Chapter 15
Space Syntax in Theory and Practice

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15.1 Introduction

Most old European cities have a large intact historical centre. In the past many of them had a strong position in terms of politics, trade and cultural activities. These activities from the past mostly have left monuments such as a set of buildings or a street pattern. Intact historical urban centres function as an attractor for cultural activities such as museums, art and crafts, tourism, concerts, and performances. All these activities and their artefacts seem to create the atmosphere and a sense of place (Norberg-Schulz 1971).

As a tool, Space syntax cannot analyse place character, but rather place structure. It can analyse the spatial configuration of past street pattern from old maps and correlate the results with the location of remaining significant old buildings. In this way an application of space syntax provides insight into why these centres were highly vital in the past in comparison with the present situation.

What space syntax measures is the two primary all-to-all (all street segments to all others) relations. On the one hand it measures the to-movement, or accessibility of each street segment with respect to all others. On the other hand it measures the through-movement potential of each street segment with respect to all pairs of others. Each of these two types of relational pattern can be weighted by three different definitions of distance (shortest paths, fewest turns, least angle change paths) which can inform urban design and planning decisions where pedestrian experience is of concern and to anticipate zones of urban activity. Each type of relation can be calculated at different radii from each street segment, defining radius again either in terms of shortest, fewest turns or least angle paths (Hillier and Iida 2005, pp. 557–558).

The space syntax method can be applied on a wide scale level in research on built environments—from the organisation of furniture in a room up to metropolis,

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making possible to compare built environments with one another from a spatial point of view. Similarly, the method is a useful tool for comparison of the spatial changes in a before-and-after situation of structural urban changes in an area. However, while the method is a tool for explaining the physical spatial set up of buildings and cities, the interpretation of the results from the spatial analyses must be done in correlation with an understanding of the societal processes and human behaviour.

Space syntax is under constant development. Its contribution to theories on built environments and methodology develop at the intersection of natural, social and technical sciences. So far, research projects range from anthropology or cognitive sciences to applied mathematics and informatics and touch upon philosophical issues. The evolution of space syntax asks for communication not just between various cultural contexts, but likewise between different scientific domains.

Obviously, there is a relationship between how human beings organize their life and shape spaces for their activities. What matters is the degree of accessibility, visibilities, adjacencies, openness and enclosures in built environments. At present, there exists few precise predictable theories on how cities function. Most writings on urbanism, architecture and society seem to have a lack of careful description of urban form, structure, a concise definition of urban space, and a consistent vocabulary. The success of space syntax seems to depend on at least two things: a concise definition of space and high degree of falsifiability and validation. The space syntax method's independence of context makes it applicable on all types of built environments, independent on types of societies, political structures and cultures. Therefore it is recognised to be a sustainable solid analysis and research method on built environments on various scale levels of a wide range of different cultures. In a geodesign processes, it can provide interesting insight into the relationship between social, cultural, and economic patterns through analyzing various design scenarios.

15.2 The Basic Platform for the Space Syntax Method

Independent on cultures and architecture, all built environments have in common a set of private and public spaces. Public spaces open up for movement from everywhere to everywhere else. Private spaces are spaces inside buildings and gardens, connected to the public ones in different degrees.

Urban public space is mostly linear. Figure 15.1 illustrates how a built environment's street grid is presented as the longest and fewest sets of axes interconnected with one another. The longest sight line in each urban space is represented as one axis. These axes are the units for calculating the inter-relationship between them. The reality is thus simplified as a spatial model consisting of a set of axes in order to calculate how each urban space relates topologically, geometrically as well as metrically to all other urban spaces.

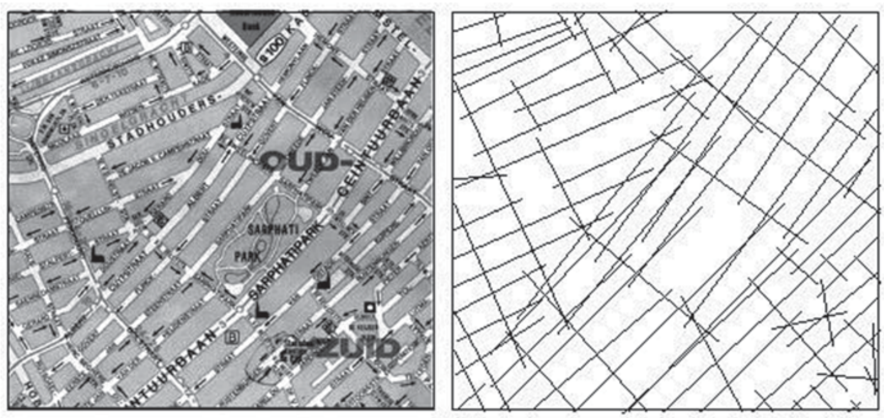

Fig. 15.1 An axial representation of an urban area in Amsterdam

15.3 The Axial Analyses

A global integration analysis implies calculating how spatially integrated a street axisis in terms of the total number of directional changes to all others in a built environment. Figure 15.2 shows a simple settlement, town X, consisting of a main street with side streets and smaller back streets. On the right side the town's street network is represented as a set of fewest axial sight lines. Each direction change is a topological step. The right lower corner shows an integration analysis of the settlement carried out by the computer program Axman, developed for space syntax. Various integration values are represented with grey scales. The black axes are the most integrated, while the light grey axes are the most segregated. As shown in the lower left corner, the justified graph illustrates how the system can be experienced from the most integrated street. In the case of the fewest line axial map, the lines are represented as nodes and the intersection of lines as nodal connections (Turner et al. 1993, p. 425). The grey scales of the nodes are the same as that used in the axial integration analysis.

