Akkelies van Nes · Claudia Yamu

Introduction to Space Syntax in Urban Studies

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Preface

In memoriam:
Bill Hillier 1937–2019
Alasdair Turner 1969–2011

For Alexander, Robert, Aurelius, and Valerius

Keywords
Space syntax

Key Concepts
Urban phenomena • Spatial theory • Spatial relationships • Street network analysis • Socio-economic behaviour of people • Land use

The Need for a Textbook on Space Syntax

Space syntax's popularity has grown rapidly in recent years. It connects the fields of urban spatial analysis and urban design in the arena of transport, land use, and people's behaviour. An ever-growing number of international scholars and practitioners are applying space syntax at various scales, from buildings and neighbourhoods to metropolitan areas and entire regions. Also, universities worldwide now include space syntax theory and methods in their curricula.

As pioneers of space syntax in our home countries—Norway, Austria, and the Netherlands—we are regularly asked to give lectures, talks, and workshops about space syntax to students and colleagues in the fields of architecture and urban design, urban planning, urban geography, road engineering, sociology, archaeology, and criminology as well as to practitioners and urban developers.

However, until now there was no textbook at hand providing an elementary introduction to space syntax, including exercises, in order to study and learn it in an easy to understand way. Thus, it was natural for us to respond to the need for a holistic textbook. The presented textbook provides a knowledge foundation on which the space syntax novice can build upon to become the most experienced space syntax researcher, and it is a resource for scholars who want to use space syntax in teaching and research. Likewise, practitioners can benefit from this book.

Both of us, like so many others interested in spaces syntax, got started with the well-known and challenging readings of Bill Hillier and Julienne Hanson's *The Social Logic of Space* (1984), Bill Hillier's *Space is the Machine* (1996), and Julienne Hanson's *Decoding Homes and Houses* (1999). Alexander R. Cuthbert, in his article 'Urban design: Requiem for an era—review and critique of the last 50 years' from 2007, not only acknowledges Hillier and Hanson's work to be "one of the most erudite and scholarly expositions of urban spatial theory" (Cuthbert 2007, p. 200), but also confirms that their *The Social Logic of Space* can be "extremely difficult to understand, much of it buried in mathematical concepts and formulae" (Cuthbert 2007, p. 200). This is in contrast to Kevin Lynch's, Rob Krier's, and Christopher Alexander's writings that are much easier to access for the reader.

After many years and a thorough insight into space syntax obtained from the perspective of academia and practice at The Bartlett School of Architecture, University College London (UCL), and Space Syntax Limited (SSL) in London, and from attending several international space syntax symposia, we observed the increasing need for a textbook to allow easy access to space syntax knowledge for all who are interested in the method.

The accumulation of personal and professional experiences was the impetus for us to write this book. This textbook gives the reader a guided tour through various aspects of space syntax in urban studies, and it further connects space syntax to urban morphology, phenomenology, and network traditions. However, this book has a long history. It has been under constant development since its first draft idea in 2004 and is based on the authors' lecture notes, research projects, scientific writings, and knowledge from practice. To test its applicability and pedagogical approach, excerpts of it have been given to students and colleagues for feedback over the years. With their valuable feedback, we developed the book's approach, clarified the content, and increased its applicability. Therefore, it serves as a pedagogical complement to the more difficult to understand body of existing space syntax literature.

In many countries, the scientific aspects of architecture and urban design do not receive sufficient acknowledgement. This is mirrored in the way that most urban designers and architects are educated and trained to intervene in the built environment without any evidence-based knowledge and skill set about how to approach and analyse the socio-economic impact of their urban interventions. Thus, there is a need and a challenge to introduce urban analytical research in the curriculum of architects and urban designers. The challenge is to combine while at the same time balance urban design and urban analytical research without falling into the trap of becoming overly normative. An introduction to a basic set of spatial analytical tools and their application in urban design research and practice is definitely needed.

Following this, the main aim of this book is to present and explain the basic elements of the space syntax method as applied to the analysis of the built environment on different scales, from buildings and local streets to large metropolitan areas. It shows how urban phenomena can be understood through configurative studies connected to people's socio-economic behaviours. We present a basic platform for carrying out space syntax analyses, and this book seeks to bridge the gap between the theoretical concerns of the scientist and the practical interests of the practitioner. It is not, however, a manifesto on urbanism. We do not judge what kinds of urban interventions are 'right' or 'wrong'. Nor is it a normative description of how one should design urban areas. Instead, it explains some solid scientific methods for analysing the built environment in order to understand how it functions both spatially and socially.

In the first chapter, we first give an overview of the three main research traditions regarding the physical aspects of the built environment. This chapter introduces the basic components of the space syntax method and how they relate to other analytic methods. The various concepts of space from various urban research traditions are also presented. In the second chapter, we explain the various spatial techniques for analysing the urban street and road network based on the axial line. Here, some of the basic mathematical formulae of space syntax are presented and discussed. In the third chapter, we present the techniques for measuring and analysing visibility, such as isovist, all-line, and point-depth analyses. In chapter four, we present the urban micro-scale tools used to analyse the relationships between buildings and streets as well as between public and private spaces. Here, the focus is on the neighbourhood level. In chapter five, we present some methods to connect and correlate data about people's activities and other data with numerical results obtained from the spatial analyses. Chapter six reflects upon how a space syntax approach contributes to theory building and understandings of how the built environment works. Here, some aspects from the elementary theory of science relevant to space syntax are presented. We conclude in chapter six with a discussion on urban sustainability and compactness connected to space syntax. Finally, chapter seven provides a discussion and demonstration of how space syntax is applied in urban design and urban planning practice.

In Brief: What Is Space Syntax?

Space syntax, originated in the 1970s by Bill Hillier and his colleagues at The Bartlett School of Architecture, University College London, is a theory and method for analysing spatial relationships. In its wider context, space syntax is a set of techniques that can be applied individually and in different combinations with one another. The combination of these different analytical techniques depends on the research or urban design and planning question(s) for one or several urban systems under scrutiny. The space syntax toolkit provides methods for finding spatial answers to these questions. In essence, the space syntax method consists of calculating configurative spatial relationships in the built environment. Hillier and Hanson (1984, p. 176ff) understood at an early stage of the method development that for the field of anthropological studies, space syntax can provide a spatial understanding of the social organisation in settlements from different cultures by demonstrating how buildings and settlements play a role in social relations.

Originally tested and applied in analyses at the scale of small settlements and buildings, the development of computing power has made it possible to analyse the complex relationships in larger cities and metropolitan areas and even entire regions. According to Hillier et.al (2007), the application of the space syntax method to urban studies consists of four things. First, the concept of the spatial units at issue is clarified and well defined. Second, space syntax is a family of techniques for analysing cities as networks of space formed by the placing, grouping, and orientation of buildings. These techniques make it possible to analyse how a street interrelates spatially with all other streets in a built environment. Third, space syntax provides a set of methods for observing how networks of space relate to functional patterns such as vehicle and pedestrian movement flows through cities, land use patterns, area differentiation, crime dispersal, property prices, migration patterns, and even social well-being and malaise. Fourth, research results from applications of space syntax have contributed to new theories and understandings of how cities are constituted spatially as an effect of social, economic, and cognitive factors and how urban space, in turn, functions as a generative power for societal and economic activities and cognitive factors. The space syntax method has been applied to a large number of cities in different parts of the world, and a substantial database now exists of cities that have been studied by using the space syntax method (Hillier et al. 2007).

Space syntax measures how every public space or street segment in a built environment relates to all other public spaces. On the one hand, space syntax measures the *to-movement potential*, or *closeness*, of each street segment with respect to all others. On the other hand, space syntax measures the *through-movement potential,* or *betweenness,* of each street segment with respect to all others. The street network's to- and through-movement potentials represent various accessibility potentials. Both types of relational patterns can be weighted by three different definitions of distance. The metric distance measures the city's street and road network as a system of shortest-length paths, while the topological distance calculates the city's street and road network as a system of fewest-turn paths. The geometrical distance gives a picture of the city's street and road network as a system of least angle-change paths. Each type of relation can be calculated at different radii from each street segment by defining the radius in terms of shortest length, fewest turns, or least number of angle changes (Hillier and Iida 2005, pp. 557–558).

Space syntax can be applied at many scales, from the arrangement of furniture in a workplace to enhance collaborative interactions all the way to understanding different centralities in urban regions. The method is also a useful tool for comparing before and after conditions such as the spatial changes resulting from urban restructuring. Because the tool is a method for analysing the physical and spatial setup of buildings and cities, the analysis results must be interpreted in correlation with an understanding of societal processes and human behaviour.

Another field where the method is applicable is in spatial layouts of excavated towns. In cases where walls of buildings and street patterns remain intact, a space syntax analysis of the spatial organisation can contribute to a more comprehensive understanding of urban life and societal organisation in the past (van Nes 2011). In the field of anthropological studies, space syntax can provide spatial understandings of the social organisation in settlements from different cultures, demonstrating how buildings and settlements play a role in social relations (Hillier and Hanson 1984, p. 176ff; Stöger 2007; Aleksandrowitcz et al. 2019).

The application of space syntax allows an insight into complex spatial problems (Yamu, 2014) and can also give an indication of future socio-economic impacts of urban design proposals. In impact assessments of proposed alternatives for urban renewal or new large-scale developments, the space syntax method can contribute by evaluating the effects on locations of economic activity and the degree of vitality of urban centres as a result of new roads and street links (van Nes 2007; van Nes and Stolk 2012).

As research has shown, there is a correlation between pedestrian and vehicular movement and the spatial configuration of the street network (Hillier et al. 1993, 1998, 2012). The space syntax method makes it possible to identify regeneration opportunities, ensuring that new proposals respond to the spatial potentials of existing urban areas. The spatial setup of new design ideas can also be tested using space syntax analysis (Czerkauer-Yamu and Voigt 2011; Karimi 2012; van Nes et al. 2017). Space syntax can also be combined with other spatial modelling techniques such as complexity-based modelling to identify regional and urban development and revitalisation potentials using an iterative logic (Czerkauer-Yamu 2012; Yamu and van Nes 2017). However, one limitation of space syntax is that it cannot measure place identity, place character, or spatial order. These aspects are taken into account in the work of, for example, Kevin Lynch (1960), Christian Norberg-Schulz (1971), Rob Krier (1984), and the various urban morphology groups (Moudon 1997). Space syntax does not analyse spatial patterns, but rather spatial structures. Likewise, space syntax does not analyse building forms, but instead looks at the spatial configuration of the spaces shaped by buildings and other urban artefacts.

Overall, space syntax can support the design and planning of safe and vital cities and neighbourhoods. There exist a remarkably large number of poor-quality neighbourhoods built from the 1950s onwards worldwide. These provide ample opportunities to gather evidence for identifying and understanding the role of spatial properties for creating a safe and vital built environment. Raising awareness of the active role of urban space can be done by applying scientifically grounded spatial analysis tools to assess these poorly functioning neighbourhoods. This will also be beneficial for strengthening research about the built environment's spatial properties.

Nevertheless, 'panta rhei' (everything flows), the famous quote associated with the Greek philosopher Heraclitus, also applies to space syntax because it is under constant development. This constant development emerges at the intersection of natural, technical, and social sciences in contributing to theories on the built environment. Space syntax research has ranged from anthropology and cognitive sciences to applied mathematics and informatics and has even touched upon philosophical issues. The evolution of space syntax requires communication not just between various cultural contexts, but also between different scientific domains.

In the arena of research and the communication of results, international Space Syntax Symposia have been held bi-annually since 1997. The number of contributors from all over the world is increasing at every symposium, indicating that the theoretical and methodological interest in and the purposeful application of space syntax is increasing worldwide. Space syntax has become a well-recognised method of urban analysis and contributes to an understanding of the relationship between socio-economic effects and the planning and design of the built environment.

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This textbook could not have come into this world without our friends, colleagues, and students. We would like to thank our space syntax colleagues around the world and research colleagues at TU Delft, TU Wien, Oslo Metropolitan University, Western Norway University of Applied Sciences, University of Groningen, University College London, and all our graduate and postgraduate students and project partners in practice throughout the years. They challenged us with their critical questions. They inspired us.

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We are also thankful for Jürgen Rosemann, Andrea Peresthu, Alex Vollebrecht, and Diego Sepulveda for their valuable support and for creating opportunities for incorporating space syntax in the TU Delft curricula; Andreas Voigt for incorporating space syntax in TU Wien courses; and Femke Niekerk at the University of Groningen, Arve Leiknes at the Western Norway University of Applied Sciences, and Einar Lilleby, Eli Børrud, Sigmund Asmervik, and August Røsnes of the Norwegian University of Life Sciences. Likewise, special thanks go to Wendy Tan, Alex Wandl, Bardia Mashhoodi, Birgit Hausleitner, and Gerd Weitkamp for inspiring collaborations in teaching and research connecting space syntax to geographic information system (GIS). This has brought about interesting experiments and new research ideas over the years. Gratitude also goes to Manuel López for giving opportunities to connect space syntax to the field of environmental criminology and to Yu Ye with whom the theory of the natural urban transformation process was developed. Hanna Stöger is responsible for introducing space syntax to the arena of archaeology.

Thanks to Chris Penfold who suggested the book's current scope, namely to address mainly graduate and postgraduate students in architecture, urbanism, and related fields dealing with the built environment. Accordingly, we adjusted its structure to implement a pedagogical approach. We are very grateful to Anna Myllymäki who developed with us the aesthetic appearance of the book. Credits are also given to Just de Leeuwe and his staff from the TU Delft library for their valuable support. From the space syntax community, we owe our thanks to space syntax originator Bill Hillier, Julienne Hanson, Alan Penn, Alasdair Turner, Nick Sheep Dalton, Jorge Gil, Tim Stonor, Kayvan Karimi, Anna Rose, Max Martinez, and Ed Parham for their inspiring contributions to this textbook through discussions, lectures, software demonstrations, and their scientific and practical endeavours in the space syntax arena over the years. It is important also to mention Georg Frank-Oberaspach, who still had one of the remaining original copies of Bill Hillier's book *Space is the Machine*, and Nikos Salingaros, who always encouraged and supported research at the fringe of other fields and who provided innovative ideas. Mike Batty has inspired with his sharp mind in discussions and through his books. Many more have contributed to whom we owe our gratitude. We take the freedom to name these people in a separate list of credits.

During the core writing process of this book, we have been literally living at the university, being away from home most of the time, or leaving living rooms with scattered manuscript pages and notes left behind after long working nights. While immersing in our writings, our dear ones have been supportive in our endeavour and dealt with our idiosyncrasies with tolerance and patience. They reminded us that there is a beautiful world outside all the manuscript pages. This textbook is dedicated to them.

Delft, The Netherlands — Akkelies van Nes
Groningen, The Netherlands — Claudia Yamu

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…and Snorre—the cat

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Endorsement

"Space syntax first emerged over 40 years ago but this is the first book that provides a gentle introduction to the set of geometrical techniques that enable us to describe spaces and movement patterns in cities in ways that show us their relative importance in generating good design. Akkelies van Nes and Claudia Yamu have done a magnificent job in grounding the theory in the wider field of urban studies, making it accessible to a broad audience. A key work in the urban designer's tool kit of methods."

—Professor Michael Batty, *CASA, University College London*

"This book is an excellent, hands–on introduction to space syntax, the architectural and environmental theory that demonstrates how the spatial configuration of pathways–whether streets, sidewalks, building corridors, or other fabricated spaces–plays a pivotal role in whether users come together physically or remain apart. Moving chapter by chapter from urban to building and interior scale, this book is trailblazing because it introduces newcomers to the space-syntax theory in step-by-step fashion that includes practical exercises and problems at the end of each chapter. The book includes a plethora of well-chosen photographs and well-conceived and well-drawn figures convincingly demonstrating the authors' verbal claims. The book is a milestone in the space-syntax literature and should work to introduce a much larger academic and professional audience to the remarkable conceptual and practical value of space syntax. The book will be particularly appealing to architects, planners, urban designers, landscape architects, and other practitioners and professionals who often are more comfortable with visual, graphic-grounded explications rather than word-based, theoretical explanations."

