the regional transit system" (Calthorpe 1993, p. 41). Like Rogers, this author promotes a normative approach. Calthorpe makes proposals as to what should be done to produce ecologically, economically and socially sustainable urban areas. However, what is missing is a genuine understanding of how the built environment and the generative power of the urban street network itself are working. Calthorpe's proposals refer to the regional level and to the level of the urban block. However, the spatial organisation of a neighbourhood unit and its location in the city as a whole are not discussed at all.

Most writings on compact or sustainable cities describe the problem built environments are facing today as regards sustainability. The various authors offer quick proposals on how to design or plan a compact city. But what is missing is a concise understanding of how compact cities function as regards social and economic activities.

According to the Brundland report, one of the basic environmental problems of modern cities is high energy use for transportation - generally speaking car dependency. Does this relate to the spatial structure of the mobility network? Public spaces between buildings are potential movement routes from everywhere else to everywhere else. The way functions in an urban street network are dispersed must to a substantial extent result from potential movement routes in these public spaces. Apparently, density and mixture of activities first and foremost depend on the spatial structure of an urban street and road network. Car dependency is one of the issues illustrating the technological complexity debates on urban sustainability presuppose. The subsequent account of compactness will reckon with this precondition.

On the other hand, cultural interaction, perception on street safety and physical movement certainly shape a built environment. There is interdependence between the physical built environment and economical as well as socially motivated movement. Thus, physical form and how human beings behave in it influence each other. Urban compactness thus should be understood in terms of movement and interaction and their relationship to urban space.

How is it possible to find out whether compactness is a necessary or sufficient condition for urban sustainability given that concepts of urban compactness are imprecise? Even though the writings above indicate to some extent what a compact city might be, the concept of density is still vague and the concept of the spatial structure of a street network is unclear. If compactness basically is a topological term, it certainly makes sense to use topological

consideration to understand urban compactness. The following section will set out in what way a spatial configurative approach can offer a more concise account of urban compactness.

4. THE SPATIAL CONFIGURATIVE APPROACH

An account of compactness and sustainability in morphological terms has to be descriptive. It concerns both structural and social aspects. While Alexander concentrated on structural aspects and while Jane Jacobs accounted for social aspects, a spatial configurative approach offers mathematical means to reconsider them jointly. Compactness is then understood in terms of urban space, and various ways to describe and measure the spatial properties of built environments that are recognised to be sustainable or the opposite.

First and foremost an approach of this kind requires a concise definition of urban space. As regards research on built environments, Bill Hillier accordingly distinguishes between *intrinsic* and *extrinsic* properties of space. Extrinsic ones determine how spatial units relate to one another, thus about the configurative laws of space. In this perspective, primarily topological issues become relevant. Extrinsic properties of space determine both built form and its possible function. While extrinsic properties of space consist in invisible, structural relationships, intrinsic properties relate to visible ones. They present themselves mostly through geometrical properties, pattern and texture. They account for the articulation of social meaning via built form (Hillier 1999a, p. 1).

The elements all built environments have in common are extrinsic properties of space and functions occupying these spaces. Thus, from a spatial configurative point of view, a city is conceived as a set of spaces. Urban space is mostly linear. It consists in mostly streets, alleys, roads, boulevards, highways, which in contrast with squares, are linear items. Spaces of these kinds can be represented as linear items such as axial sightlines or segment lines (Hillier 2001, p. 02.1). The axial and segment map is the basis for calculating the inter-relationship of these lines, in particular their topological distance from one another. Topological distance is about calculating how every street is related to all others in terms of the total number of direction changes.

According to Hillier, economic and social activities are influenced by the spatial structure of a city as an object (Hillier 2001, p. 02.1). The kind of rationale behind economic activities in cities is that the predominant implicit intention is profit maximising. All cultures exhibit this feature. In a free marked, shops and retail owners choose spatially the most optimal location to reach as many potential customers as possible. While the rationale behind economic activities is rather unambiguous, the rationale behind social activities depends on understandings of society and cultures (van Nes 2017).