Figure 15.3 provides an example of how to calculate the interrelation of one street to all other streets in town X. The back street (axis number 3) is represented at the bottom of the justified graph, thus at step zero. First calculate the sum topological depth from the back street to all other streets. If one change of direction occurs away from the back street, one street or space is found. If two changes of direction occur from the back street, three spaces are found. The sum depth of the back street is calculated by multiplying the number of spaces by the number of depths and then taking a sum of all the values. Thus, the more integrated a street is, the shorter topological distance it has to all other streets. Similarly, the more segregated a street is, the greater the topological distance is to all other streets.

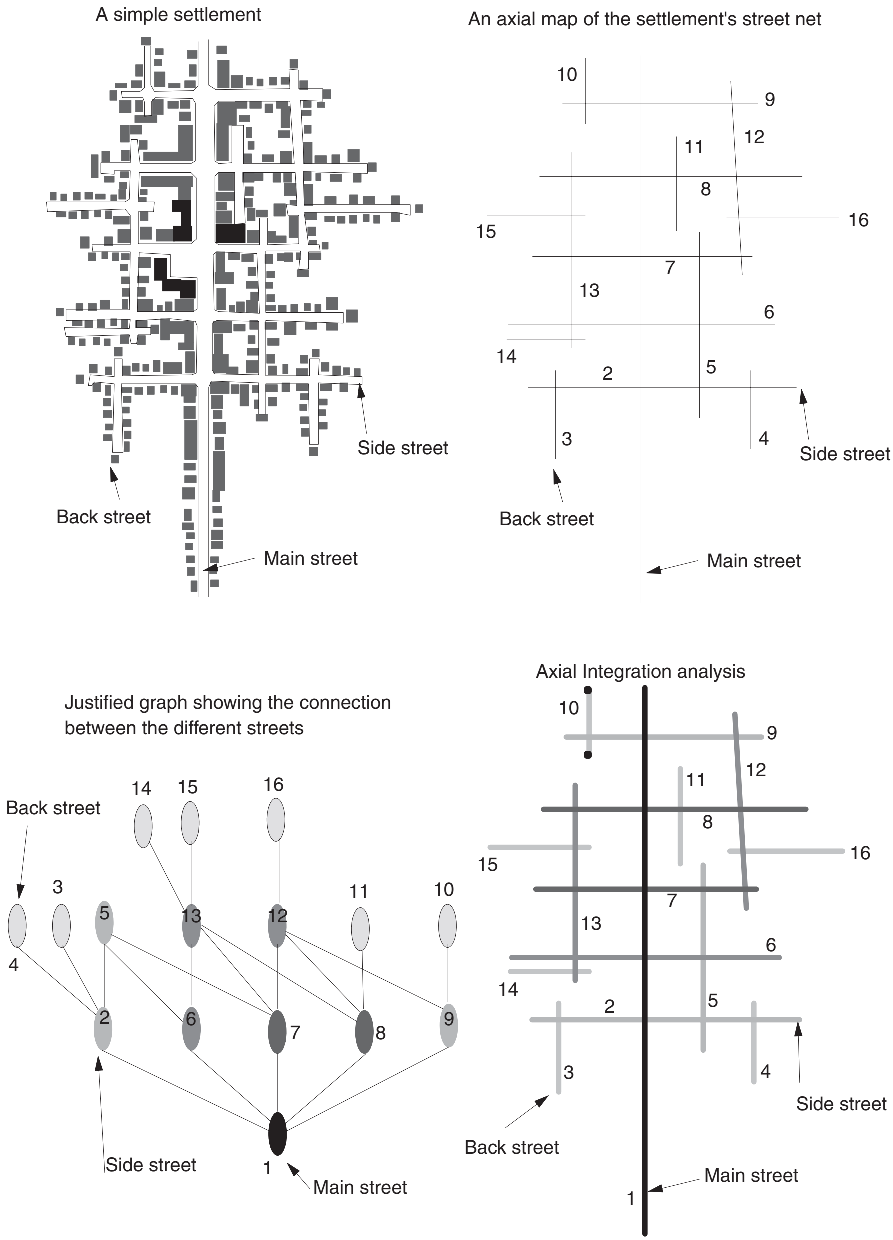

Fig. 15.2 A global integration analysis of town X

Figure 15.4 shows a comparison of the justified graphs of the back and the main street. Topologically shallow graphs such as the main street case have high integration values while topologically deep graphs such as the back street case have low integration values.