—Professor David Seamon, author of Life Takes Place: Phenomenology, Lifeworlds, and Place Making (2018) and Professor of Environment-Behavior and Place Studies, *Department of Architecture, Kansas State University, Manhattan, Kansas, USA*

"This book manages to assemble tips and guidance that until now were conveyed through word of mouth and teaching in one reference volume. In addition, the accessible presentation of the theoretical base and the guided exercises in this book will ensure that this book is set to become one of the 'go to' sources for space syntax for years to come."

—Professor Ruth Conroy Dalton, *Lancaster University*

"Different from many analytical and graphic tools such as GIS and CAD (geographic information systems and computer aided design), Space Syntax provides a living structure view of space, thus it is beyond nonliving structure view of GIS and CAD that focuses on geometric details such as points, lines, polygons, and pixels. The living structure, as demonstrated by numerous examples in this book, enables us to better understand many human activities in cities such as pedestrian movement and urban traffic, which are mainly shaped by the underlying living structure. In this connection, Space Syntax provides a powerful and unique tool for urban modeling and prediction. The two authors did an excellent job in introducing the subject to a wide audience, so I highly recommend this book. My congratulations to the authors for the newborn baby! My advice to the readers of the book is that bear it in mind the living structure view while going through the book."

—Professor Bin Jiang, *University of Gävle*

"Introduction to Space Syntax is definitely a much-needed contribution to the textbook market in architecture, urban design, and related subjects on the built environment. The book puts together both the theoretical background as well as the methodological approach of Space Syntax: including observation methods and the use of specific software. This is the first time that a comprehensive approach on Space Syntax has been attempted. The two founding books for this subject are "The Social Logic of Space" by Bill Hillier and Julienne Hanson, where most of the theoretical background can be found, and "Space is the Machine" by Bill Hillier, where a collection of ground breaking syntactic ideas are put forward, many through case studies. Nevertheless, none of the two books offer explicit instructions as how and when to apply one or another measurement or observation technique. Here you will find it!"

—Professor Margarita Greene, *School of Architecture, CEDEUS, Universidad Católica de Chile*

"This book as an elementary introduction to space syntax is especially geared towards novices of the techniques and methodologies used in spatial analysis of urban spaces. It provides an excellent framework for understanding and comprehending space syntax by creating a consistent and understandable space syntax language for easy communication with practitioners and space syntax novices from urban planning, urban design and other related disciplines. Simple visual and diagrammatic language is created for successful communication of space syntax results with practitioners who need to understand these results.

The book of Akkelies van Nes and Claudia Yamu, where they offer a new interpretation of Space Syntax methodology is also invaluable for teaching space syntax. They provide exercises, references and further readings at the end of each chapter for students to comprehend Space Syntax. In their writing, the quantitative concept and formulae structure including measures and modelling techniques has gained a simple expression. Especially the mathematical formulae structure of space syntax that might create confusion for beginners is simplified in this book. In other words, the authors' clear explanation of measures and modelling techniques has provided a simple expression for the hesitated researchers/designers on the confusing quantitative and formulated explanations that take place in most of the space syntax publications.

The book provides a foundational knowledge on which interested researchers as well as practitioners can built upon to become the most experienced space syntax researchers. The book is also a great resource for university professors who teach space syntax both at undergraduate and graduate levels."

—Professor Ayse Sema Kubat, *Istanbul Technical University*

Contents

1 Established Urban Research Traditions and the Platform for Space Syntax

Contents

Abstract

This chapter provides an overview of established research traditions in the analysis of physical elements of the built environment. Herein, we address the morphological, place phenomenological, and urban network traditions. Following this, a synopsis about spatial elements applied to these traditions, including space syntax, is given. Furthermore, in this chapter, we explain the differences between extrinsic and intrinsic properties of space and clarify the typology concepts of the built form. Finally, we introduce the basic spatial elements used in space syntax and the simplest spatial structures that cities can have. Exercises are provided at the end of this chapter.

Keywords

Built environment • Human activities • Spatial elements • Extrinsic and intrinsic properties of space

Key Concepts

Urban morphology analyses • Place phenomenology analyses • Urban network analyses

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Learning Objectives:

After studying this chapter, you will

- have an understanding of the relationship between urban space and human activities and their mutual influence, the socio-spatial relationship;
- have knowledge about the three research traditions with regards to the physical aspects of built environments, namely urban morphological tradition, place phenomenological tradition, and urban network tradition;
- be able to conduct simple analyses based on the Spacematrix, mixed-use index (MXI), street functions, street profiles, and Kevin Lynch's image of the city methods;
- be able to reflect on the differences between extrinsic and intrinsic properties connected to space syntax.

1.1 Space and Human Activities

Every city and neighbourhood is unique and differs from all others. There are no two cities or neighbourhoods that are alike. Despite their diversity, they also share similarities. Some cities have similar building types and architectural styles, while others embrace similar street patterns, types of transportation hubs, or types of bridges. But how can we compare cities and their neighbourhoods with each other? What kind of spatial tools do we have for comparing cities?

Human societies are spatial phenomena—they occupy regions of the Earth's surface, and within and between these regions material resources move, people encounter each other, and information is transmitted (Hillier and Hanson 1984, p. 26). Human activities influence the shapes of cities, their urban patterns, the order of their physical elements, and their meanings. Politically accepted plans, building regulations, and the way human beings spatially conduct their social and economic activities have an impact on how urban areas are built. Thus, cultures shape cities over time.

Vice versa, the urban form influences human activities. For example, with regard to active land use and location choice, shop owners will always try to optimise the location of their shops to reach the greatest number of customers. If an optimal location is affected by a significant change of the urban area, they will relocate their businesses (van Nes 2002, p. 300). Another example is that of an urban area where pedestrians feel unsafe due to high criminality. In many post-war urban areas, crime and vandalism started to become a problem just a few years after such areas were built (van Wegen and van der Voort 1991). These were unpredicted effects because the original planning intervention was to create quiet and harmonious dwelling areas. Incidents like these naturally are a combination of an urban area's spatial structure and the social composition of its inhabitants (Shu 2000). All these examples show that there is a strong relationship between the built environment's spatial arrangement and human activities.

The spatial arrangement of the built environment has its own laws (Hillier 1996). Therefore, tools are needed to reveal the underlying logic of the relationship between the physical objects of the built environment. Comprehending how physical objects are placed and related to each other in cities can contribute to the understanding of integrated, segregated, connected, or disconnected spaces and urban areas in cities. Learning about the 'hidden laws' and how the socio-spatial relationships can be calculated provides us with knowledge on how the built form functions as a framework for creating contact or avoidance for its users. Often, inherent rules for how spaces are organised are taken for granted in the way humans organise their lives. Thus, there is little awareness of these underlying logics.

Analysing and comparing different cities and their urban areas with one another require the analysis of spatial parameters separately from social parameters. In a subsequent step, the numerical results from the spatial analysis can be correlated with socio-economic data. Indeed, spatial analysis and modelling always deal with the abstraction and thus the simplification of reality. However, this two-step procedure of first conducting a spatial analysis and second correlating the results with socio-economic data provides an understanding of how human activities shape cities and how the shape of cities influences human activities.

In order to explain how spatial relationships affect social relationships, we use the spatial setup of a dwelling as an example. Figure 1.1 depicts the plan of a Norwegian bungalow from the 1970s for a family of two adults and two children. The parents' bedroom is adjacent to the kitchen, and the children's bedrooms are adjacent to the TV room.

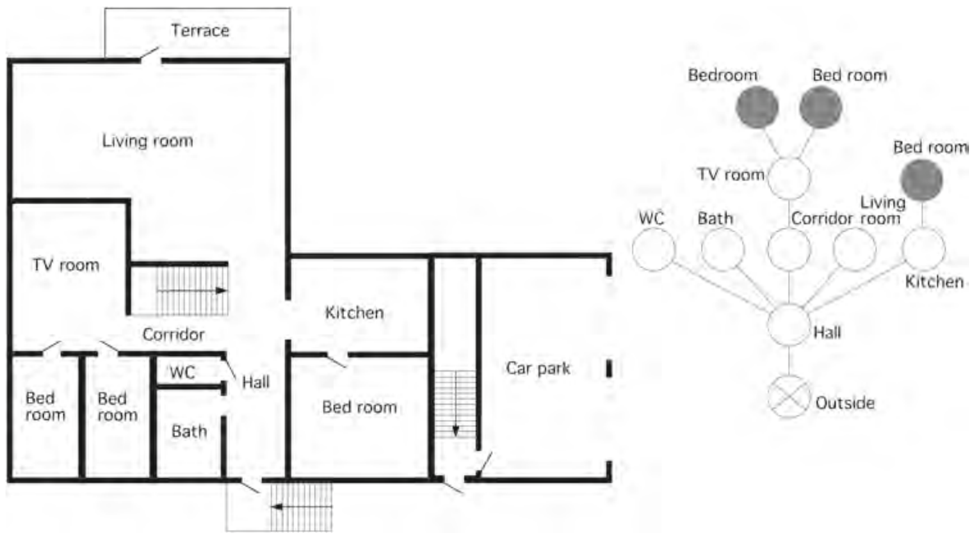


Fig. 1.1 Floor plan of a Norwegian bungalow (left) and a justified graph (right) representing the spatial relationships

A justified graph (Fig. 1.1, right) illustrates the spatial relationships or connections between the bungalow's various rooms. Each room is represented by a circle (= node) while connections, herein doors, between the rooms are represented by lines (= edges). The graph shows how the bungalow is experienced starting from the main entrance, represented as a circle with a cross through it (= root node). Every time a new room is entered, or there is a direction change within a room, a so-called *topological step* is taken. Because we only depict the spatial relationships, the geometries and sizes of the rooms are not of interest. In order to generate a justified graph, only the spatial configurational relationship is taken into consideration when studying spatial patterns or the spatial configuration.

The justified graph is used in graph theory, which is the study of mathematic structures between objects. The objects, which are rooms or spaces in our case, are represented as nodes. The connections between these nodes are represented as edges. The justified graph in Fig. 1.1 displays in a uniform, but abstract, way the spatial configuration of a bungalow. This architectural example allows us to explain in a simple way the relationship between space and human activities. In Chap. 2. we will show how this graph can be used to calculate the relations between spatial elements for cities.

One of the findings of the justified graph for the Norwegian bungalow is that all bedrooms are topologically farthest away from the main entrance. Thus, they are located 'topologically deep'. Moreover, these bedrooms are 'dead-end' spaces meaning that they cannot be passed through to enter other rooms. These kinds of spaces can be meaningful where privacy is highly appreciated. Another example of a dead-end space is the bathroom. Also, here privacy is the main characteristic.

To build a narrative of spatial change, the bungalow was later sold to a young family with one toddler and was refurbished. Two walls were torn down, one to merge the bath and a bedroom, and another to merge the kitchen and the bedroom. This was to have a large kitchen and bathroom. The former terrace was converted to a winter garden serving as an extension to the bungalow. The narrative behind these changes are, for example, activities related to more space for a whirlpool in the bathroom and only one additional bedroom is necessary because the new owners have only one child. However, the direct access from the master bedroom to the child's bedroom might compromise the privacy of the parents at a later stage when the child is an adolescent.

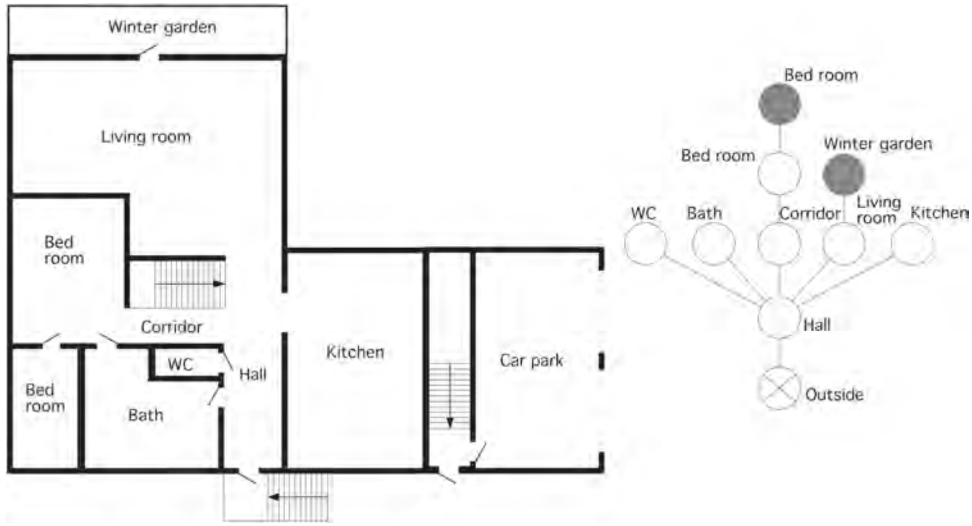


Fig. 1.2 Floor plan of the refurbished bungalow (left) with a corresponding justified graph (right)

As shown in Fig. 1.2, the removal of only two walls and adding the former porch as a winter garden to the spatial arrangement have a significant impact on the bungalow's spatial configuration. From the former three bedrooms (Fig. 1.1), now two bedrooms, only one bedroom remains a dead-end space. In Fig. 1.1, all three bedrooms were dead-end spaces. From this architectural example, we can derive a clear relationship between how people organise their lives and shape spaces for their activities and needs. Vice versa, these spatial setups shape the possibilities and limitations of human activities.

In general, the relationship between space and society is conditioned by degrees of accessibility, visibility, permeability, adjacency, openness, and enclosure in the built environment. Therefore, operational theories and corresponding methods for analysing spatial relationships contribute to planning and designing cities from an architectural scale to a citywide scale suitable for its users. The question arises on how we can understand spatial patterns linked to human activities for entire cities. A city is definitely more complex compared to a single bungalow. Therefore, it is challenging to develop a comprehensive understanding with an underlying theory about how cities function spatially and socially. For comparing cities and for evaluating 'before and after conditions' of urban interventions, we need to have operational scientific methods for analysing urban forms.

For an analytical comparison of cities, we encounter two main approaches in the elementary theory of science, the *normative* and *descriptive* approaches. For a normative approach, the city is understood through the lens of a universal subject and established standards. This rational or blueprint planning approach offers descriptions on how successful cities should be planned and designed, but lacks evidence for how cities will function according to implemented norms and standards. In contrast, a descriptive approach focuses on how the city functions. Normative statements about how cities and selected urban areas should be planned and designed rely on a careful descriptive understanding and explanation of how they currently function (van Nes 2017; van Nes and Yamu 2020). In the arena of functional or descriptive theories of city form, examples are the books from Jeremy Whitehand (1981), Pierre G. Gerosa (1992), Kevin Lynch (1960), Alexander R. Cuthbert (2007), Michael Batty and Peter Longley (1994), Michael Batty (2007, 2013, 2018), Christopher Alexander et al. (1977), Michael R. G. Conzen (1960, 2004), Michael P. Conzen (2018), Gianfranco Caniggia and Gian Luigi Maffei (2001), Guiseppe Strappa (2014), Giancarlo Cataldi (2018), Vitor Oliveira (2018, 2019), Philippe Panerai, Jean Castex, Charles DePaule, and Ivor Samuels (2004), Bill Hillier and Julienne Hanson (1984), and Bill Hillier (1996).