The Space Syntax method, developed by Bill Hillier and his colleagues at the University College London, consists in calculating and describing spatial configurative inequalities in an urban street and road network. These calculations have been compared with registration of human movement, social and anti-social behaviour and location pattern of shops, dwellings, social and cultural institutions. As world-wide research has shown, streets with the highest

spatial integration have the highest flow of human movement and tend to be the economic centres in towns and cities. Later on, the urban micro scale tools are developed by van Nes and López in a research project on space and crime in urban areas (van Nes and López 2010). These micro scale tools are able to analyse the spatial relationships between private spaces inside buildings and the public streets. As the application of these tools in research have shown, the more direct the spatial accessibility and visibility is between buildings and streets, the more the streets are perceived to be safe (Rønneberg et al 2019) gender balanced (Rooij and van Nes 2015) and enhance walkability (de Koning and van Nes 2019).

Three aspects of spatial configuration can provide an understanding of lively urban areas and illustrate the configurational inequalities responsible for attractional inequalities in an urban street network: to-movement and through-movement potentials of the street and road network and the private-public interface of buildings. The next section will discuss these aspects more precisely in light of the question of urban compactness and urban vitality.

4.1 Spatial to-movement & through movement potentials and their influences on economic vital urban centres and sustainable mobility means

If urban sustainability consists in encouraging the location of a large variation of economic activities in city centres with short walking distances, the aim must then be to understand where the most optimal location is for shop and retail along a built environment's street and road network. Research carried out by Hillier and his colleagues have shown the following results: First of all, shops locate themselves in streets where most people move. Apparently, shops tend to become attractors for the people's urban movement. Attractors and movement may influence each other, but they do not influence the configuration of the urban street network. On the other hand, the street network seems to influence movement and attractors. The dispersal of global and local integration and connectivity is decisive (Hillier et al. 1993, p. 61). This is known as the theory of the natural movement economic process. The next step is to identify the spatial properties of the street and road network that encourage sustainable mobility means or the opposite.

Figure 1 shows a global and local spatial integration analyses of the Oslo's street and road network. Here the degree of spatial integration is calculated in terms of the total number of direction changes from all streets to all others. The red and orange lines show the streets with the fewest total number of direction changes to all others, thus they are the spatially highest integrated streets. Global spatial integration indicates where the globally most integrated roads or streets are located in a city on a macro scale. In the case of Oslo, the highest integrated roads are located on the outer ring road. At every junction car-based shopping malls are located.

When calculating how integrated each street is within three times direction changes, the local integration can thus be calculated. Local integration indicates the various vital local pedestrian based centres. In the case of Oslo, the pedestrian based shopping areas are situated along the locally most integrated streets, while the car-based shopping centres are situated along the junctions of the globally most integrated streets (van Nes 2002, p. 211). As the local

integration analyses of Oslo show, a high number of direct connections from a shopping street to its vicinity within a short metrical distance influence the degree of walkability. Figure 2 illustrates an example on a two steps analysis for two different types of shopping streets in Amsterdam. The two steps analysis illustrate the degree of accessibility two direction changes away from a particular street. The image of the left shows the local catchment area of the shopping street Ferdinand Bolstraat in Amsterdam and the car-based shopping centre Amsterdamse Oostpoort. Most of the customers in Ferdinand Bolstraat do they shopping on foot, bike or public transport, whereas most customers in Amsterdamse Oostpoort use the car. In comparison with Amsterdamse Oostpoort, Ferdinand Bolstraat has a high density of the street network within a short metrical radius from the shopping street.