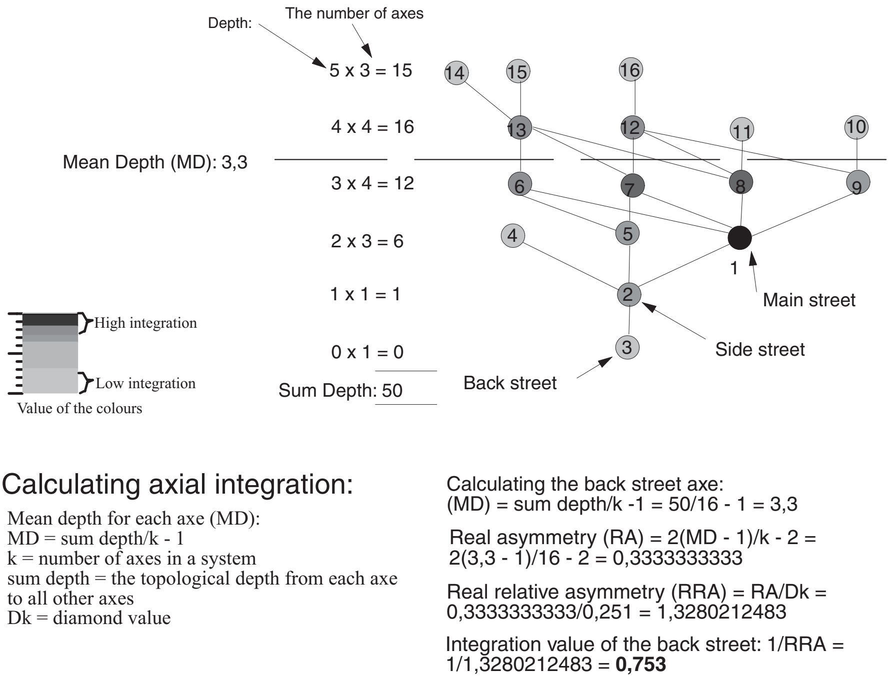

Fig. 15.3 How global integration is calculated

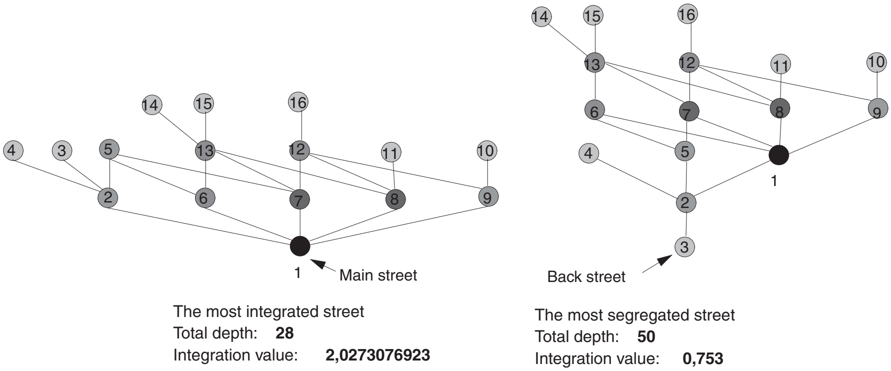

Fig. 15.4 Comparison of the justified graphs of the back and the main street with global integration

Commercial activities seem to take place in the most globally integrated streets (Hillier et al. 1993; van Nes 2002, p. 287). Dwelling areas are mostly located in the segregated areas (Hillier 1996, p. 175). There are two problems with a global integration analysis. One is the way a built environment's outskirts become very segregated, and the other is that many cities consists of several centres. A global

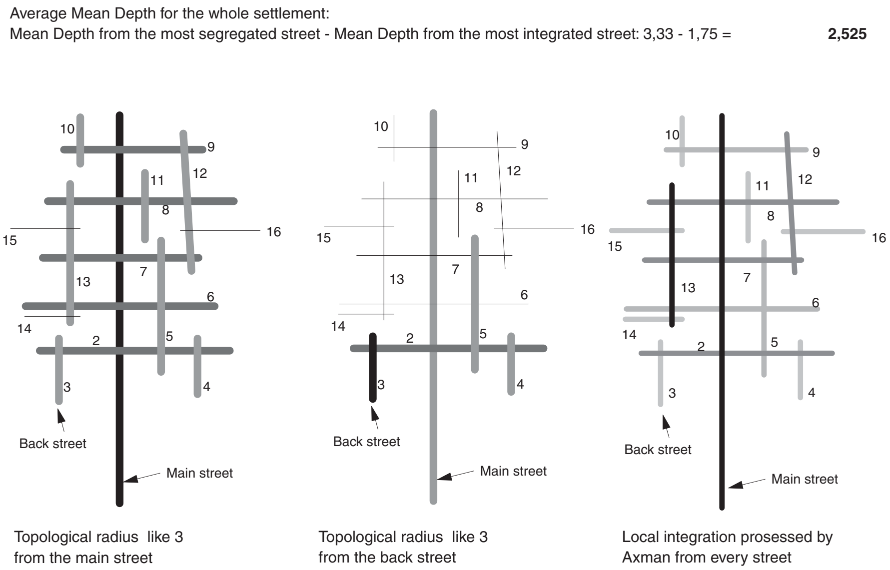

Fig. 15.5 Local integration calculations of town X with radius 3

integration analysis highlights only one centre. Therefore, a local integration analysis is needed using a local integration radius.

Figure 15.5 illustrates what local integration with a radius of 3 looks like in town X. In calculating the value of the main street (Fig. 15.5, left), the axes number 14, 15 and 16 are left out from a local integration analysis with a radius of 3. In the case of the back street (in the middle of Fig. 15.5), only 5 axes are included in the local integration analysis. The system to the right shows a local integration analysis of every street in town X processed by the program Axman. The value of the axis in a topological radius of 3 from each street is calculated.

Studies have shown that flow rates of pedestrians through cities correlate with local integration values while vehicle flow rates correspond with global integration values (e.g. Hillier et al. 1998). Moreover, local integration gives indication of local shopping areas in a city. However, applying local integration analyses on Dutch cities tend to show weak results. For example, in Leiden city center, most long main streets are curved. Axial analyses count each change of direction as one topological step, even though the angle between two axial lines is close to 180°. In this way, Leiden's centre is modelled as a fragmented street network consisting of many short axial lines. As follows, the integration values with various radii will not be the highest in these kinds of areas, which do not always correspond with shop locations. For example, the curved shopping street Haarlemmerstraatis not particularly highlighted as a highly integrated street in either the global or local integration analysis. It is only indicated in the radius-radius integration.