Applied methods for comparing cities and studying their morphologies must have a high level of testability, objectivity, falsifiability, explanatory power, precision, systemic structure, empirical support, applicability, and generality (Troye 1994, p. 30). They must be applicable to different morphological typologies independent of their economies, cultures, and societies. This allows us to predict the socio-economic effects of urban interventions and to understand the space–society relationships of cities. Falsifiability and testability also relate to the work of Karl Popper in his book *Conjectures and*

Refutations: The Growth of Scientific Knowledge from 1963. Robust theories and methods are context independent and are applicable to all spatial systems at all scales independent of types of societies, political structures, or cultures—from hamlets, villages, and towns to cities and regions. Thus, they have a high degree of generalisability. This also applies to space syntax theory and methods. Its high level of falsifiability and testability lies in the fact that the method has been developed through years of trial and error, and the methods have been tested and applied in built environments worldwide (Yamu et al. 2021).

Space syntax as a static street network model indicating spatial dynamics is simple, but robust, allowing for quick syntactical analysis of a wide range of cases (Yamu 2014). Its robustness allowed space syntax to survive many criticisms (Ratti 2004; Cuthbert 2012). Space syntax has been undergoing constant development through methodological improvements, increased computational power, and its growing application in various fields.

1.2 Established Traditions for the Physical Form of Cities

There are currently three established traditions for the physical form of cities: urban morphology, place phenomenology, and the urban network approaches. Each tradition addresses different spatial components of the built environment allowing all approaches to be complementary to each other to support a comprehensive understanding about cities. The aim in this section is to give a brief overview of how space syntax relates to other established research methods on built environments.

1.2.1 Urban Morphology Tradition

Urban morphology assumes that the city can be understood and analysed by its physical form. Three main schools in urban morphology tradition emerged over several generations of scholars, namely the school of Muratori in Italy (Caniggia and Maffei 2001; Cataldi et al. 2002), the school of Conzen from the United Kingdom (Whitehand 1981; Conzen 2004), and the school of Versailles in France (Gerosa 1992; Panerai et al. 2004).

The first beginnings of urban morphology as a research tradition date back to the 1840s in Germany. In 1841, German geographer J. G. Kohl published morphological maps and a buildings height diagram of Moscow. By the 1920 and 1930s, an urban morphology group was established in Germany. Inspired by the work of the late Otto Schlüter, M. R. G. Conzen drew several morphological maps of Berlin as a student between 1926 and 1933. During the Nazi regime, Conzen fled from Germany to England where he continued his research (Whitehand 1981; Conzen 2004). Together with Jeremy Whitehand, the Anglo-German school of urban morphology wes established at Birmingham University. It was Conzen who made the historical–geographical foundation for analysing urban form with Whitehand as a key contributor for the definition of urban morphology as a discipline with concepts, methods, and understandings on urban transformations (Oliveira 2019, p. 27). Well-known scholars, such as Michael P. Conzen, and Anne Vernez-Moudon, are intellectual offspring from this school (Oliveira 2019).

M. R. G Conzens 'philosophy' consists of classifying the intrinsic properties of space. It made distinct classes or grouping of spatial or physical artefacts based on how they immediately appear to us. He writes that:

> The division of reality into phenomenal classes for the purpose of separate investigation may proceed by grouping phenomena according to their apparent differentiating or dominant characteristics which may be those of inherent particularity of 'objective' nature, of spatial arrangement, or of temporal arrangement. Thus investigating becomes particularized or phenomenally orientated. Selected phenomena or phenomenal classes becomes the focus of attention, being the central object of investigation by which separate fields of knowledge are identified (Conzen 2004, p. 15).

The elements of the German-Anglo urban morphological approach are as follows: (a) time, (b) economic factors, (c) the provenance of agents, (d) governmental control of development, (e) conflicts between the forces of preservation and changes, (f) town plans on paper that are both realised and not realised, (g) frenetic building activities, (h) infill and piecemeal redevelopment, and (i) the influence of the decision-making process (Oliveira 2019, p. 2). All these societal forces have to be taken into consideration for understanding the transformation of the physical elements of the urban landscape, consisting of streets, street blocks, spaces, plots, buildings, and building elements (Oliveira 2019, p. 81).

The Italian school of urban morphology emerged in the 1950s with Saverio Muratori's studies on building typology and urban texture for Venice and Rome. Through these studies, Muratori developed an understanding of urban architecture based on the historical idealism of Benedetto Croce (Cataldi 1991). Building on Muratori's work, Caniggia and Maffei (2001, p. 25) compared different anthropic structures of building typologies. They claimed that the heritage of civil continuity substantially belongs to the typological processes, which remains hidden from the intentional components that the architect superposes on his work (Caniggia and Maffei 2001, p. 41). Caniggia and Maffei's works consistently compared contemporary and past buildings products, focusing on what exists and what appears in a built environment. They studied historical analyses of the building typologies, how society has influenced the building type, and the intentions of the buildings' designers/architects. While the German-Anglo school focused more on the intricacies of the town plan itself, the Italian school focused on the evolution of building types and their settings within the ground plan (Conzen 2018, p. 127). Hence, the Italian school is often named "the school of urban typo-morphology" (Caniggia and Maffei 2001, p. 32).

The elements of the Italian school of urban morphology consist in (a) analysing built objects, (b) analysing the interpretation by the designer of the object who observes the built landscape, the problems it poses and the transformative potential that it presents, and (c) the possible congruent transformation forecast in the built reality (synthesis). The forecast considers all the components that contribute to the urban transformation, including the contributions of disciplines different from architecture (Strappa 2018, p.159). The architecture of the built objects are seen as a process, which requires the reading of urban form as a continuous transformation process through time. Therefore, their analytical approach consists in registrations or observations of man-made objects from different time periods. Caniggia and Maffei also investigated how buildings are influenced by the routing system (the street system). New buildings, also coined infill buildings, that are constructed in areas with an existing plot and street pattern tend to adjust themselves to existing urban morphological structures (Caniggia and Maffei 2001, p. 135).

Aldo Rossi, inspired by Muratori's work, showed that the different physical elements of the city are driven by political, economic, and social forces (Moudon 1997, p. 5). As Rossi claims, explanatory interpretations of urban form based solely on political, social, and economic aspects are insufficient. Rossi had a particular interest in the residential areas, because these areas consist of small internal components, such as urban blocks with many single small plots. These small internal components are generators of a specific urban form and are capable of accelerating the urbanisation processes. These areas undergo continuous transformation processes, where some artefacts (named primary elements) constitute the future form of cities. Rossi rejected the historical dimension. However, he was aware of the role of technical, social, and economic changes affecting the transformation of cities (Marzot 2002, p. 67). The Norwegian architects Karl Otto Ellefsen and Dag Tvilde applied Rossi's principles for analysing a city's historical development based on Rossi's contribution (Ellefsen and Tvilde 1990).

The French school of urban morphology emerged in the 1960s in Versailles. The main focus of the research of Philippe Panerai, Jean Castex, and Charles DePaule is the historic descriptions of the morphology of urban blocks. The role of the social, technical, and economic setting and the influences and design intention of the architects at that time are seen in relation to the design problem that has to be solved. All these aspects influence the shape of the blocks. Panerai, Castex, and DePaule's work represents a historical development on how the placements of buildings contribute to changes of closed building blocks towards freestanding buildings dissolving urban blocks. As Panerai, Castex, and DePaule claim, studying the urban block enables understanding the interplay of differences and continuities. The urban block represents the transition from the dwelling to other spaces that are both adjacent to it and a part of the larger urban spatial system (Panerai et al. 2004, p. 124). The main message is that blocks consisting of different sets of elements (buildings) are more robust when these buildings change without affecting the overall plot arrangement, whereas a large freestanding building on a plot is incapable of adapting to changed circumstances (Panerai et al. 2004, p. 200).

While the school of Conzen takes a historical–geographical approach focusing on the city, the fringe belts, and the surrounding region, the schools of Muratori and Versailles focus more on the urban block, various building typologies, and the influence and intentions of the architects when shaping the vernacular buildings at that time. The Italian morphological tradition has acknowledged a close link between tradition and innovation (Marzot 2002, p. 61), whereas the German-Anglo morphological research tradition takes whole regions into account. As M. R. G Conzen claims, urban geography is a part of regional geography. As he writes, “Human society can control and change the geographical substance within that complex only within limits, and must respect and preserve its systematic balance as a whole as well as in its parts, or else will upset it as its peril” (Conzen 2004, p. 36).

All tools and morphological analyses from urban morphology researchers are based on the following three principles (Moudon 1997, p. 5):

(a) The buildings and their related open spaces such as plots, lots, and streets form the fundamental physical elements/artefacts that define urban form.
(b) Urban form can be understood at different levels of resolution, namely the building and its lot, the street and the block, the neighbourhood and the quarter, and the city and the region.
(c) Due to continuous transformation and replacement, urban form can only be understood historically (post-diction).

The principles that most urban morphology scholars are using are defined as follows. The city is a ‘manufact’, which is the sum of all its built-up elements, where each element is defined as an ‘artefact’. Some of these artefacts constitute the future development or transformation of a built environment. An artefact of this kind is a ‘primary element’. Examples of primary elements are railway stations, amphitheatres, events such as a fire, or a city plan. As cities continuously transform, sometimes the artefact itself is no longer visible, but its manifestation might remain inherently visible in land subdivision patterns, street patterns, or building patterns. Urban transformation is influenced by technical, political, and societal changes. Some urban areas transform faster than others, while other areas remain stable over a long period of time due to their artefacts’ collective memory for their inhabitants.

The study of urban morphology has contributed to the classification of artefacts, in particular to building volumes, shape of urban blocks, street patterns, and land subdivision patterns. Herein, the Krier brothers with Robert Krier in the lead introduced a classification that distinguishes between internal and external spaces. “Internal space is the sum of all indoor spaces and a symbol of privacy. External space is conceived as space for unobstructed movement in the open air. It includes public, semi-public, and private zones” (Krier 1984, p. 15). Following from this, R. Krier distinguishes between subjective and objective factors. For him, the judgement of taste is purely subjective. With regard to objectivity, he established a spatial typology and a morphological classification of the urban space shaped by buildings. Krier defines the street and the urban square as the two basic external elements of urban space, and he believes that the urban square is primarily to “let man discover his usage of urban space.” Houses grouped around an open area create the urban square. In contrast, streets result from the spreading of a settlement. “They come into being once houses are built on all available space around the square they form” (Krier 1984, p. 17).

Krier’s urban space typology recognises three main groups in line with their geometrical patterns identified in urban figure ground maps, namely triangles, circles, and squares. By including how building heights and building sections affect urban space, he completes his morpho-typological approach. Furthermore, with examples from historical places connected to identified geometrical patterns, he connects his approach to historical heritage. Krier tried to develop a method for studying urban order in a systematic way through urban form. However, his work cannot be regarded as a comprehensive urban theory because it does not allow for a comprehensive investigation of a city in its entirety. His descriptive approach confines itself to the registrations of geometrical shapes of urban spaces and to grouping them under various labels on a local scale. Different from the three established schools of urban morphology, Krier classified urban spaces according to geometrical shapes instead of the buildings, the blocks, and the lots.

Most urban morphology analyses took a qualitative approach until the 1980s. A recent contribution to the urban morphology tradition is Johan Rådberg’s suggestion on how to quantify building density and building form at the same time using a single method. In a project for identifying areas for densification in the Swedish town of Västerås, Rådberg developed in his PhD research in 1986 a new method with the purpose of developing strategies for densification on the municipality level. Rådberg developed a matrix where he correlated the floor space index with the ground space index. This matrix allowed for the classification of various types of building morphologies and how each type influenced the available open spaces (Rådberg 1996). Other measurements such as the open space ratio and layers (numbers of floors) can also be measured in the same matrix. The open space ratio shows how much of the plot is used, and the layers depict how many floors a building has on average for a lot. Rådberg's multivariable density method was applied in the Dutch context by Meta Berghauser Pont and Per Haupt, and they first coined Rådberg's method as 'Spacemate' (2004) and later as 'Spacematrix' (2010).

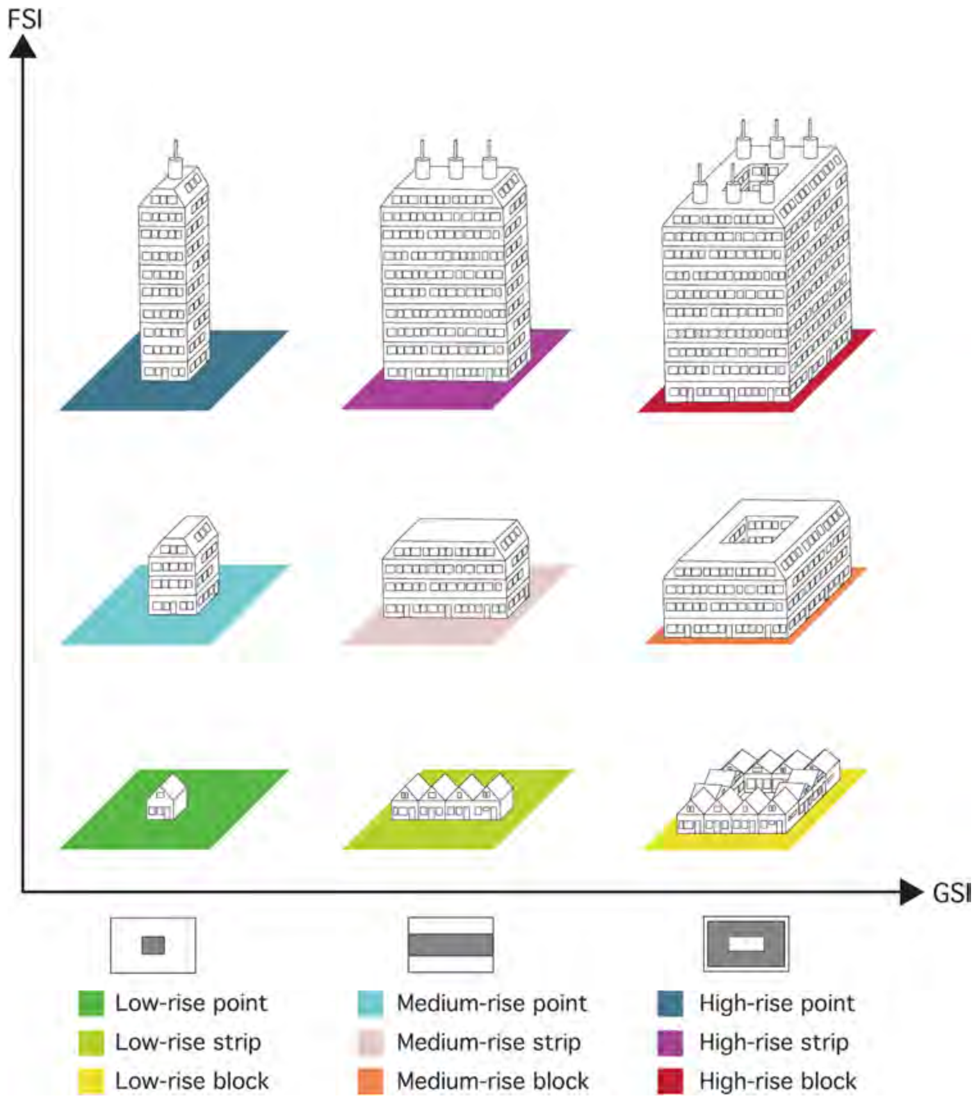


Fig. 1.3 A simplified illustration of Spacematrix showing the floor space index (FSI) and ground space index (GSI)

In the Spacematrix diagram in Fig. 1.3, the category of building density is classified into low-rise, mid-rise, and high-rise buildings depending on the number of floors. The category of building types is classified into point-type, strip-type, and block-type depending on the building's footprint. Thus the built environment can be classified into nine types: low-rise point, low-rise block, low-rise strip, mid-rise point, mid-rise block, mid-rise strip, high-rise point, high-rise strip, and high-rise block (Fig. 1.3).