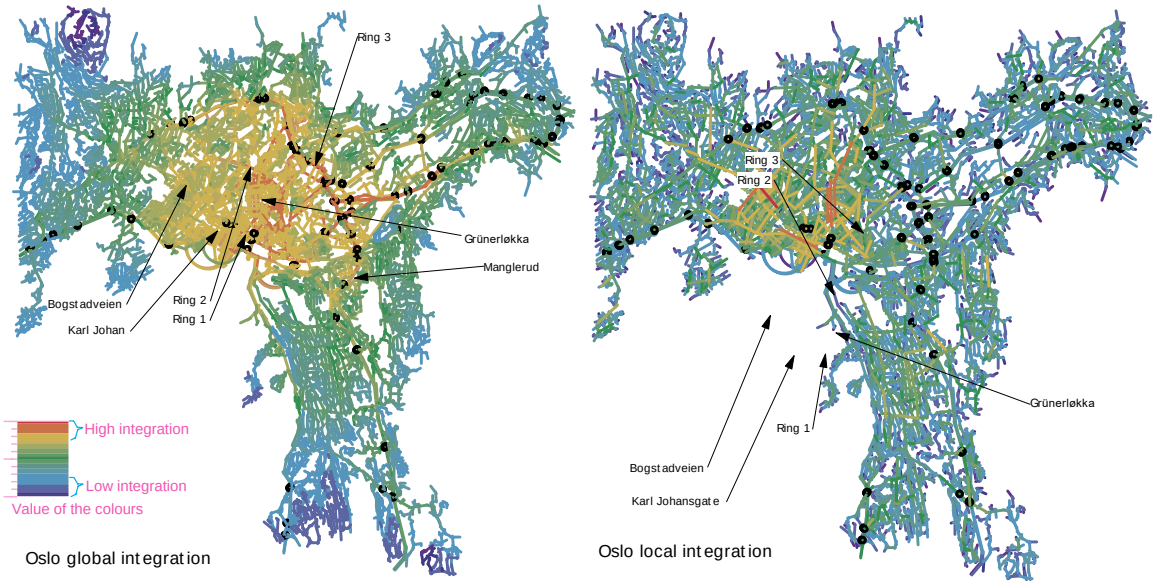

Figure 1: Global (left) and local (right) integration of Oslo. The car based shopping centres are located at the junctions along the highest globally integrated streets (the black circles).

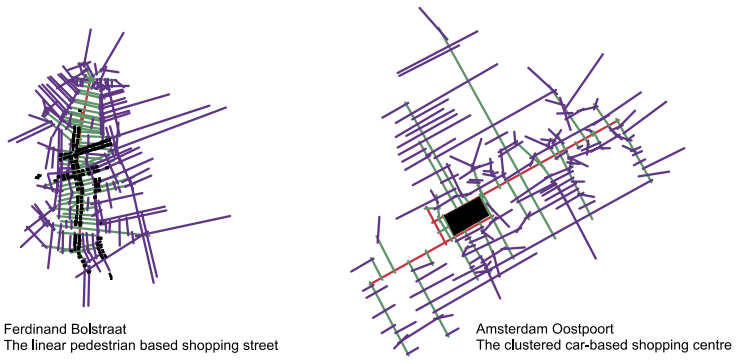

Figure 2: Two steps analyses of two different shopping streets in Amsterdam.

How can a street network's spatial configuration decide upon how people move by foot or by car? High local spatial integration conditions the location of successful pedestrian-based shopping areas. It often is indicated by a dense structure on the street network in the vicinity of a shopping street. Shops have a linear location pattern along the most locally integrated streets, while they tend to be clustered at the junctions of the most globally integrated roads where the local integration is low. Thus, indication of a successful vital shopping and retail area which is pedestrian based requires a strong local and global position in an urban street and road network. If urban growth changes the integrated core, either on a local or a global scale, the optimal location for profit maximising is affected.