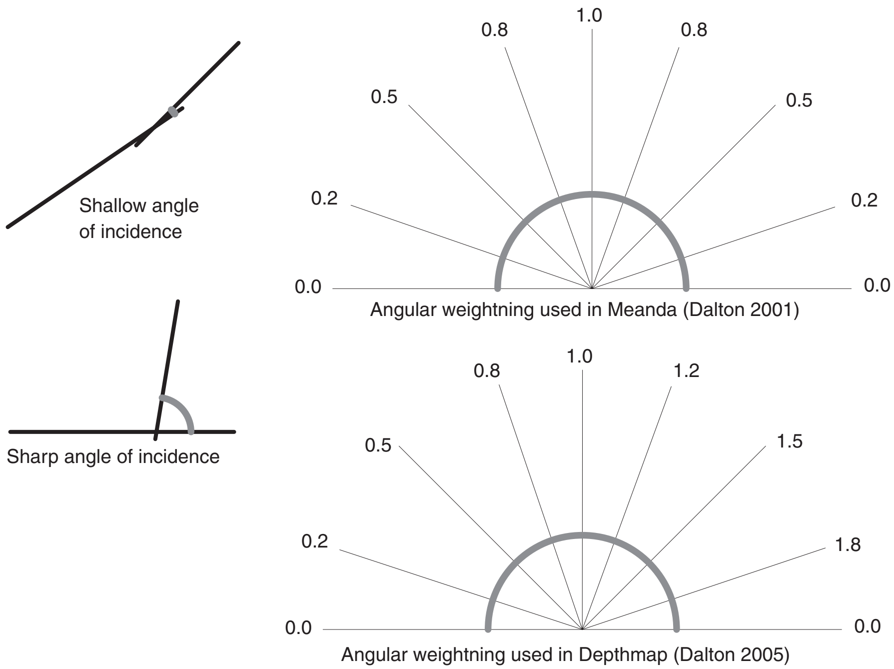

Fig. 15.6 Angular weighting

15.4 The Angular Analysis

The angular analysis is essentially an extension of visibility graph analysis and axial analysis (Turner 2001, p. 30.1). Here, each axial line is weighted by the angle of its connections to other axial lines. As shown in Fig. 15.6, two axes which meet at an angle of almost 180° have a shallow angle of incidence while two axes with almost 90° between them have a sharp angle of incidence (Dalton 2001, p. 26.7).

The angular relationships between streets play a role in the way people orient themselves in built environments. This is empirically supported by the research of Ruth Conroy Dalton who carried out experiments on how street angles influence people's choice of routes at road junctions. She concluded that people tend to conserve linearity through their routes, with minimal angular deviation (Conroy Dalton 2001, p. 47.8). There is a competition between the desire to select the simplest route and the desire to maintain the shortest route from origin to destination. As soon as the difference in angles become too great, the shortest route will win out over the simplest (Conroy Dalton 2001, p. 47.12–47.13). Therefore, geometrical distance, such as the "least angle change" of direction towards one's direction plays a role in way-finding through cities. Hence, it has to be taken into account together with the topological distance (i.e. "the fewest turn").

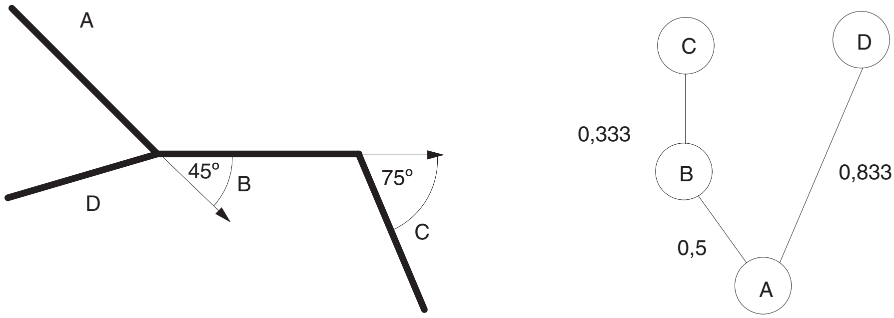

Fig. 15.7 The calculation of angular choice

The axial lines represent the longest and fewest sightlines in the area. For example a curved street consists of several axial lines. A segment line represents a street or road link between two junctions. The degree of curviness does not count in this case. When three or more lines intersect, a junction is defined. In the axial line representation a curved street segment consists of a "junction" every time there is a change of direction.

Consider four street segments connected to one another at different angles, as illustrated in Fig. 15.7. The depth from segment A to B is 0.5, since they constitute a turn of 45°. The depth from segment A to C is 0.833, the sum of the turn of 45° from segment A to segment B and the turn of 30° to segment C. When calculating the angular mean depth, or the local angular integration, the case shown in Fig. 15.7 is used as an example. The angular mean depth from street segment A is calculated as follows:

$$\text{angular mean depth of}\,(A) = \frac{(B)0.5 + (C)0.833 + (D)0.833}{(3)} = 0.722$$

The least angle analysis seems to be the best predictor of movement, followed closely by the fewest turns (the results from the global and local integration analyses). Metric distance comes far behind the two first ones (Hillier and Park 2007). When correlating angular choice (geometric distance) with topological distance in Leiden, it is possible to identify the local main routes in local areas and through the whole city. Figure 15.8 shows a local angular analysis with a topological radius of 3 of Leiden. The two main shopping streets Haarlemmerstraat and Breestraat are clearly highlighted as being the locally most integrated streets for the whole city.