For the category low-rise, the buildings have one to three floors, and for mid-rise they have three to five floors. The high-rise buildings have more than five floors and tend to have a lift. Figure 1.4 illustrates how building volumes in relation to their plot are placed in the Spacematrix scheme.

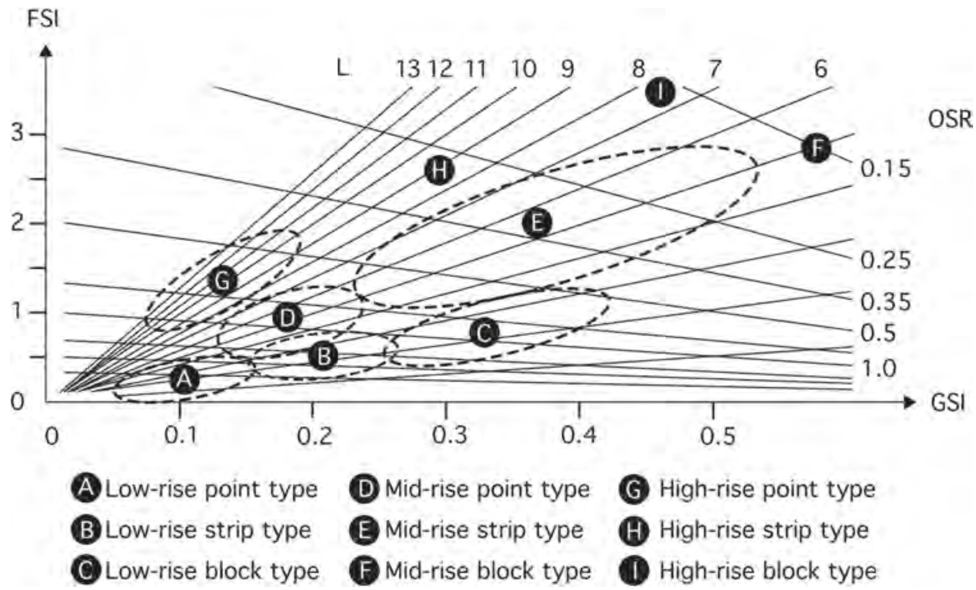


Fig. 1.4 A Spacematrix diagram applied to Dutch and Chinese cities (Ye and van Nes 2014)

Most of the depicted building types in Fig. 1.4 can be found in many towns and cities. The building types vary from place to place. For example, high-rise block types are seldom found in Scandinavian towns, whereas low-rise point types are seldom found in places with land scarcity such as Tokyo, Hong Kong, and Singapore.

The use of the Geographic Information System (GIS) and current data availability with information about plot sizes, buildings, and their numbers of floors allows a quick and easy aggregation of data. For getting a fast overview, examples can be manually classified using the information from Fig. 1.4. Following this, we applied the classification of Spacematrix to the figure ground map of the town centre of Bergen in Norway (Fig. 1.5).

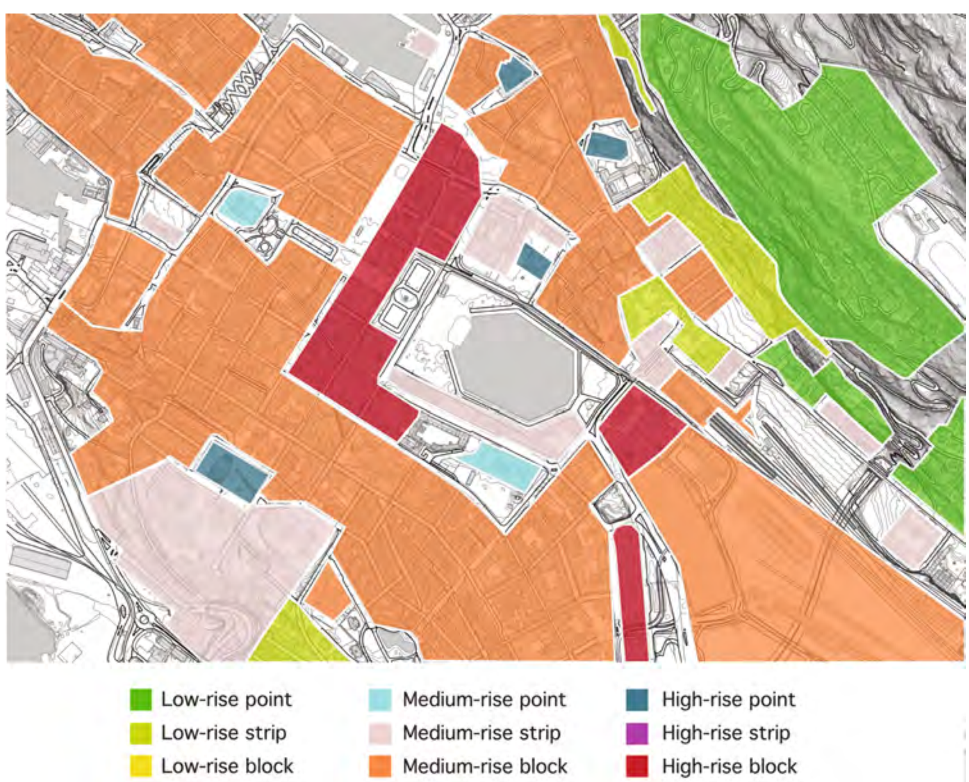


Fig. 1.5 Application of Spacematrix to the town centre of Bergen in Norway

Yet another recent quantitative approach in the urban morphology tradition is Joost van der Hoek's (2010) triangle matrix, the so-called 'Mixed-Use Index' or MXI, that is used to distinguish degrees of mono-functionality versus multi-functionality of urban blocks. Urban areas with only one function, such as dwellings, working places (industrial areas or office parks), and amenities (leisure activities like sports, shopping, etc.) are defined to be mono-functional. Urban areas are bi-functional when two of these three functions are present, and they are multi-functional when all three functions are present (van der Hoek 2010). The original MXI model measured the percentage of housing, working space, and amenities occupying urban blocks. The function 'housing' included various residential dwellings such as apartments, condominiums, and townhouses. The function 'working' encompassed offices, factories, and laboratories. The function 'amenities' covered commercial facilities such as shopping centres, schools, and universities in addition to leisure facilities such as sporting arenas, cinemas, concert halls, and museums. Thus, MXI is defined as depicting an urban block's percentage of housing, working, and amenities simultaneously.

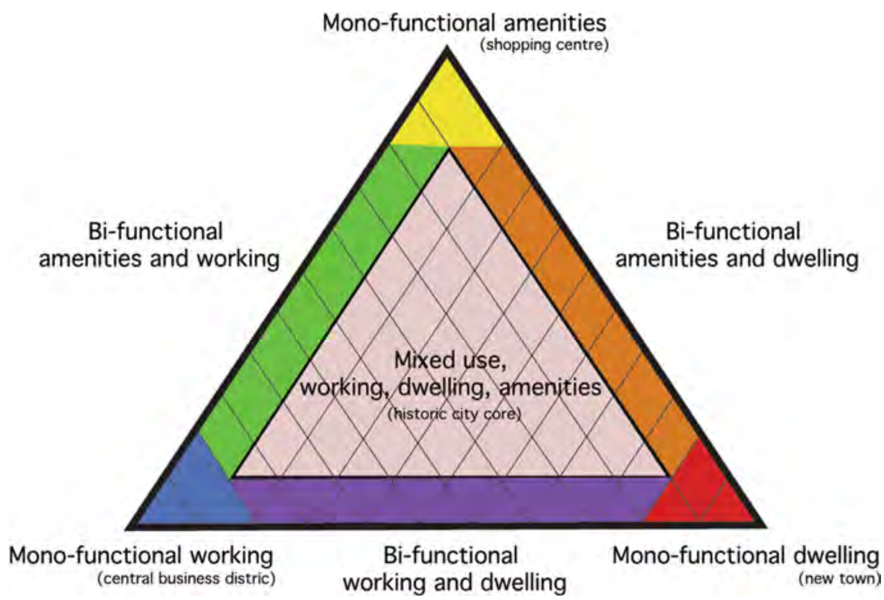


Fig. 1.6 Van Hoek's MXI triangle matrix

MXI can be applied to large urban areas thus allowing for meaningful results (de Koning and van Nes 2019; Ye and van Nes 2013, 2014; van Nes et al. 2012). The misfit of this triangle matrix is that the margin of the function leisure under the category 'amenities' can also fall under the category 'working places'. Moreover, shops and cafés can be both working places and leisure places. Despite such shortcomings, the MXI method is useful for describing urban areas' degree of mono-functionality versus multi-functionality.

Figure 1.6 shows an MXI diagram where the mono-functional areas are located at the edge of the triangle and multi-functional areas such as historic city centres are located in the triangle's centre. Historic city centres tend to have a balanced land use with a mixture of dwellings, working places, and amenities. Again, we apply this method to the figure ground map of Bergen's town centre in Fig. 1.7. Here, only four categories of functions are used, namely mono-functional dwelling, mono-functional working, mono-functional amenities, and mixed use. The mixed-use areas contain more than one function. Juxtaposing the MXI map with Spacematrix, we can see that urban areas with high floor space index and high ground space index also have a high degree of multi-functionality. In conclusion, the degree of land use diversity is related to building density.

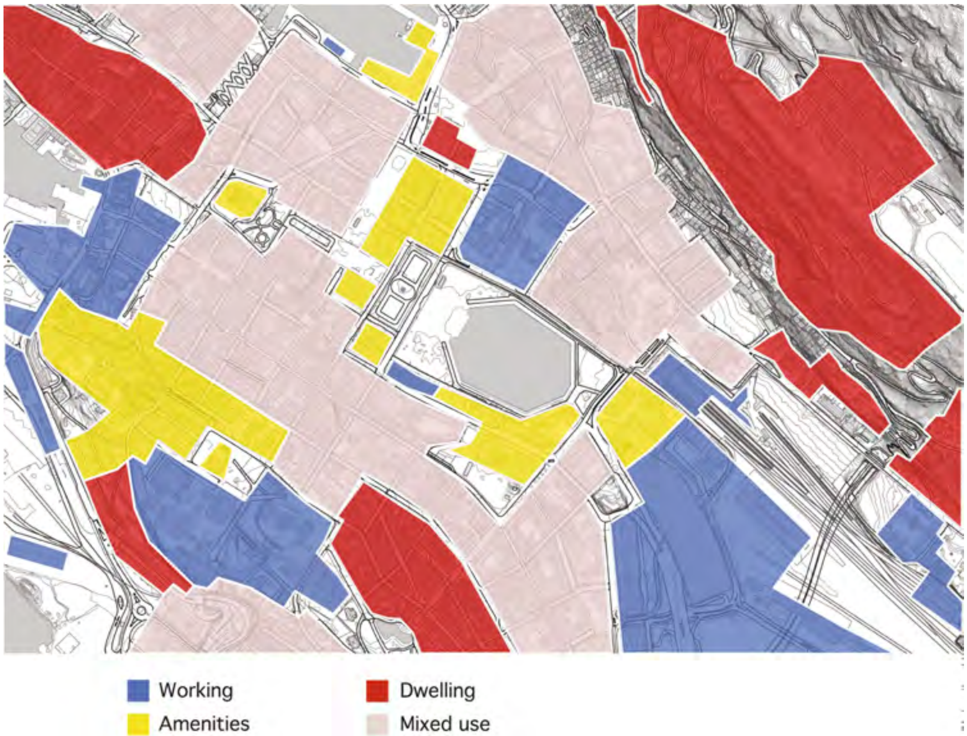


Fig. 1.7 Application of MXI to Bergen's centre in Norway

Through the use of GIS, space syntax research can be merged with the quantitative parts of urban morphology research. These correlations have contributed to broadening our understandings of how cities work and how various spatial and physical elements are interrelated with one another. In Chap. 6, we will elaborate on how these correlations have contributed to new theories on how cities function.

1.2.2 Place Phenomenological Tradition

The place phenomenology approach describes the sphere of a place based on Martin Heidegger's work *Bauen Wohnen Denken* [Building Dwelling Thinking] from 1951. The phenomenological movement was a counter-reaction to the positivistic approach in natural sciences. While positivism explains reality with mathematics and focuses on objects, phenomenology describes impressions of reality as it immediately appears to us. To illustrate both approaches, Fig. 1.8 depicts how water can be represented and experienced. The image to the left shows its chemical formula, and the images in the middle and to the right show some scenic impressions of a waterfall and a glacier.

Fig. 1.8 A positivistic (left) and phenomenological (middle and right) approach for water

Christian Norberg-Schulz (1980) builds upon Heidegger's work for the arena of architecture. For him, Heidegger's concept of existential 'space ' includes aspects of 'place' and 'character' complying with basic psychological functions such as 'identification' and 'orientation'. Heidegger proposes existential space not to be a mathematical term, but takes it to stand for a basic relationship between man and his environment. For defining existential space in architecture, Norberg-Schulz suggests, "[…] man dwells when he can orientate himself within and identify himself with an environment, or, in short, when he experiences the environment as meaningful" (Norberg-Schulz 1980, p. 5). This existential space does not differentiate between space and place. However, Norberg-Schulz's understanding of 'Wohnen' [dwelling] is that lived spaces create places. Hence, a place is defined as a space with a distinctively social character.

An integral description in line with the thoughts of Norberg-Schulz can be applied to describe a place's character. His method does not draw upon quantifiable categories to analyse a place and its hidden laws. Instead, it is about the interpretation of a place as follows:

(1) Understanding a place's *genius loci:* This is about understanding a place's distinctive atmosphere, or the 'spirit of a place'. How places are experienced or perceived depends on the identification and description of their architectural psychological conditions. Herein, Le Corbusier summarises in his work *Vers une architecture,* "[…] Architecture is a thing of art, a phenomenon of the emotions, lying outside questions of constructions and beyond them. […] Architectural emotion exists when the work rings within us in tune with a universe whose laws we obey, recognise and respect. When certain harmonies have been attained, the work captures us. Architecture is a matter of 'harmonies', it is a 'pure creation of the spirit'" (Corbusier 1971 p. 23).

(2) Identification of a place's spatial order: In this respect, Norberg-Schulz's analyses consist of the identification of the spatial features of an urban environment. It is meant to find out, for example, where streets are leading to or what features a settlement's buildings appear to have. Unfortunately, Norberg-Schulz does not propose or justify any conceptual tools appropriate for this purpose. His reference to Lynch's urban-image concepts illustrates that in this second respect, his architectural existentialism aims at a perceptual interpretation of urban orders.

(3) Definition of a place's character: Norberg-Schulz defines a place's character through (a) the definition of the shapes of the built elements such as building shapes, openings shapes (doors and windows), and ornaments, (b) buildings in relationship to the surrounding landscape, (c) building forms, and (d) the organisation of the interiors and the spaces between them. Inspired by Lynch (1960), for Norberg-Schulz urban space is divided into three types—the street, the square, and the neighbourhood. The square is the centre of the surrounding settlement. It is a place within the place. While the street is a place we move though, the square represents a kind of destination we have reached. The street is not an aim in itself. It connects one place with another. A neighbourhood is defined as a place where the buildings are located close to one another. It is a place where people live together.

Some of Norberg-Schulz's PhD students developed analytic methods based on his theories. The most well-known approaches are those of Thomas Thiis-Evensen (1987, 1992) and Anne Marie Vagstein (1999). Thiis-Evensen set up a classification of building openings, building shape types, and street types. This was in contrast to Vagstein, who developed a manual for qualitative place analysis. However, the operationalisation of their approaches has not been successful in practice. The reason is that Vagstein's method is rather subjective and has a lack of precision for the elements used, and Thiis-Evensen's method on archetypes in architecture is useful for the classification of building levels, but not on a neighbourhood or city level.