In order to survive in a competitive environment, shop and retail owners will always search for the optimal location to reach potential customers. Thus, creating a vital city centre and sub-centres calls for an account of their global and local location in an urban street network and the respective degrees of connectivity to their vicinity. High density of the street network within a short metrical radius encourages human movement on foot or by car. A globally integrated street net with poor connections to its vicinity and low density of the street network within a short metrical radius encourages private car use.

Recently the angular weighting between street segment and metrical radius is added into space syntax analyses (Hillier et al 2012). Two types of refined space syntax analyses have emerged through testing on pedestrian flow data and location of economic activities; to-movement and through-movement potentials. The segment integration analyses show the to-movement potentials and the results have similarities with the classic axial integration analyses discussed in figure 1. Obviously, shops locate themselves along the highest spatially integrated streets, on different scale levels (van Nes 2002, 2017).

The angular choice analyses show the through-movement potentials on various scale levels. The results correlate with the flow of pedestrian and vehicle transport movement (Hillier et al 2012). The angular choice analysis is applied on a research project on space and energy use for transport in Bergen and Zurich (de Koning and van Nes 2019). Here the angular choice analyses with a low and with a high metrical radius is applied. With other words, here we measure how integrated the various main routes are in terms of the fewest angular deviation within a radius of 500 meters or 5000 meters. As the results show, neighbourhoods with high values on the angular choice analyses with both a high (5000 meters) and a low (500 meters) metrical radius have low energy use for transport. The public transport lines tend to be located on the angular integrated main routes running through locally integrated neighbourhoods. The degree of walkability is high. Conversely, neighbourhoods with low values on the angular choice analyses with both a high and a low metrical radius have high energy use for transport (de Koning and van Nes 2019).

Figure 3 shows a bar chart with a juxtaposing of the angular choice analyses with energy use for transport for Zurich. Here the numerical values from the angular choice analyses are juxtaposed with the energy data for transport. The higher local angular choice integration values, the higher degree of walkability. As Jane Jacobs presumes, short urban blocks

enhance short walking routes. The same results on spatial configuration and energy use for transport are found in Bergen too. Thus, the spatial structure of the street and road network on a local scale matters for to what extent people use sustainable mobility means or not.

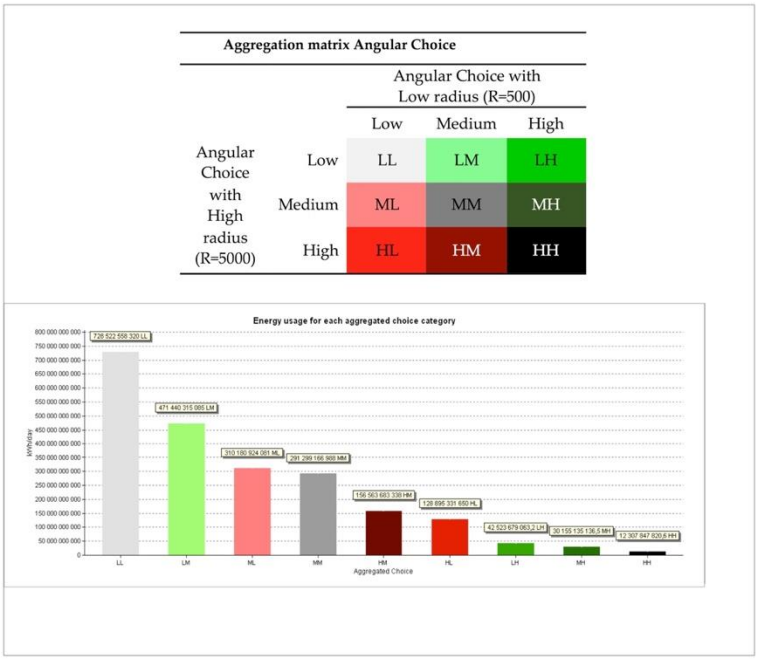

Figure 3: The juxtaposing between aggregated choice (combination of choice with a high and low metrical radius) and energy use for transport for Zürich (de Koning et al 2019)

4.2 The building-street interface and its influence on street safety & vitality in urban areas

As Rogers, Jacobs and Calthorpe suggest, one of the aims of repopulating city centres is to provide safe central areas where streets are free from anti-social behaviour. As mentioned earlier, neighbourhoods with highly integrated street network on a local scale enhance walkability. However, if the streets lack inter-visibility from adjacent buildings, people tend to avoid being in the streets and the streets are perceived to be unsafe (van Nes and López 2013).