15.5 Angular Analyses with Metrical Radii

Figure 15.9 shows some examples of how various types of radii affect various types of street grids. The street grid consists of a strict orthogonal street grid and an organic street grid. When applying the two-steps analysis to the thick line, all streets

Fig. 15.8 The local angular analysis of Leiden

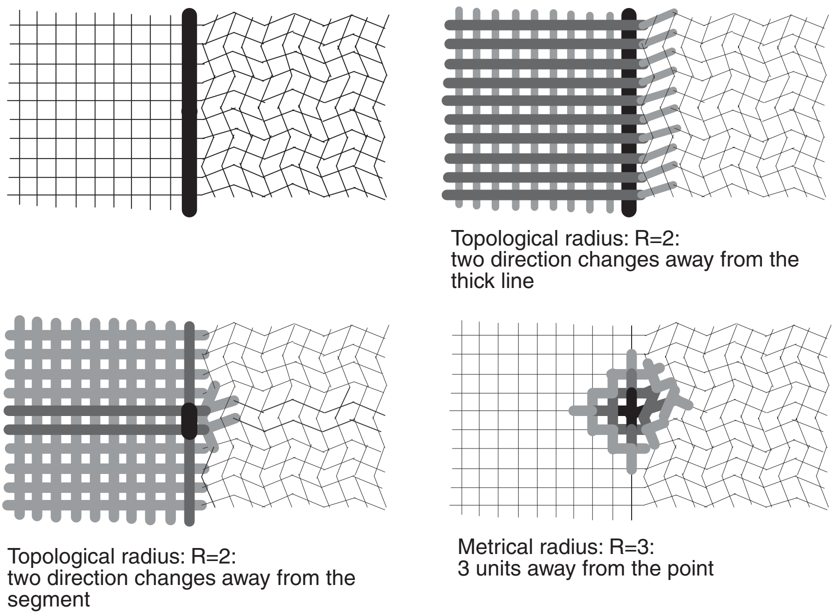

Fig. 15.9 The difference between topological and metrical radius

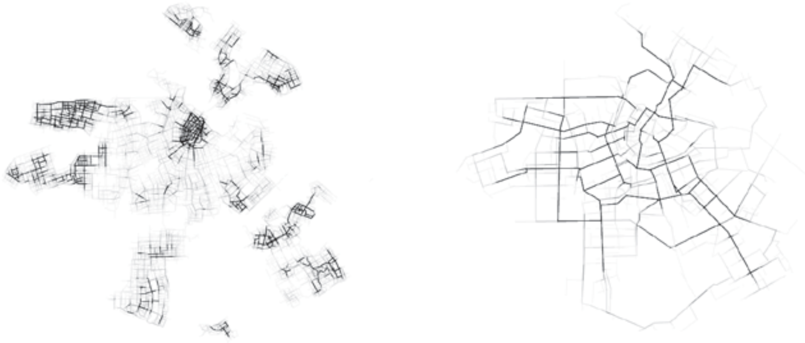

Fig. 15.10 Analyses of Amsterdam with metrical radii

in the strict orthogonal grid can be reached within two direction changes. Likewise, when applying the two-steps analysis to a street segment (below left in the figure), more or less the same local catchment area can be found as in the previous example. The only difference is that the organic street grid is less accessible than the previous example. When applying the metrical radius from a point, the strict orthogonal street grid as well as the organic street grid has more or less the same catchment area. The next step is to show what metrical radiuses add to the analyses of topological and geometrical distances.

Figure 15.10 shows an example of Amsterdam. For a small metrical radius (like 800 m), the old historical city centre is highlighted to be very vital. This area is neither highlighted in the traditional spatial integration analyses, nor in the angular analyses.

Probably this centre was originally developed to have everything accessible within a shorter metrical distance than the today's situation. Today it is the touristic centre of Amsterdam, where everything is easily accessible on foot. When using a larger metrical radius (for example a unit of 8,000), the main routes in the Pijp area in Amsterdam are highlighted as being the most vital streets for the whole city. For Amsterdam's inhabitants, this area is known to be the most vital and lively city centre for the whole of Amsterdam. The area offers a large variation of shop types and has very lively streets at all times of the day. Everything is easily accessible by bicycle, tram, car, and partly by foot.

In order to demonstrate what a metrical radius implies for urban centrality when combining it with topological and geometrical distances, an example of a new and an old town is used. The Dutch new town Lelystad is 40 years old. It has around 74,500 inhabitants. The car traffic routes and pedestrian and bicycle routes are separated. Figures 15.11 and 15.12 show angular integration analyses with a low and a high metrical radius for Lelystad's mobility network. As can be seen in Fig. 15.11, the streets where the small local supermarkets are located are highlighted in black. Conversely, as shown in Fig. 15.12, the main routes between the various local areas

Fig. 15.11 Angular analyses of Lelystad with a low metrical radius

are highlighted in black. These routes are trafficked predominantly by vehicles. Lelystad's main mega shopping mall is located in the middle, where the density of the integrated main routes is the highest.

When applying the same analyses to the old Dutch town Hilversum, founded in 1424, a different structure can be seen. Hilversum has around 84,500 inhabitants. In the analysis with a low radius in Fig. 15.13, the town's local as well as central shopping streets are highlighted in black. When applying a high radius, as shown in Fig. 15.14, the main routes through the urban areas are highlighted in black. These routes cross the local centres highlighted in the small radius analysis. As presumed, an optimal location for shops is along streets accessible to its vicinity as well as along main routes connecting various neighbourhoods with one another. Therefore, the variation of shops in local shopping areas tends to be higher in old towns than in new towns.

Figure 15.15 shows the principles of the main route network in an old and a new town. In the top of the figure, the principles of a traditional urban area are shown. The centres with a low radius are located either on or adjacent to the main routes. These centres are easily accessible by foot as well as by car. The principles of urban centres in a post-war neighbourhood are shown. The main route network in post-war neighbourhoods is separated from the local centres whereas it is integrated

Fig. 15.12 Angular analyses of Lelystad with a high metrical radius

with the local centres in pre-war neighbourhoods. Thus far, the results indicate that the spatial conditions that define vital urban centres are the presence of a topologically integrated street network, with the least deviation of angular direction change on its main routes through the area within a short metrical distance to its potential customers.

15.6 The Micro Scale Analyses

Micro scale spatial relationship in urban studies is about the relationship between buildings and street segments. More precisely it is about demonstrating how dwelling openings are connected to the street network, the way buildings' entrances constitute streets, the degree of topological depth from private space to public space, and inter-visibility of doors and windows across streets.