The most used method from the place phenomenology tradition is the work of Lynch about the 'image of the environment' in his book *The Image of the City* from 1960. A city image may be analysed according to the three components of identity, structure, and meaning (Lynch 1960, p. 8). He relates physical and qualitative attributes of identity and order to a mental image. He is not only concerned with urban form, but also with the form in which urban order is perceived by its residents (Lynch 1960, p. 3). The acquisition of an image is a reciprocal development between the observer and the observed.

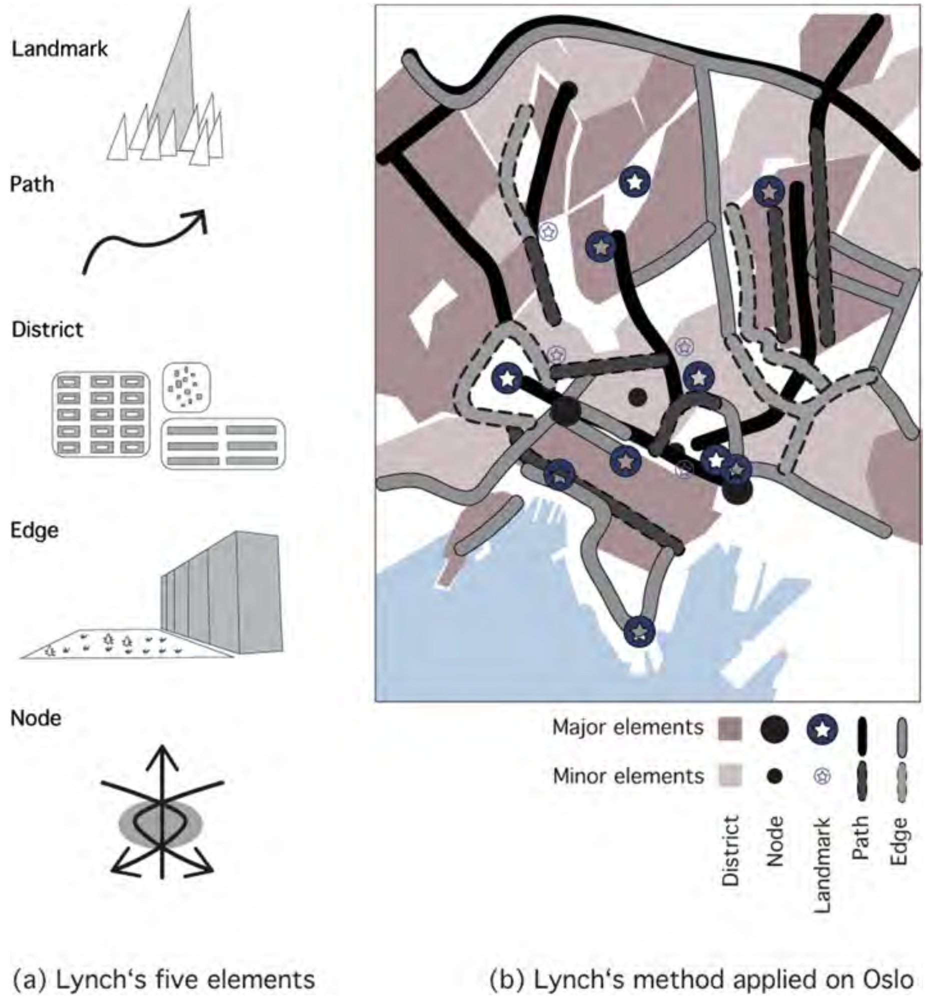
For him, the identification of an object, e.g. an urban environment, consists of the possibility to distinguish it from other objects and to recognise it as a separate entity. An object's image thus must include the pattern of its relation to an observer and to other objects. Meaning is a subjective matter on which physical manipulation has less influence than it does on identity and structure (Lynch 1960, p. 8). Lynch uses a number of other terms such as an environment's legibility and visibility and thereby indicates his intention to provide an analysis of urban form based on perception. For Lynch, the environmental image is a function of permitting purposeful mobility. Lynch introduces five basic elements:

(a) Paths are channels through which people are moving.
(b) Edges are linear elements the observer does not consider to be paths.
(c) Nodes are strategic spots people can enter.
(d) Districts are sections of the city conceived to have a 2D extension with or without a particular character.
(e) Landmarks are points of reference visible to the observer.

Lynch applies these elements to generate visual form maps. These maps allow one to identify general visual problems and strengths, critical elements, and elements' interrelations, including their detailed qualities and possibilities for change.

Figure 1.9 depicts a visual form map of Oslo representing Lynch's five elements. The relative importance of these elements for a 'good' city image will vary with different persons in different situations; one will prize an economical and sufficient system, another an open-ended communicable one (Lynch 1990, p. 9).

Fig. 1.9 Lynch's five elements (**a**) and a visual form map of Oslo (**b**)



Lynch's analytical method is derived from the psychology of perception, and different observers apply Lynch's five elements to draw a visual form map for a chosen city. A significant advantage of his method is that it provides a means to analyse urban form. His approach is based on taking into consideration the relationship between the user and the artefacts of a city. Moreover, he pays attention to visibility, movement, and orientation in a city in relation to physical objects.

According to Kayvan Karimi, a weakness of Lynch's method is the unjustified choice of elements the observer is supposed to take into consideration when designing their image of an urban environment. Lynch does not discuss whether most persons, strangers as well as inhabitants orientate themselves based on these five elements. Yet another problem of Lynch's method is the fact that different observers might perceive some of the five elements differently. For some observers, a ring road might count as a path, while others might take it to be an edge. Therefore, observation maps can vary between observers. Moreover, the transformation of interviews of a city's inhabitants into orientation maps is not free from individual judgements (Karimi 1998, p. 47).

1.2.3 Urban (Street) Network Tradition

The urban network tradition addresses mobility, accessibility, visibility, and orientability (Hillier and Hanson 1984; Hillier 1996; Marshall 2005; Batty 2007). In the field of architecture and urban planning, the urban network tradition addresses how the street network functions as a spatial armature for the socio-economic life of cities. The focus here is thus on space instead of form. It is about the spaces that are shaped by the borders made by physical objects placed in space.

There exist two different approaches—street pattern and street structure. Most researchers of the urban street network tradition focus primarily on the street pattern (Marshall 2005; Klaasen 2004; Dupuy 2008). Street network patterns appear as regular and irregular patterns. Planned and unplanned street patterns include hybrids, and there are various permutations of simpler forms and basic typologies. In addition, different scales are used for describing and analysing urban agglomerations. The diverse combination of different patterns at various scale levels, and thus the hierarchical impact, often reveals differences in accessibility patterns between traditional and modern cities.

In his book *Streets and Patterns* from 2005, Stephen Marshall introduces the ABCD typology for street patterns. He comments that this typology was developed with the intention of "reflecting typical street patterns that are encountered in different kinds of urban analysis" (Marshall 2005, p. 84). The four types feature different stages of the growth of towns and cities, from the historic nucleus to the suburbs of an agglomeration. Figure 1.10 shows an overview of these four types and how Marshall derives different compositions and configurations from these street patterns.

The A-type represents the nucleus of old cities, especially walled cities. Angularity in combination with a variety of directions generates a rudimentary radiality. The B-type is a typical newly founded settlement. The four-way perpendicular junctions give rise to a bilateral directionality. The C-type describes arterial routes whether constituting the centre of a village, a whole settlement, or suburban extensions along a route. The D-type represents a modern hierarchical layout. It can be compared with the analogy of distribution. The ABCD types can emerge singularly or in a mixed mode, or also be arranged according to the order of centrality in urban systems. In particular, this phenomenon exists in traditional European towns.

For the compositions of street patterns, Marshall applies a geographical map of urban layout, whereas for the configuration he presents a diagram or abstraction of the street pattern type. Marshall uses the distinction between composition and configuration to explore different urban systems and structures with the purpose of revealing the hidden structure of each street network type (Marshall 2005, p. 175).

For quantifying street patterns, Marshall operates with a matrix for which he introduces two types of street junctions and two types of street networks: (a) T-junctions and X-junctions and (b) tree-structured and network-structured street networks. His method first calculates the X-ratio of X-junctions and the T-ratio of T-junctions for the entire urban area street network under consideration. This means simply calculating the percentage of X-junctions and T-junctions for a given street network. In networks only comprising T- and X-junctions, clearly the sum of the T-ratio and the X-ratio will equal one.

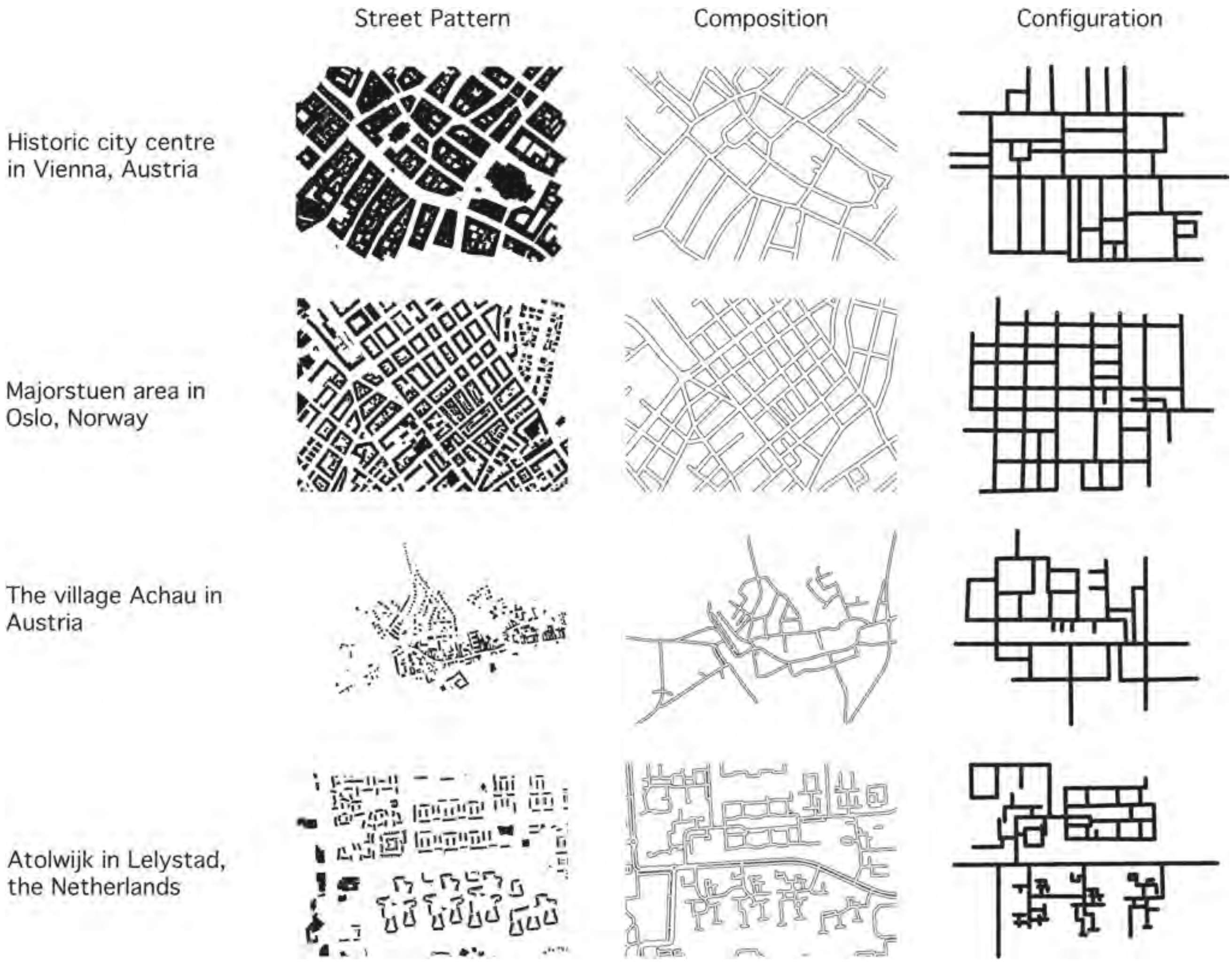
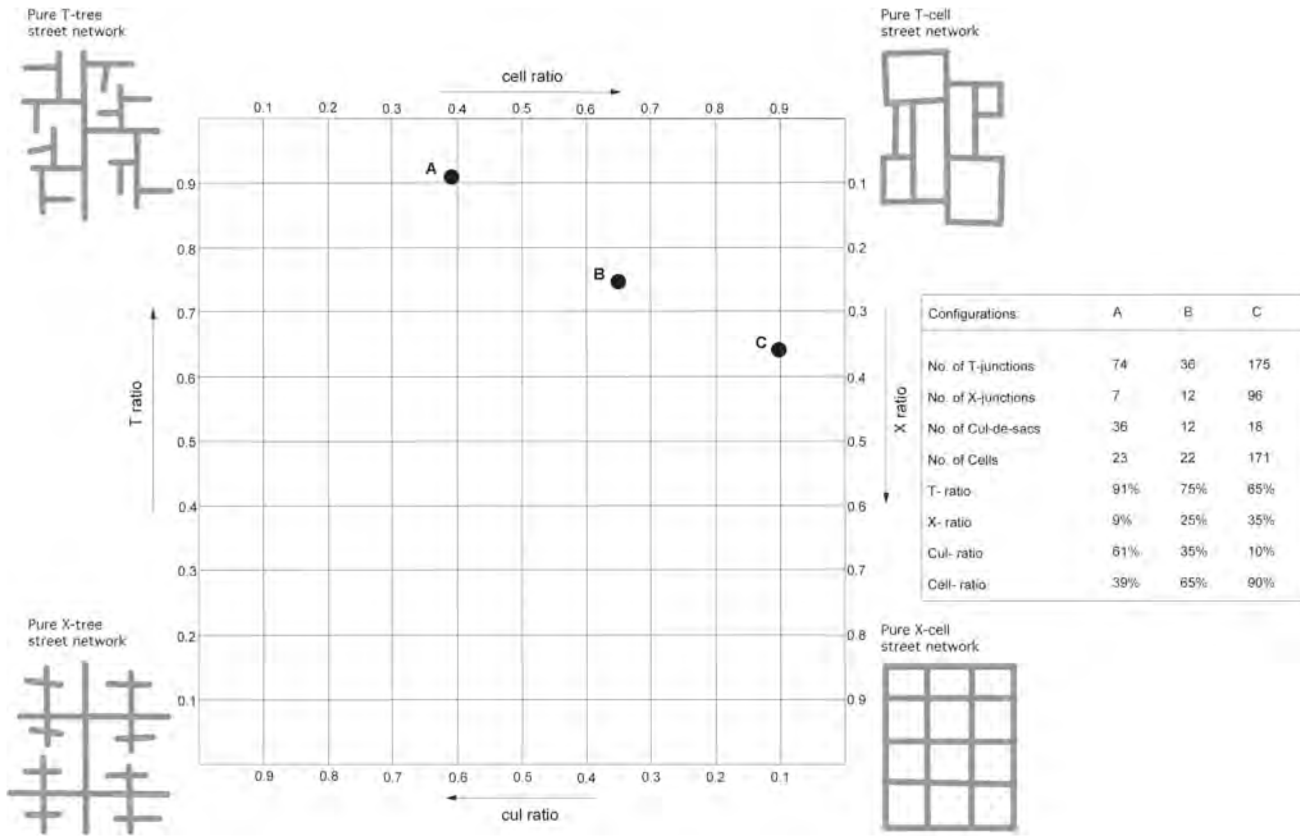


Fig. 1.10 Marshall's ABCD types in compositional and configurational terms applied on urban areas in Vienna, Oslo, Achau, and Lelystad

As Marshall explains, in almost any real street layout there will be a mixture of T- and X-junctions and the corresponding ratios will lie somewhere between zero and one (Marshall 2005, p. 102). In the next step, the cell and cul ratios of the network are calculated. For the cell ratio, the percentage of cells for the whole network is calculated taking into consideration the number of cells and cul-de-sacs. A cell is a structural unit enclosed by street segments. For the cul ratio, the percentage of



Configurations	A	B	C
No. of T-junctions	74	36	175
No. of X-junctions	7	12	96
No. of Cul-de-sacs	36	12	18
No. of Cells	23	22	171
T- ratio	91%	75%	65%
X- ratio	9%	25%	35%
Cul- ratio	61%	35%	10%
Cell- ratio	39%	65%	90%

Fig. 1.11 Marshall's matrix applied on three different neighbourhoods in Singapore (A), (B), and (C)

cul-de-sacs is calculated for the whole network taking into consideration cells and cul-de-sacs. The numerical values of the T- and X-ratios are plotted against the cul and cell ratios in Marshall's matrix (Fig. 1.11).