The topological relationship between private and public space matters for street safety and gender balance. A method was developed for quantifying the relationship between private and public space. Figure 4 shows five different street segments with five different entrance situations. For each semi-public or semi-private space, a topological step is taken. Often, after two steps, there is a lack of visibility from buildings towards streets. Figure 5 shows a topological depth analyses of two different neighbourhoods close to the city centre in Bergen, Norway. In the Laksevåg neighbourhood, most of the streets have adjacent buildings that are turned away from them. The area is often perceived as unsafe to walk through. Conversely, in the Sandviken neighbourhood, most buildings have their entrances with windows located on

ground floor level oriented towards the streets. The area is perceived to be lively and safe. Families with children prefer to live in this neighbourhood.

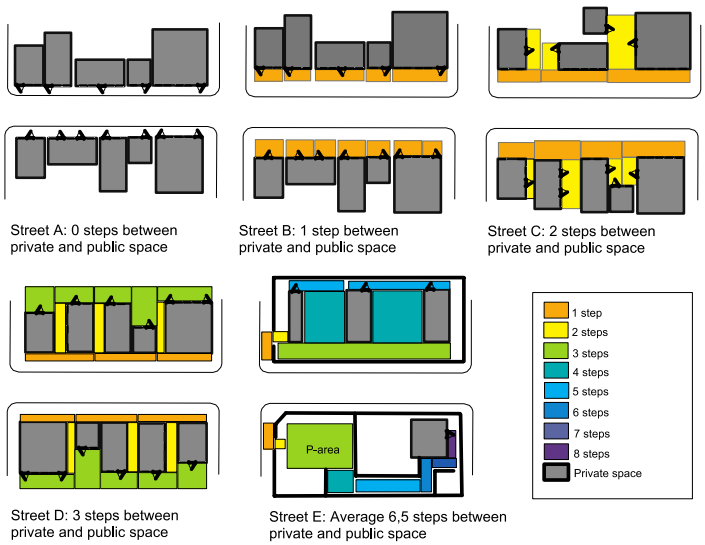

Figure 4: Topological depth between private and public space

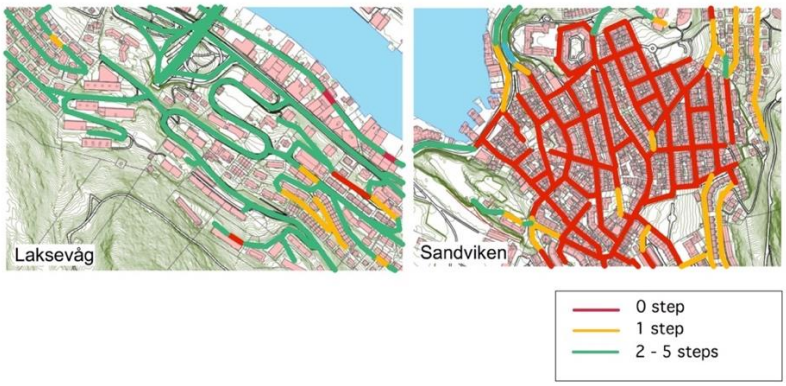

Figure 5: Topological depth analysis between private and public space for the Laksevåg and the Sandviken neighbourhoods of Bergen, Norway.