A registration of the *topological depth between private and public space* is done by counting the number of semi-private or semi-public spaces from the private space to the public street. If an entrance is directly connected to a public street, it has no spaces between private and public space. Then the value or depth is zero. If there

Fig. 15.13 Angular analyses of Hilversum with a low metrical radius

is a small front garden between the entrance and the public street, it gets the value one since there is a space between the closed private space and the street. Moreover, if the entrance is located on the side of the house and it has a front garden or covered behind high hedges or fences it has a value two. Entrances from back paths covered behind a shed have a value like three. It is the topological steps between the street and the private spaces that are counted. In a study on the dispersal of burglaries in Alkmaar and Gouda, the degree of permeability was used as a rule of thumb. In those cases where a flat's front door or main entrance was permanently locked but was provided with a doorbell or calling system, it was registered as a private space. As regards to flats with open main entrances, the number of semi-private spaces was counted up to the apartments (López and van Nes 2007).

Each side of a street segment must be registered separately. There exist many streets where entrances are for example directly connected to the street on the one side, while there is a flat on the other side with an upper walk gallery. In street segments with different depth values between private and public spaces, the average value can be used. The diagram in Fig. 15.16 illustrates various types of relationship between private and public spaces. The black dots illustrate the private spaces, while the white dots illustrate semi-private and semi-public spaces.

Fig. 15.14 Angular analyses of Hilversum with a high metrical radius

A street's *degree of constitutedness* is about the degree of adjacency and permeability from buildings to public space (Hillier and Hanson 1984, p. 92). If, and only if, a building is directly accessible to a street, then it constitutes the street. Conversely, when a building is adjacent to a street, but its entrance is not accessible directly from the street, the street is un-constituted. Naturally, there must be no other buildings with entrances directly connected to this street (Fig. 15.17). Few people tend to sit or stand for a long time in un-constituted streets due to a lowered level of safety (Alford 1996). In his PhD thesis, Shu's research results showed clearly that un-constituted streets were affected more by criminal activities than in the constituted ones. Moreover, entrances covered behind high fences and hedges have little visibility from neighbours (Hillier and Shu 2000).

The density of both entrances and windows in buildings with an active function (dwelling, office, shop, etc.) on ground floor level can to some extent indicate a degree of street liveliness. However, high density of entrances connected to a street does not imply high *inter-visibility*. There is a distinction between *constitutedness* and *inter-visibility*. The way entrances and windows are located opposite of each other in a street gives a high probability in the way people can observe the street (a natural surveillance mechanism). Figure 15.18 shows some diagrammatic principles on the relationship inter-visibility and density of entrances. The micro spatial

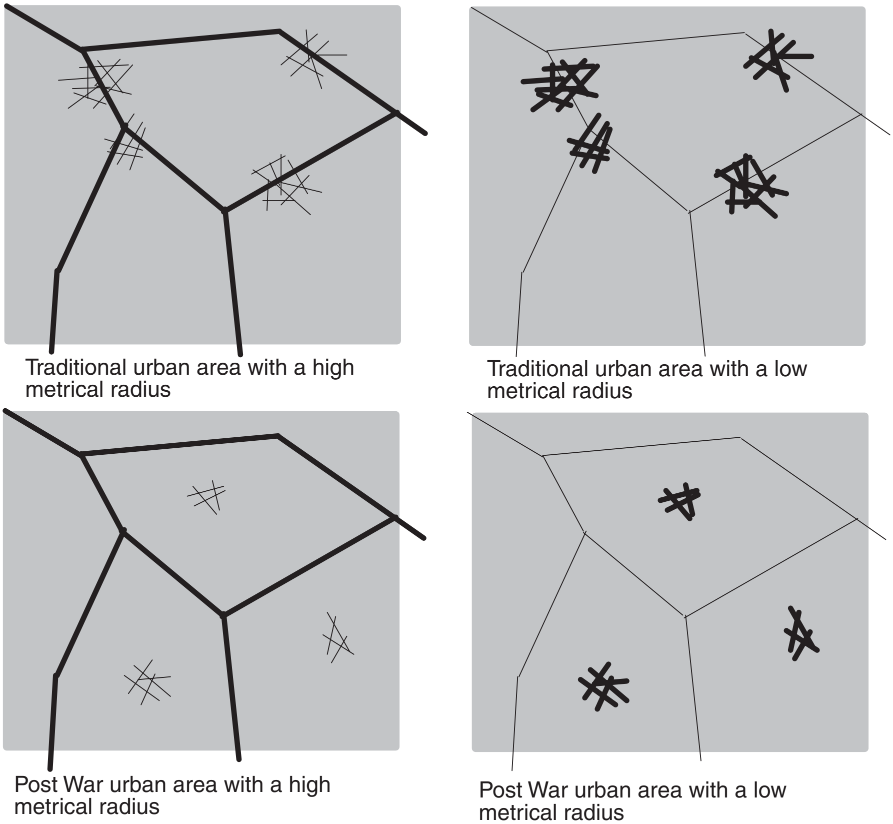

Fig. 15.15 The spatial principles of the location of urban centres in relation to the main route network in a new and an old built environment

conditions influence the quantity and quality of street life and the risks on criminal victimization (van Nes and López 2007).

Micro scale conditions are often neglected in the contemporary planning and design of urban areas. In particular, urban renewal projects, modern housing areas and new large-scale urban development projects often tend to lack adjacency, permeability and inter-visibility between buildings and streets. This has negative effects both on the quality and quantity of the street life and the safety of these urban areas. Urban project developers nowadays tend to build with high density or high floor-space-index and propose large variations of urban functions (dwellings, offices, etc.) in these areas. However, the public-private interface between buildings and streets is often forgotten. Safety and degree of street life depend on how the spatial configuration is on the plinth or built up street sides. Therefore, there is a need to bring micro scale spatial relationships on the research, policy making as well as on the design agenda in the urbanism discipline.