This simple but useful method in the tradition of network representation provides insights into the pattern specification and presents properties such as clarity, coherence, and connectivity in distinct compositional or configurational terms. The graphic presentation allows the demonstration of areas—however precisely of fuzzily identified—in which 'preferred' or 'discouraged' patterns might lie (Marshall 2005, 98).

Another concept used in studying urban areas is whether a street is distributed or non-distributed. When a street is distributed, there is a possibility to leave it without travelling back the same route. Conversely, a non-distributed street is a street with a dead end or cul-de-sac without a through footpath (Hillier and Hanson 1984, p. 78). Distributed streets form a network of possible movement routes, which open up for a mixture of visitors and inhabitants, while non-distributed streets form simple movement routes mainly for inhabitants. The latter tend to create built environments with a semi-public and semi-private street structure. In Fig. 1.12, we show the distributed and non-distributed streets for a town X.

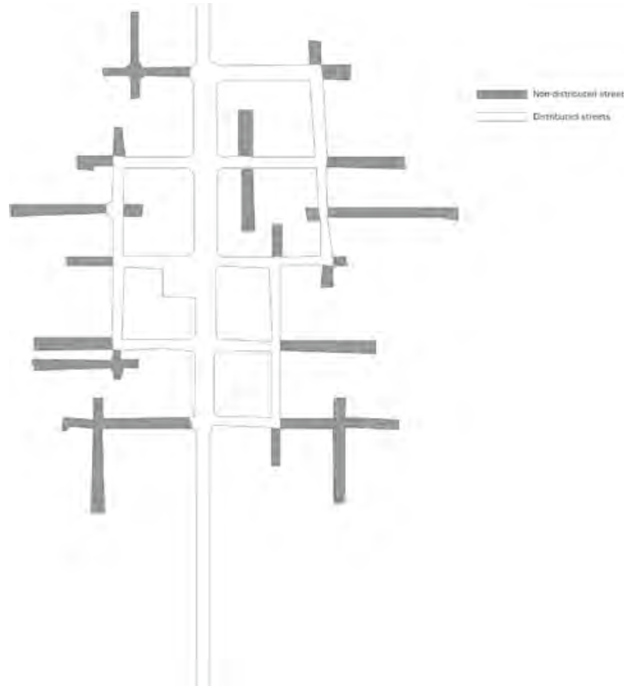


Fig. 1.12 Distributed and non-distributed streets for town X

Using Christopher Alexander's (1965) distinction and definition of natural and artificial cities, artificial cities, i.e. planned cities, with a tree structure consist mainly of a non-distributed street structure. Natural cities that have emerged over time consist of a semi-lattice structure and thus incorporate a more distributed street network. Cities with a semi-lattice structure usually have a complex transportation network, and their functions are well integrated. According to Alexander, this structure improves a city's economic development, its safety, and its liveliness. Thus, a distributed street network encourages a mixture of functions and movement patterns, while a non-distributed street network promotes the opposite. Highlighting the difference between a distributed and non-distributed grid on a map indicates the degree of complexity of movement routes for a city.

On a more urban micro-scale level, Job van Eldijk's (2014) work contributes to the registration of street functions connected to street profiles. He tries to understand how the design of street profiles affects its users. Even though he names them 'street functions' based on what kinds of transportation modes the various street types are designed for, his proposed typologies give indications on a micro-scale level about the degree of urban street life.

Van Eldijk distinguishes between four different types: (a) streets only accessible for pedestrians and cyclists, (b) a balanced use of streets for vehicles, bicycles, and pedestrians, (c) streets and roads dominated by vehicle transport with pavements on both sides for pedestrians and bicycles, and (d) roads only accessible for vehicle transport. Figure 1.13 shows how these four street profile types are applied in an analysis of a neighbourhood in Oslo. As research has shown, the balanced street type enhances street vitality and safety for children (Meinert et al. 2019). The results are in line with the presumptions of Jan Gehl (1971) and Jane Jacobs (1960) that pavements are important for generating life on streets between buildings.

Fig. 1.13 Four different street profiles including functions as classified by van Eldijk (left) and translations of these into a map of the Grefsen area in Oslo (right)

In reality, street profiles can be more complex than those proposed by van Eldijk. One example is the 'shared space concept' by the late Hans Monderman in the early 1990s, consisting of promoting spaces free from traffic regulations. His underlying idea was a self-organisation of street users and permanent negotiation about space (Yamu et al. 2016). This should raise awareness between different users including different modes. To classify the shared space concept, it uses the functional logic of van Eldijk's first type with the transport modes of the second type. Balanced streets tend to be shaped by their adjacent buildings with their entrances facing the street. In contrast, vehicle-only roads lack pavements and tend to be completely non-accessible for pedestrians. In most cases these roads are highways with barriers, nearly impossible to cross safely for pedestrians. However, there exist some dwelling roads with very low car traffic that also lack pavements. These roads are mostly found in built environments with single-family houses (Fig. 1.14).

Fig. 1.14 (Left) Shared space in Vienna, Austria, and (right) a typical dwelling road in Bergen, Norway

1.3 The Platform for Space Syntax: Definitions of Urban Space

Space syntax also falls under the urban network tradition. In contrast with the other urban network approaches that focus on street patterns and compositions, space syntax focuses on street structures or spatial configurations. Through graph theory, the space syntax method is able to calculate the mathematical relationships between spaces. Space syntax was pioneered in the 1970s by Bill Hillier and colleagues at the Bartlett, University College London.

Space syntax is a mathematical street network model that originated in the field of graph theory for calculating topological spatial relationships. The first calculations were made by hand. In the 1980s, computational power and software development allowed the computation of the first models and the calculation of the interrelationships between all the streets of larger towns and cities.

Before the millennium, topological relationships introducing syntactic steps were calculated, and these explain how each street relates to all other streets in terms of the number of direction changes. After the millennium, angular weighting between street segments and metric radii were introduced, and increasing computer power made the calculation of even larger metropolitan areas possible. In addition, the use of geographic information system (GIS) has increased since the millennium. GIS provides the platform for processing georeferenced place-bound socio-economic data, and by building up the spatial analyses model in GIS, place-bound socio-economic data and the results from the spatial analyses can be easily correlated. The importance of GIS is continuously increasing for space syntax for aggregating the large data sets for larger cities and regions.

Interestingly, space syntax is often regarded as a morphological approach (Whitehand 2018), although it differs from the traditional morphology tradition in the definition of the spatial elements and the way they are quantified. Space syntax does not focus on the shapes of physical objects but on the spaces between these physical objects and how these are connected to all other spaces in the built environment. Nevertheless, many studies combine space syntax analyses with urban morphology data such as building density, building height, and land use diversity (Ståhle 2005; Hausleitner 2010; Yamu and Voigt 2011; Ye and van Nes 2014; van Nes et al. 2012; de Koning and van Nes 2017, or Yamu and van Nes 2017 for a synthesis).

What space syntax offers is a theory and method for describing and quantifying the spatial properties of the built environment that shape socio-economic activities. Important contributors for understanding the relationship between physical factors of the built environment and social life in cities are Jane Jacobs (1960) and Jan Gehl (1971).

In her book *The Death and Life of Great American Cities*, Jacobs addresses the role of the pedestrian in making cities lively. She suggests physical indicators on what kind of spatial framework generates lively and safe cities. Her work includes a discussion about urban blocks, eyes on the streets, clear demarcation between public and private space, and mixed use of functions.

Gehl focuses in his work *Livet mellem husene* [Life between buildings] from 1971 on the types of activities that create life between buildings. His definitions about necessary (going to work or school), optional (strolling, 'le flâneur'), and social (playing, meeting people, and playing sports) activities are taken from his research from the 1960s and later applied in his architectural practice . Gehl claims that optional activities in particular contribute to life between buildings and strongly depend on the physical qualities of the built environment. Jacobs and Gehl provide an insight into how the degree of urban vitality is coupled to spatial qualities of the public realm. Following the work of Jacobs and Gehl, space syntax provides a toolbox for analysing urban space and testing urban design options to create lively cities and neighbourhoods.

In general, space syntax works with the concept of space. Space is an essential aspect of the built environment, but space is an abstract word. It cannot be touched, only perceived. Space and time are constructions that help people to arrange the world into fitting schemata. It is through physics and mathematics that the terms time and space find an interface to the physical word and therefore an interpretation. In cities, space is formed through existential connections. Through these a meaning and allocation of things, places, boundaries, and qualities can be defined. Through its various definitions of and thoughts about space through time, from Aristotle and Heidegger to Sloterdijk and Lefebvre, the idea about space needs to be assessed with care in its applied context.

Understanding a society's effect on the built environment and vice versa requires a concept of physical space. If human activities manifest in space, then the organisation of these activities affects a settlement's spatial organisation. Thus, social activities can be understood with a reference to the physical structure of the built environment. On the other hand, if the physical structure and organisation of architectural space influences human behaviour, it will impact social activities.

With regard to urban space, we have to distinguish between public and private spaces as discussed by Jacobs (1960). Hillier and Hanson (1984, p. 92) state that public space is "[…] the result of the arrangement of buildings, and possibly other bounded areas such as gardens, parks and the like". The main concern of space syntax in urban studies is to analyse the spatial configuration or spatial structure of public spaces and how they relate to private spaces.

Hillier distinguishes between 'extrinsic' and 'intrinsic' properties of space. Extrinsic properties determine how spatial units relate to one another. In this respect, we can think of configurative laws of space. If we intend to understand settlements in terms of these laws, such settlements are regarded as sets of spaces. It is primarily the arrangement of elements and topological issues that become relevant, and metriccal properties such as distance are not considered. Urban spaces are regarded as purely extrinsic entities, and they are shape-free. In line with Hillier, it is solely their interrelational aspects or structure that is at hand. Every space has one or more functions either in terms of occupation or with regard to movement (Hillier 1999, p. 1), and the extrinsic properties of space determine both the space's built form and its possible functions.

While extrinsic properties of space consist of invisible structural relationships, intrinsic properties of space are visible, such as the shape, size, volume, pattern, and texture of the physical objects or built mass. Intrinsic properties of space present themselves mostly through geometrical properties, and they account for the articulation of social meaning via the built form (Hillier 1999, p. 1). We have many words for describing intrinsic properties of space, like 'a narrow street', 'a large square', or 'a massive building'. These properties enable us to describe urban artefacts.

In general, the concepts of extrinsic and intrinsic properties of urban space contribute to clarifying the typology concept that is often used in urban studies. Here, we have to distinguish between *phenotype* (how a built environment immediately appears to us) and *genotype* (the hidden structure of the built form). This will be elaborated upon in the following sections.

1.3.1 Intrinsic Properties of Urban Space

What can be immediately seen is easy to identify and describe. Consequently, many established methods in urban studies deal with intrinsic properties of space—among others, the place phenomenological method of Lynch (1960) and methods from different urban morphology schools (Gerosa 1992; Whitehand 1981; Oliveira 2018; Conzen 2004; Caniggia and Maffei 1981; Panerai et al. 2004). In Fig. 1.15, we describe the intrinsic properties of example town X. The figure ground map of town X depicts the built-up mass and the widths of its streets. The density of the building's footprint or ground space index along the main street is higher than for other streets of the settlement. For the housing types, terraced houses and larger buildings are located along the main street, while detached houses can be found on most of the other streets. The overall shape of the settlement is an orthogonal grid pattern with a high number of X-junctions. For a more elaborate description of town X's intrinsic properties, the existing different architectural styles of the buildings and building typologies, for example, can also be considered.

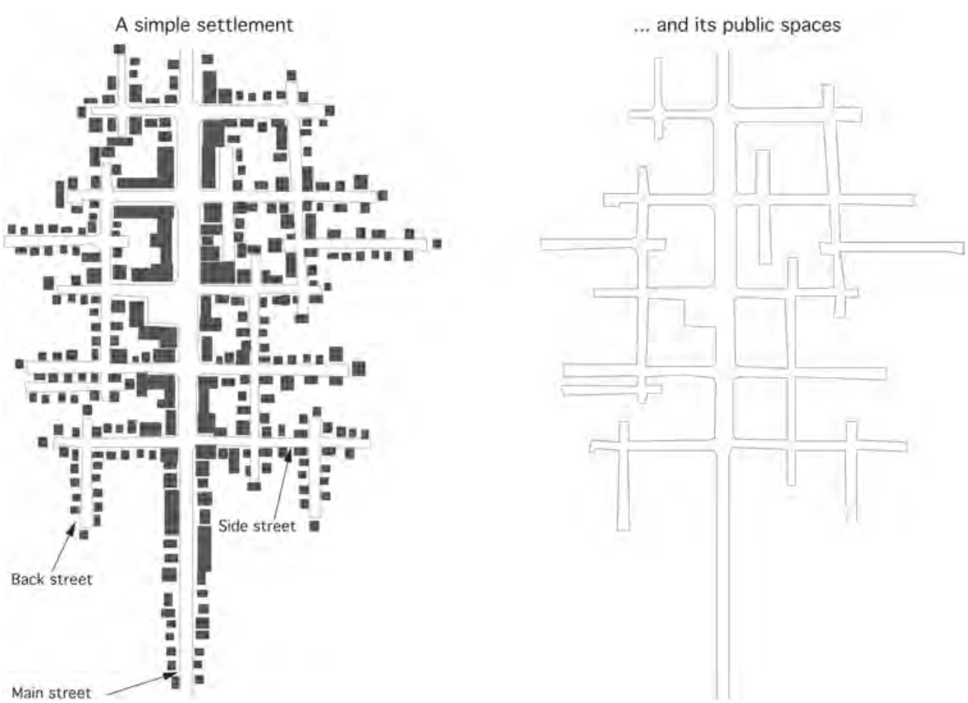


Fig. 1.15 Building morphology (left) and its orthogonal street pattern (right) for town X

To understand the present visible conditions of the built environment, comparisons must be made with past conditions. This resonates with Lynch when saying "[…] the city is a construction in space, but one of vast scale, a thing perceived only in the course of long spans of time" (Lynch 1960, p. 1). Thus, history matters. Historic events connected to policies, natural disasters, or socio-economic conditions influence cities and regions and how they have emerged in their present form. Herein, Lynch (1981) in his book *Good City Form* puts forward that the main force of transformation for human settlements is human motives that influence the built form. Impersonal factors such as natural disasters are only influential on rare occasions. City form has to be understood from its artefacts that consist mostly of built elements. New emerging artefacts can function as primary elements for a future urban trajectory, constituting the future urban pattern and functions (Rossi 1966; Caniggia and Maffei 2001). Examples of primary elements are important buildings, land subdivision patterns, urban development plans, railway stations, and railway tracks.