In a research project on space and crime, the position of building entrances influences also the burglary risk, the perception of safety, the presence of women in streets and sexual harassment rates. The more the building entrances are turned away from streets, the higher burglary risk (van Nes and López 2010), the streets are perceived to be unsafe (Ritland et al 2019), women avoid to frequent streets (Rooij and van Nes 2015), and higher risk of sexual harassment (van Nes and López 2013)). The design of urban space can thus affect the perception of safety and the use of space. This issue seems to touch upon the problem of architectural determinism. However, whether crime or social malaise will occur in spatial segregated areas with a lack of active building frontages or not naturally depends on the

behaviour of their inhabitants. A space syntax approach, on the other hand, can identify the spatial features of the areas that have a high level of crime and social misuse. As research has shown so far, the means a built environment offers are physical while its ends are functional - not visa versa as believed in many writings on built environments.

4.3 Identifying urban compactness through spatial configurations

The following examples will demonstrate how a compact vital city can be described with a spatial configurative approach. Figure 6 (above) shows Rogers' diagram where he tries illustrating or clarifying the relationship between a compact city centre and its compact sub centres (Rogers 1999, p. 53). The darkest colours indicate high density or high urban compactness. In what way these centres are compact is not clear. This diagram illustrates rather a tree structure on the relationship between city centre and sub-centres. The finer spatial content inside the circles is missing. It does not say how these centres can function socially and economically in a sustainable manner. Likewise, a concise understanding of the way each centre relates to their surrounding areas and the whole city is lacking. In general, the fine-grained street network and its inter-connectivity are not taken into consideration at all.

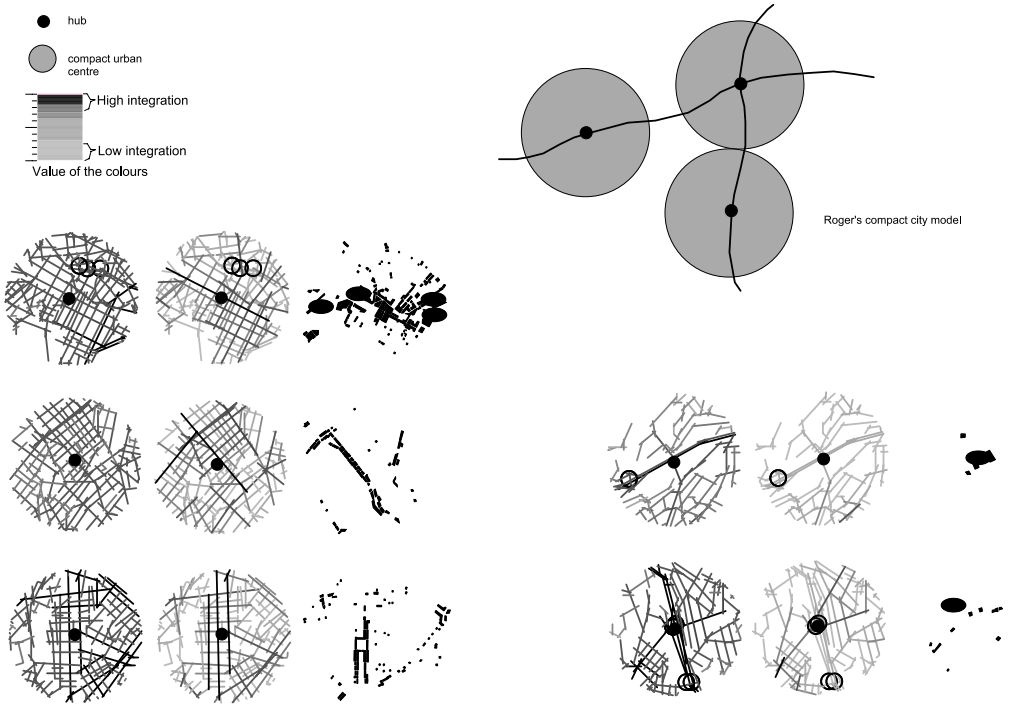

Figure 6: Using space syntax for demonstrating urban compactness in the pedestrian and car based shopping areas in Oslo.