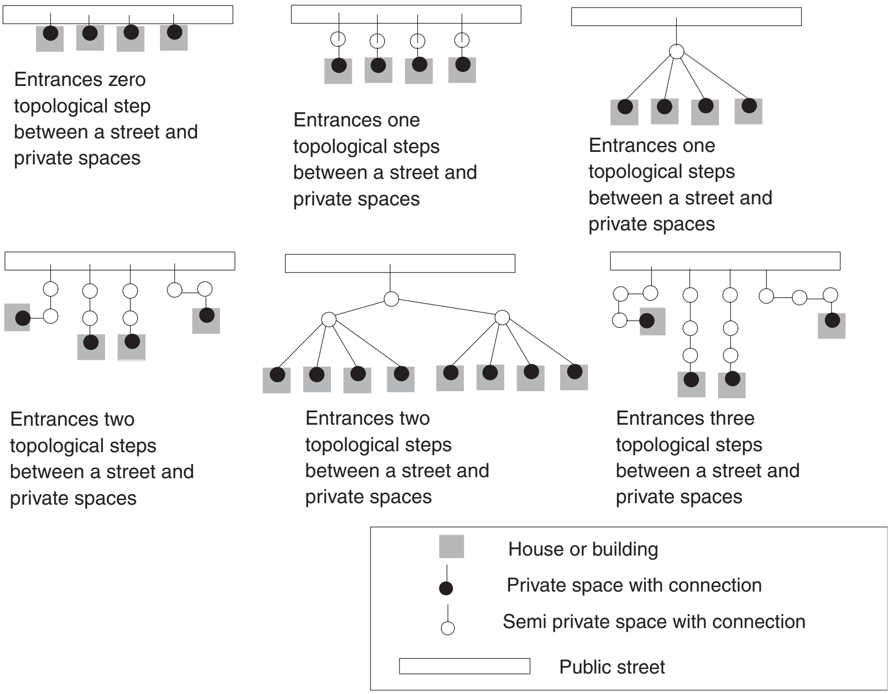

Fig. 15.16 The principles of the topological relationship between private and public space

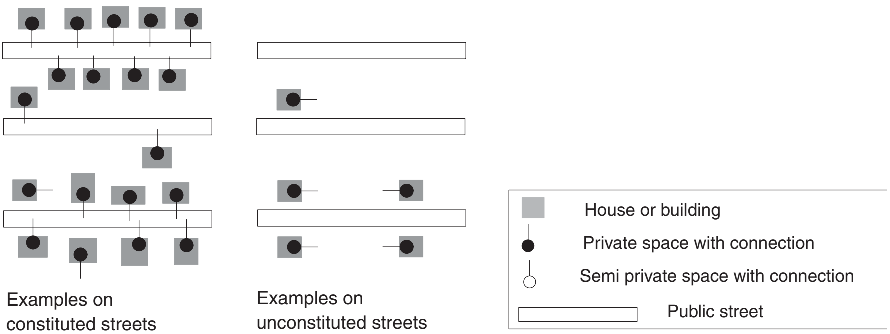

Fig. 15.17 The principles of constituted and un-constituted streets

15.7 Added Value in the Geodesign Process

Space syntax has contributed to an understanding of the spatial structure of the city as an object shaped by a society and conversely how this spatial structure can generate or affect certain socio-economic processes in society. To some extent, it

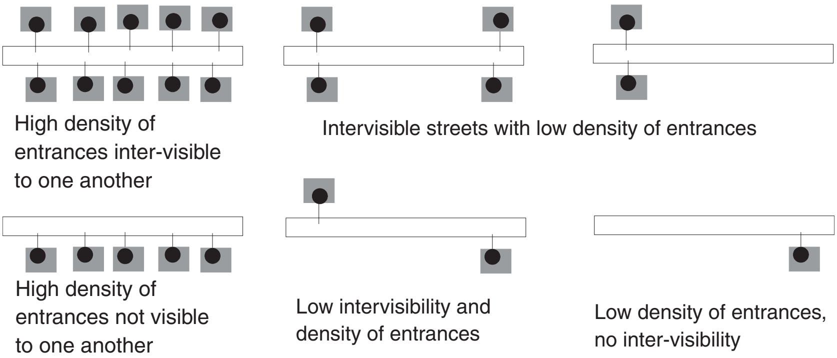

Fig. 15.18 The principles of density and visibility of entrances and windows

is possible to predict some types of economic processes as an effect on urban interventions. Likewise, space syntax provides understandings on the spatial possibilities for certain social activities such as crime, social segregation and anti-social behaviour. It is all about how spatial integration and segregation conditions social integration and segregation.

How a street or an urban area is centrally located can influence its economic attractiveness. *Metric centrality* implies that something is located in the middle of an area with the shortest metric distance to all other points in that area. Sometimes temporal aspects like time use for travel are taken into account. Obstacles like traffic-junctions, bad street quality and a fragmented street network influences the temporal aspects of metric centrality. *Topological centrality* is the most accessible centre in terms of the fewest number of direction change from all streets. The more fragmented street network in a built environment, the weaker the spatial conditions become for a vital economic centre. *Geometrical centrality* occurs along the main route network with the fewest angular deviation from all other streets. The most accessible main route network linking a city's edges towards its centre tends to have the highest flow of through travellers.

For describing social and economic activities in built environments, there is a difference between *economic* and *cultural* centrality. *Economical centrality* is the places where trade, shopping and finances take place. The aim for these kinds of activities is to be both in a metrical and topological central position to all potential customers. Their optimal position depends on the structure of the street net.