In his book *L'architettura della città* from 1966, Rossi advocates for a rediscovery of the traditional European city. He illustrates how present cities and their urban fabric are constituted by the past. Rossi develops three distinct concepts: (a) urban development has a temporal dimension, (b) the city has some spatial continuity, and (c) in an urban environment, there are some primary elements of a particular nature that have the capacity to accelerate or retard urban development.

For example, Rossi (1966) illustrates how the urban fabric follows the building footprint of a previous amphitheatre. While the amphitheatre has disappeared, its shape can be still identified in the urban fabric. For this example, the amphitheatre functioned as a primary element. Figure 1.16 shows two examples of urban traces left after past primary elements and their influence on current urban patterns and built forms for cities. In the case of the city of Lucca, we can still identify the urban footprint of an ancient amphitheatre and identify how it shaped current urban patterns and buildings. The same goes for the Piazza Navona in Rome, where an ancient Roman stadium has constituted the shape of the present large urban square fringed by building blocks.

Understanding how past policies and important buildings have constituted the development of a city requires insight into political, social, and technical changes that have occurred over time. Furthermore, how these changes had an influence on the built environment matters. Societal meanings and self-perceptions are closely intertwined with the built form (Lynch 1981), and the field of urban morphology is concerned with an understanding of the changes in the urban fabric over time (Strappa 2018; Panerai et al. 2004; Conzen 2004). Because this is always context dependent, it is difficult to derive a general statement about future effects when only taking the intrinsic properties of space into consideration.

Fig. 1.16 An amphitheatre's influence on the urban pattern in the Italian town of Lucca (left), and an ancient Roman stadium's influence on Piazza Navona's built form in Rome (right)

Because societal meaning and the self-perception of people are closely intertwined with the built form, we can conclude that every urban space has a place character. A place is a space with meaning. Place character and its identity are concerned with the intrinsic properties of space. Several factors influence place character, including location, topography, physical geography (e.g. a valley or hills), cultural traditions, local building materials, local weather conditions, demographics, and economics.

Norberg-Schulz describes the character-shaping elements of places. He takes into account how the assembly of local building materials, lighting, vegetation, landscape forms, weather conditions, and colours contribute to shaping the character of a particular place. The opening's shape, building materials, colours, rhythm, and tension determine the character. The meaning of the openings, such as doors, entrances, and windows, connects the private interior with the public space in terms of movement, light, and transparency. All these aspects express the way of life the city assembles. Every city has its local architectural motives (Norberg-Schulz 1971, p. 60).

Figure 1.17 shows three levels for understanding place character from the landscape level to the building level, and to the interior level for a Dutch and a Norwegian place. Seemingly, the building façade's orientation is influenced as a contrast to the natural landscape. Where a Norwegian landscape has a vertical orientation of the objects in the panoptical view, the structure of the traditional building façade's materials has a horizontal orientation. Conversely, the flat Dutch polder landscape has a horizontal orientation, which probably influences the vertical orientation of the shapes of windows and volumes of traditional Dutch buildings. The colours and textures of the interior are also influenced by local nature and weather conditions. The Norwegians like to bring the warm colours from the short Norwegian summer into the interior, whereas the Dutch use bright colours in their interiors for bringing light into their homes.

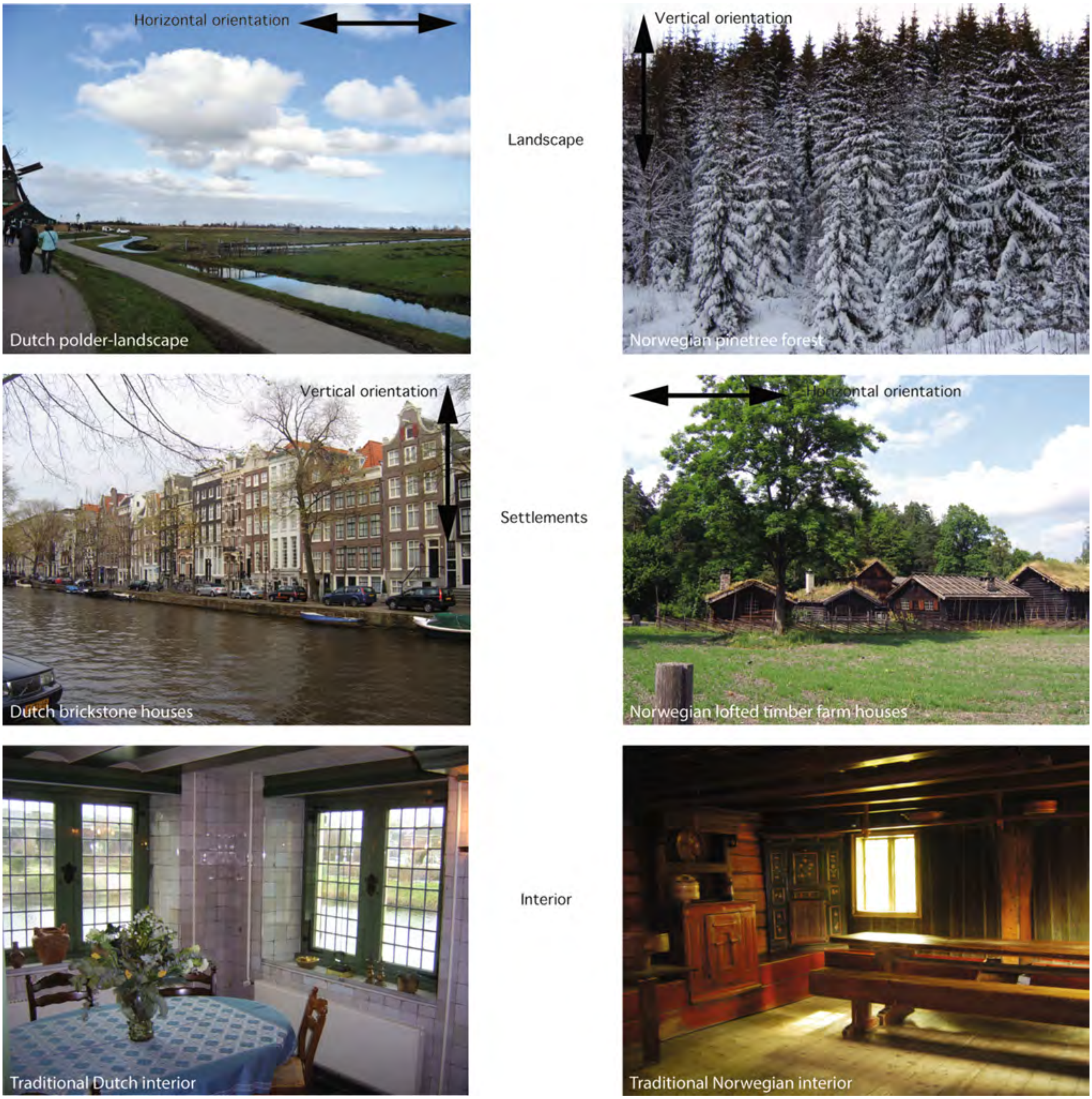


Fig. 1.17 Interpretation of Norberg-Schulz's approach to understanding the differences between a Dutch and a Norwegian place in the tradition of intrinsic properties of space

According to Norberg-Schulz, the experience of a place's character is spontaneously given in the way the direct feeling of being in a particular place offers us safety when we return home and excitement when we visit an unknown or new place. A place can be perceived as being friendly, cold, sombre, lively, enclosed, open, etc. The experience of a place's character creates the spirit of the place, the *genius loci*, and its inhabitants in the way it is expressed by the spatial structure and spatial elements. A vast space can never offer an intimate atmosphere, while a narrow space can never offer an atmosphere of openness and grandness. Every spatial structure can be organised in such a way that it conditions various character traits. Hence, the man-made built environment has a high degree of adjustability to the given natural surroundings. Urban place character depends on built boundaries and surfaces. It has a floor and walls. It is sometimes roofed. These elements influence how we experience urban place. Urban boundaries are not where a place stops, but where it begins, where its character is conditioned (Norberg-Schulz 1971).

For example, the rhythms of façades with their openings and windows express in cities a particular relationship between the inside and outside spaces. Different cities embrace very distinguished façades. Every place has its architectural theme driven by human motives and repeated with variations in a place's buildings. Thus, places are a combination of unity and variation. An urban theme consists of several motives; for example, a theme might be a certain type of façade with its particular windows (Norberg-Schulz 1971).

In general, urban morphology and place phenomenology in urban studies aim to understand the particular form and pattern of a city as an effect of processes. It is necessary to understand the intentions behind a built environment's artefacts and primary elements. With both the morphological and place phenomenological traditions, the future effects of new emerging and planned artefacts cannot be predicted. Analytical tools developed within these traditions are useful to understanding the existing/current relationship between built form and meaning.

Urban morphologists study the transformation rules guiding the change of urban patterns. They deal with type and typology and the classification of both based on common characteristics. The work of Rossi (1966, 1983), Muratori (1960), Caniggia (1976), Caniggia and Maffei (2001), Conzen (1960, 2004), Whitehand (1981), Panerai et al. (2004), Lynch (1960, 1981), and both Krier brothers (1984) are examples of applying intrinsic properties of space in urban studies. The work of these authors accounts for the built environment's observable characteristics, which refers to a built environment's phenotype, i.e. how the built objects in an urban space immediately appear to us.

Intrinsic properties of space are about built form and meaning, and describing and analysing a space's intrinsic properties require a place phenomenological approach. The meanings attached to single physical objects and the visible patterns these objects generate as a whole for a city combined with the atmosphere of the places need to be taken into account when trying to understand a particular built environment. Intrinsic properties of space describe the *phenotypes* of settlement *patterns* and the shape of their artefacts.

1.3.2 Extrinsic Properties of Space

The space syntax method works mainly with extrinsic properties, and it analyses the topological spatial relationships of settlements. It is difficult to describe the extrinsic properties of space with words. For example, if a visitor in a city asks an inhabitant the direction to the railway station, the inhabitant will use words like 'here', 'there', 'this way', and 'that way' to explain the route. Or the inhabitant will show the visitor the location of the railway station on a map.

Concepts like 'here' and 'there' or 'inside' and 'outside' are useful to refer to simple spatial relationships. But to describe an entire building or town using only the above-mentioned terms becomes very complicated. Language seems unable to spell out complex spatial relationships in a concise and simple manner. Therefore, abstract models or maps are often used to represent and grasp such complex systems of space. These models, which can represent large parts of our world, are necessary to explain spatial relationships.

During the development of space syntax, Hillier defined a number of basic terms for describing extrinsic properties in a systematic manner. This requires considering the city as a set of spaces. Wherever people move or live, their activities happen not just in a singular space, but also in multiple spaces. How these spaces are interrelated to each other influences the type of human activities (Hillier 1999).

In terms of how we name things, urban space is recognised to be mostly linear, perceived as a sequential constellation of spaces. Apart from squares, multiple names are used for the routes between squares such as alleys, streets, roads, avenues, boulevards, highways, paths, pavements, subways, bridges, and stairs. All these kinds of urban spaces shape a grid or network—a potential pattern of movement from everywhere to everywhere else. The way in which the square is used depends on where it is located in the linear mobility network. Therefore, urban space can be represented as linear items.

The urban street and road network is defined as the "pattern of public spaces linking the building of a settlement, regardless of its degree of geometric regularity" (Hillier 2001, p.02.1). The street network is the armature of a city and allows people to orientate and navigate through it. These urban public spaces give the possibility to move from everywhere to everywhere else in the city. The network of public spaces shapes the possibilities to spatially locate functions in response to the varying configurations of the urban street and road network. Space syntax works with the concepts of 'isovist field', 'convex space', and 'axial line' (Fig. 1.18).

An isovist field is a visualisation of the panoptical view of a viewer from a particular standing point in the built environment (Bendikt 1979). Turner et al. (1993) argue that Tandy (1967) appears to have been the originator of the term ‘isovist’. An isovist can be briefly explained as a visual record of what can be seen in a 360-degree view from a given point. The concept of an isovist is closely related to the idea of visual perception and spatial description, also connecting to Lynch’s work. The visual record is taken at average eye height. Batty summarises an isovist as “[…] a field of vision from which various geometrical properties, such as area and perimeter, can be calculated. Isovists can be defined for every vantage point, constituting an environment, and the spatial union of any particular geometrical property defines a particular isovist field” (Batty 2001, p. 123). We will address the isovist analysis in depth in Chap. 3.

Moving on from this, a convex space is defined as a space used mostly for occupation, such that “all points (locations) within that space can be joined to all others without passing outside the boundary of that space. […]” (Hillier 1988, p. 68). In other words, two persons can see each other when they are located on every spot within a particular convex space. The panoptical view is essential in the definition of a convex space. Convex space is mostly occupied by place-bound functions and human activities such as standing and sitting. In terms of spatial analysis, convex maps are used for analysing spaces inside buildings and the public spaces between groups of buildings in a neighbourhood or small village. The analytical scale ranges from architectural space to a neighbourhood’s public realm.

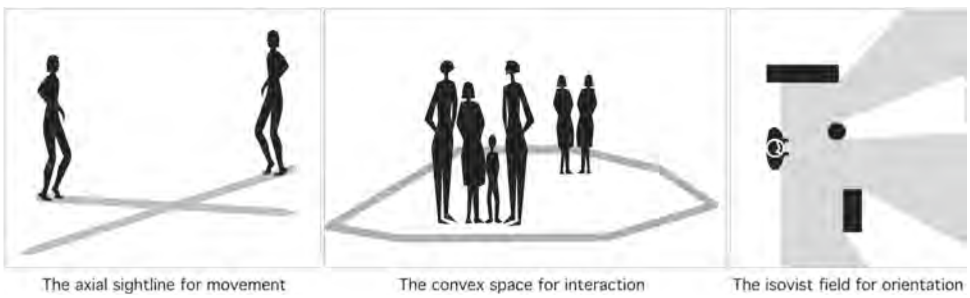


Fig. 1.18 An illustration of the basic elements of space syntax

The convex map is redeemed by the axial map simply because the axial map can be generated and drawn much faster than a convex map. Moreover, the analytical results of a convex analysis comply with those from an axial analysis (Hillier and Hanson 1984). For readers who are interested in learning more about convex spatial analyses, Chap. 3 in Hillier and Hanson’s book *The Social Logic of Space* from 1984 offers insights into how to generate and analyse a convex map in the context of the French village of Gassin.

An axial map is the minimal set of axial lines, and an axial line represents the longest sightline distance for movement within a set of convex spaces. The axial line represents the way human beings move linearly through the urban street and road network. An axial line runs through a set of convex spaces that can be seen and passed through consecutively (Hillier and Hanson 1984, p. 94ff). In many ways, the axial line represents at the same time the movement line and the visual sightline. As Hillier and Hanson discovered in their studies on urban public space, the set of axial lines linking together convex spaces as ‘beads on a string’ can represent an urban network. The axial lines are the string (one-dimensional space representing the movement through built environments), and the convex spaces are the beads (2D space linked by one-dimensional space) (Hillier and Hanson 1984, p. 91).

For the analysis of towns and cities, the axial map is the least time consuming to prepare. For the axial map, the street and road network is represented with the longest and fewest sightlines indicating movement paths, presenting direction changes in terms of visibility. The most recently developed analytic techniques depart from the axial map as a basis, even though the use of the road centre line is becoming more popular for analysing large cities and regional areas. The axial map is a topological representation of the relationship of urban convex spaces and belongs to the representation of extrinsic properties.