From a space syntax approach, figure 6 (below left) shows the street network of the three main pedestrian-based shopping areas in Oslo within a radius of 1 km. The highest global integration is on the main roads and the highest local integration is on the main shopping

streets. The areas' location patterns of shops are shown next to the space syntax analyses. The black ovals indicate large shopping centres. All these areas have in common providing a dense street network within a short metric distance. Moreover, all adjacent buildings have windows and doors faced towards the streets. Seemingly, these spatial features are present in urban areas that are defined to be compact and sustainable. Conversely, figure 6 (below right) shows two car based shopping centres located at the globally most integrated ring road 3 in Oslo. The local integration and the density of the street network are low. It does not encourage movement by foot. In addition, most buildings inside these areas are turned away from the streets, in terms of complex entrance situations and lack of windows on ground floor level. These spatial features do not enhance walkability, and encourage private car usage.

5. SPATIAL CONDITIONS FOR GENERATING SUSTAINABLE MOBILITY MEANS

How can these findings on street network integration, through-movement potentials and the building-street interface provide an understanding of urban sustainability? At least since the industrial revolution we have seen in what way comprehensive technical inventions affected the spatial structure of built environments, and conversely its spatial product affected social and economic behaviour. Man is able to change its built environment and has purposes and intentions to do so. It is not always clear what the intentions are, but those concerning economic activities strive for profit maximising. Aiming at the creation of urban areas developing in a sustainable way cannot ignore the behaviour of producers and consumers and the way the built environment influences them. From a spatial configurative point of view, understanding what an urban area's sustainable development consists in depends on an according account of the topological structure of its street and road network and the topological relation between private and public spaces. Thus, a highly integrated street network on various scale levels is a *sufficient* condition for the location of economic activities. Likewise, a highly integrated street network with high angular choice values with both high and low metrical radii is a *sufficient* condition for high sustainable through-movement potentials in terms of high degree of walkability.

High density of streets and their inter-connectivity within a short metrical radius contributes to vital urban centres and dwelling areas. It is not enough encouraging high density of building volumes in neighbourhoods for reducing energy use for transport. It is the *density* of the street network and its local and global position in the whole system that matters. The same accounts for the degree of street-building interface on buildings' ground floor level. Lively well-functioning urban areas with high density of the buildings seems to be a by-product of the density of the urban street network, the dispersal of integration values on it (Ye and van Nes 2014), and short topological connections between private and public space (Ritland et al).

My approach to the question of urban sustainability in from a topological approach consists in conceptual application of a spatial configurative approach to the debate on sustainable urban development in terms of compactness. What are the results?

If a compact city is conceived as having a dense well-connected street network, both on a local and metropolitan scale, high inter-visibility between buildings and streets, then urban compactness of this kind is a *complex set of sufficient* conditions for generating sustainable urban processes in terms of low degree of energy use for transport. All these spatial parameters must be present for enhancing walkability, street safety, street life, and low energy use for transport. If a street is highly spatially integrated, but all buildings have their entrances and windows on ground floor level turned away from streets, the degree of walkability and perception of street safety will be affected. Blind walls and buildings turned away from streets are perceived to be unsafe and enhance avoidance.

Seemingly, the spatial structure of the street network on various scale levels matters for achieving some of the United Nations' sustainable development goals. Lesser energy use for transport touches upon parts from goal 7 (affordable and green energy) and goal 11 (sustainable cities and communities). Walkability touches upon parts from goal 11 and 3 (good health and well being). Streets enhancing gender balance touches upon goal 5 (gender equality), whereas safe streets and possibilities for micro economic activities touches upon goal 11. Compared with many other accounts of urban sustainability, a space syntax approach can offer specific concepts of spatial and functional aspects to explain or understand compact cities and their effects on economic and social behaviour – whether it turns out to be sustainable or not.

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