As regards to the theory of the *natural movement economic process*, the configuration of the street grid influences the movement rates through an urban street network and where economic activities take place. Attractors, such as shops, retail and large firms tend to locate themselves along the most integrated streets (Hillier et al. 1993, p. 61). Figure 15.19 shows the relationship between configuration, attraction (the location of shops) and movement. It explains how a built environment functions independent on planning processes. Movement and attractors influence

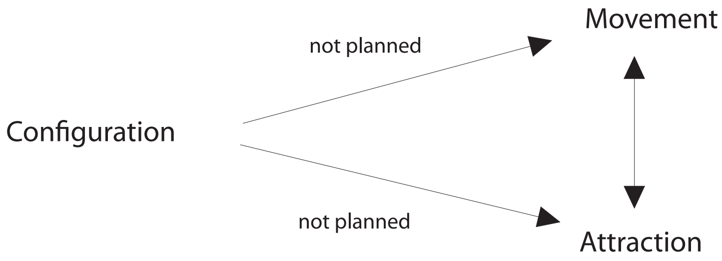

Fig.15.19 The theory of the natural movement economic process

each other. The more people in a street, the more it attracts shops to locate along these streets. The more shops locate along a street, the more they attract people.

If an economic centres' optimal position change through changes on a street network, the location of this centre is likely to change too (Hillier 1999; van Nes 2002, pp. 287–301). Friederichstrasse in Berlin provides an example on this. Before the Wall it was one of Berlin's high streets. During the Wall no shops was located along it, while after the Wall shops returned to Friederichstrasse. At present it is slowly becoming the high street of the new reunited Berlin. Therefore economical centrality is not something static. It is a dynamic process. "At all levels of the hierarchy, centres grow and fade, often in response to changing conditions quite remote from the actual centres" (Hillier 1999, p. 108). Therefore an economic centre is heavily dependent on a street structure, which relates to topological and geometrical centrality. Accessibility to potential customers and catching the through travellers is an issue.

The way human beings act and behave in urban space depends on their motives and intentions. Therefore it can be difficult to predict their behaviour after urban interventions. So far, research has shown that the location of shops, retail, national and international firms and in general the location of urban centres depends on a high degree of integration of the street net on various scales (Hillier 1999; Hillier et al. 1993). Likewise, land values and rent process tend to be influenced by the various integration values of the street net (Desyllas 2000). High degree of accessibility or reach ability is at issue for creating vital urban centres and generating economic activities inside them.

In studies on built form and meaning, dealing with place character and architectural styles, touches upon the limits of space syntax. Therefore *cultural centrality* is a broader issue than economic centrality. Places with a large concentration of historically important buildings and monuments from the past are defined to be cultural centres. The meaning of artefacts and the tradition related to them can be understood from the technical, social, cultural and economic activities that took place in the past (Moudon 1997).

What is happening in extreme segregated streets? In research on urban space and human social interactions, it is difficult to set out general statements on how the spatial layout of a built environment can provoke criminal activities, create social segregation, steer political processes and provoke anti-social behaviour. In contrast with market rationality, where the intentions tend to be unambiguous, social rationality concerns a wide range of intentions. Even though occurred incidents can be understood from a spatial point of view, an understanding on space and crime depends at least on understanding the behaviour of local inhabitants and an insight of the social composition. Sometimes the social composition of the inhabitants can overrun the spatial generative power.

In general segregated streets have more complex routes to all other streets in a city. Areas with segregated spaces, with urban grids visually broken up and with few dwelling entrances constituting streets are often affected by crime and social misuse (Hillier and Shu 2000, p. 232; Hillier and Sahbaz 1984, p. 456). The same investigations prove that spatial organisation can generate movement according to co-presence and co-awareness in the built environment.

A space syntax approach can at least identify the spatial properties to understand why some already established urban areas have a high level of crime and social misuse. These identified spatial properties provides at least precise understandings on how spatial configuration plays a part in broader social processes of perceived and actual decline. Thus space syntax can illustrate that the spaces of a built environment can affect human behaviour (Hillier 1996, p. 184). A configurative approach makes one understand that the means a built environment offers are physical while its ends are functional—not visa versa.

Even though space syntax offers precise concepts to operate with, it cannot analyse the place character, the sphere and the symbolic meaning of the built form. However, space syntax can analyse the configurative structure of their spatial set-up as an independent factor of the built form's symbolic meaning. Therefore space syntax deals with place *structure* and not with place *character*. Analyses of place character require a genuine understanding and insight of their society's cultural background and spiritual traditions from the present as well as the past.

While researchers with a phenomenological approach seek to describe the underlying essential qualities of human experience and the world where these experiences happens (Seamon 1994, p. 37), researchers with a space syntax approach identifies the spatial conditions for lively or quiet urban squares, streets, neighbourhoods, etc. Understandings of the spatial conditions of pedestrian flow rates and degree of urban vitality is also an essential component of the sphere of a place. As Hillier and Hanson writes, space syntax is about understanding "the social content of spatial patterning and the spatial content of social patterning" (Hillier and Hanson 1984, p. x–xi). It is a small, but significant contribution towards a comprehensive theory on built environments.

When applying space syntax in urban design or on any kind of physical intervention on the street network or on the building-street interface, it is heavily dependent on evidence from research and theory development on the relationship between space and society. Space syntax makes possible to some extent the evaluation of socio-economic effects of various design proposals for an area, and is a critical piece in the geodesign process, especially when communicating impacts to stakeholders. At present, space syntax has been applied to urban design, urban regeneration and strategic planning projects. Designing with the use of space syntax is slowly entering the design field in regenerating poorly functioning urban areas. Some successful projects are already implemented, such as the regeneration of Trafalgar Square and the South Banks in London. It is a first step towards a scientifically grounded urban design process, rather than working on guesswork or intuition when intervening in built environments.

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