Figure 1.19 illustrates the extrinsic properties of the spaces of town X. The left image depicts all publicly accessible spaces including all buildings. The right image represents the minimal set of axial lines for these spaces. This is coined the 'fewest-line axial map' (Turner et al. 1993, p. 425) because it illustrates the fewest and longest sightlines covering all public spaces in a built environment. The buildings' types and shapes do not matter. It is only their indoor spaces that are of interest if the axial analysis is applied to spatial relationships inside buildings.

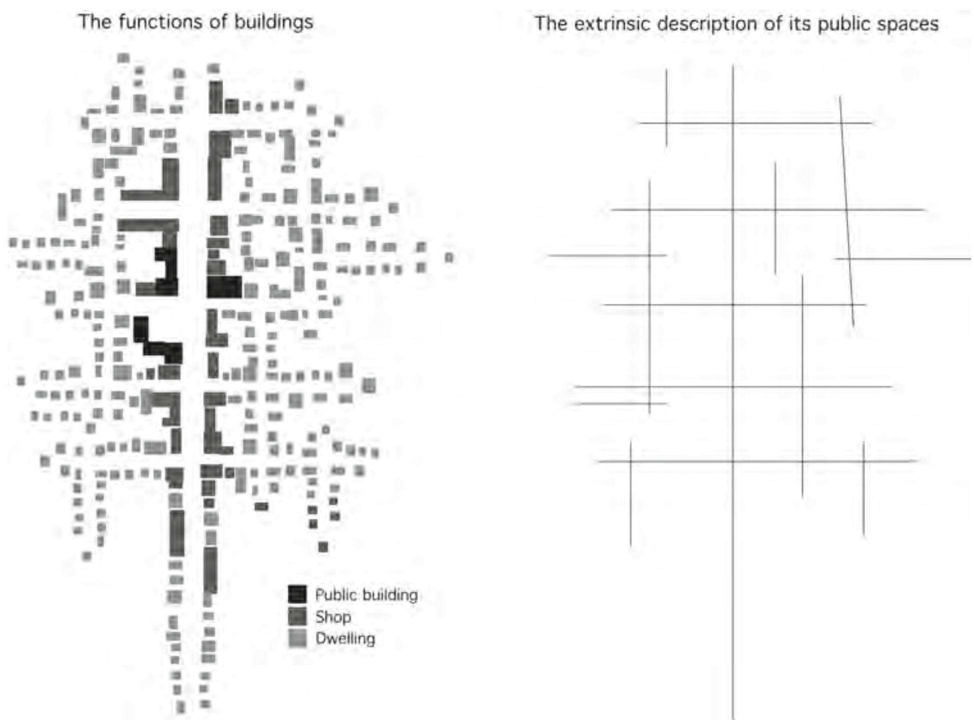


Fig. 1.19 How to represent a settlement's extrinsic properties of space

Describing extrinsic properties of space requires that urban elements of the complex urban reality can be represented in abstract models. Spatial models never cover the whole spectrum of urban reality due to their abstractive characteristic. They are a simplification of reality, and they cover what is of interest for the modeller and which urgent challenge should be addressed. As Joutsiniemi (2005, p. 360) says, "In the case of space syntax, the fewest and longest sightlines axial map is seen as a representation of publicly accessible spaces. It models or represented the required correspondence between world and model". In line with Turner et.al. (1993, p. 428), the objective way of modelling an axial map is to use the following rule of thumb: An axial map is the minimal set of axial lines such that the set taken together fully surveils the system.

Simplifying the extrinsic properties of the public spaces of the built environment in abstract units is needed in order to reveal their spatial interrelationships and to describe the spatial *structure* of these interrelationships. Figure 1.20 depicts a variety of basic spatial elements and presents them in their simplest diagrammatic form, followed by an axial representation and accordingly justified graphs. The root nodes are marked in black and represent the streets (a, b, c, and d) that are taken into consideration as a starting point.

The a-structure represents the tree-structured street network. The street with an a-structure is well connected and has high integration and high local choice of routes. However, this street has low traversability. The b-structure represents the street segment as part of a path. There are no side streets to the path. This linear structure therefore has low connectivity, has low integration values, and offers no local choices of other routes. The c-structure represents the street segment as part of a circular route. Like the path, the circle has low connectivity, low spatial integration, and low choices of other routes. However, the traversability of the circle is high. The d-structure represents the street segment as part of a network. Here the street segment is well connected, has high spatial integration, has high traversability, and offers a large number of choices of alternative routes (Hillier 2019).

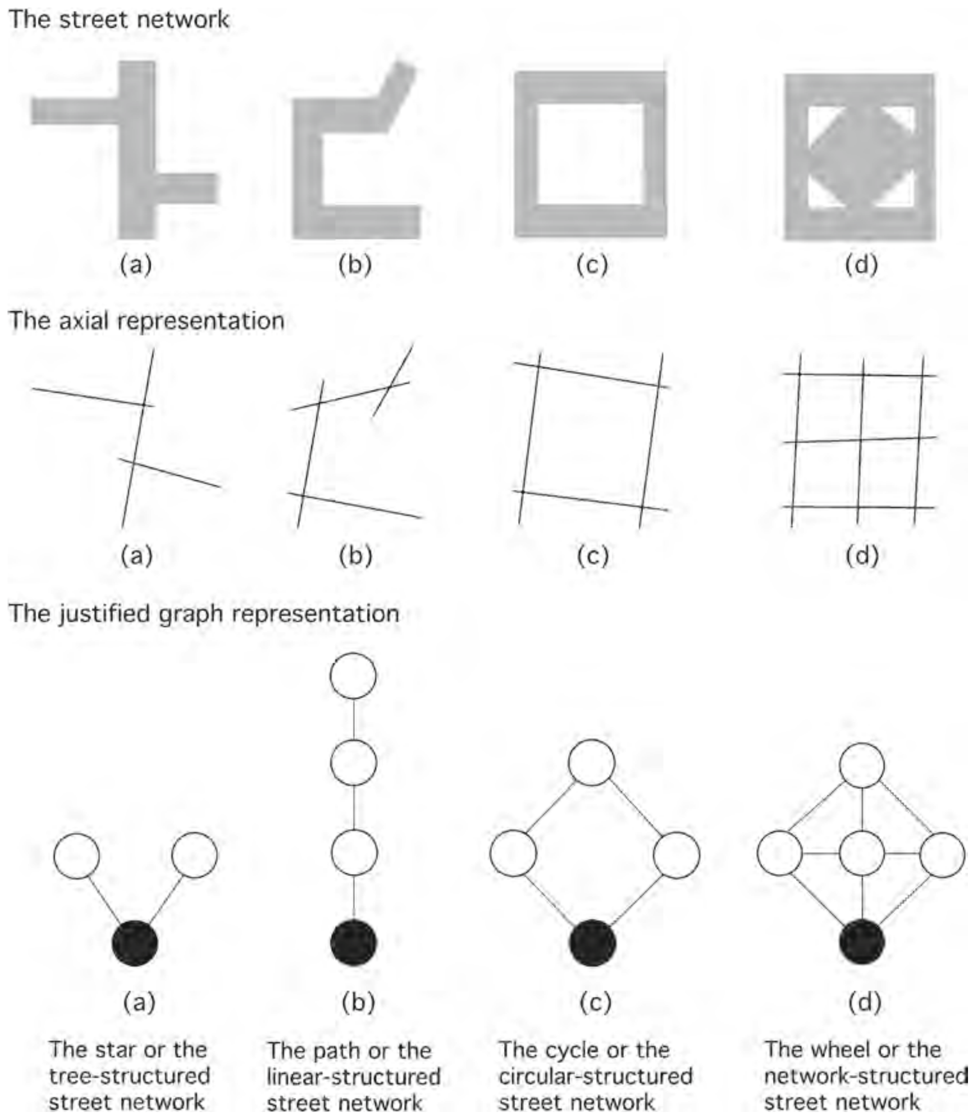


Fig. 1.20 Four types of elementary spatial relationships of public spaces

Each of these elementary spatial relationships is a syntactic expression that is best expressed in relation to movement in public urban space. In spatial terms, the a-structure has a 0-directional movement. Here the key concept is *stasis*, which creates dead-end streets connected to the street. The stasis or star model is a non-distributed spatial system. The b-structure has a 1-directional movement, and the key concept is *axis,* which allows through movement but only the same way back. This axis is also a non-distributed spatial system. The c-structure has a 2-directional movement, and the key concept is *route,* which allows movements in two directions in a circle. Different from the first two, the c-structure is a distributed spatial system (Hillier and Hanson 1984, p. 91). Finally, the d-structure has a multi-directional movement, and the key concept is *network,* which offers several movement possibilities and many route choices. Clearly, the d-structure is a distributed spatial system. In social terms, the a-structure *generates* long models thus generating absence of movement, the b-structure *distances* long models, the c-structure *accesses* short models, and the d-structure *generates* short models (Hillier 2019).

In summary, extrinsic properties of space are about the spatial relationships and the way these spatial relationships affect the location of various urban functions and the flow of human movement. The *meaning* of spaces, *ergo* places, is not considered in the analysis and description of the built environment in this context. Instead, the invisible spaces, shaped by objects and walls, and their interrelationship to each other are taken into account. Contrary to intrinsic properties, extrinsic properties of space are about identifying and describing a built environment's *genotype*—describing its hidden DNA or the spatial structure and underlying its spatial order.

1.4 Conclusions

Intrinsic properties of space are about describing patterns of built objects and place character. In the analysis of the arrangement of places, the work of urban morphologists like Muratori, Canaggia, Whitehand, Conzen, Panerai, and others supports the description of the spatial pattern of a place and relates it to socio-economic processes (Moudon 1997). Describing place character implies identifying the formal aspect of a built environment's spatial components. Our language is able to describe these elements and compare different settlements to one another. Moreover, these elements are also visible in the built environment.

Applying an extrinsic approach to describing a spatial structure is rather difficult. Herein, the spatial mathematical models are useful when describing spatial relationships. As David Seamon acknowledges, "Hillier and his colleagues have developed clearly defined concepts of space and spatial relationships for describing the hidden spatial structure determining a built environment's degree of liveliness and vitality" (Seamon 1994, p. 35–48). Space syntax is a configurative approach applying the logic of graph theory.

Urban spaces and places are shaped through social activities. Their spatial structures, arrangements, and orders influence human activities, perceptions, and existence. Movements in shaping cities have embraced diagrammatic, planned, and regular geometries representing normative approaches in contrast to the organic city or the city as an organism representing the evolved city. In general, it is hard to predict what urban planning and design interventions might mean for the everyday life of the users.

Urban change is refreshing for some people, while it is considered instability in their lives for others. Herein, space syntax as a spatio-social approach allows for testing the spatial–social effects of urban design proposals and for creating guidelines for generating places that function according to the plans' intentions by taking into consideration the spaces between the built objects. We have to focus on both urban *space* and urban *form*. Often the spatial structure shaped by the objects is forgotten when planning built environments even though urban space actively influences how human beings arrange their movements and functions. As shown in Chap. 6, urban form is influenced by urban space. Space syntax can analyse spatial structures, but not place character or building densities. Therefore, for a comprehensive analysis of the built environment, all three research traditions are needed.

Figure 1.21 shows the analysis of Oslo centre where we show one method of each of the three established research traditions on built environments. From the urban morphology tradition, we apply Rådberg's quantification of building morphology or the Spacematrix method (left). From the place phenomenology tradition, we apply Lynch's visual form map (middle), and from the urban network traditions we apply a space syntax analysis (right).

The Spacematrix approach and Lynch's visual form map both analyse the intrinsic properties of space. While the Spacematrix map depicts the urban pattern similar to a figure ground map, the visual form map allows one to learn about the visual quality and mental image of a city held by its residents. The visual form map further depicts the main phenotypes of a city's image appearing immediately before us.

Conversely, the space syntax analysis of the street network identifies the relationships of the public spaces to each other. Streets with a low number of direction changes (marked in red) in relation to all others have high spatial integration. These streets have high pedestrian flow rates and are often lively shopping streets. Conversely, streets with a high number of direction changes in relation to all others have low spatial integration and are marked in blue. These streets have potentially low pedestrian flow rates. This is an example of analysing extrinsic properties of space. Space syntax analysis depicts the built environment's 'hidden' spatial structure, aggregating various degrees of intensity of urban vitality, street life, and the location of active land use like shops and micro-economic businesses.

In which way built forms and functions are related depends on the spatial configurative relationship of the publicly accessible spaces represented by streets and squares. Some streets are spatially more highly integrated, and thus more 'central', while others are more spatially segregated. In general, active land use in the form of shops is located on spatially integrated main streets, while dwellings are located on spatially more segregated side streets. Thus, extrinsic properties of

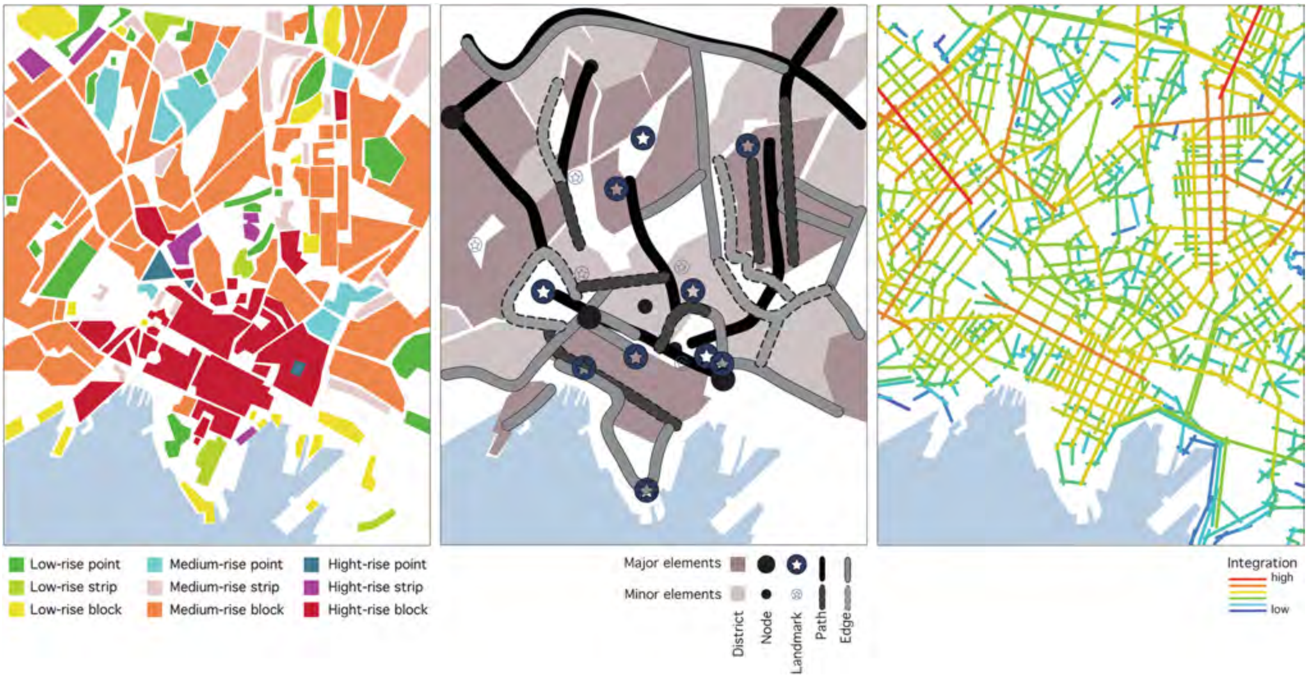


Fig. 1.21 Analysis of intrinsic and extrinsic properties for Oslo's historic centre from 2000: (left) Spacematrix analysis, (middle) visual form analysis, and (right) space syntax analysis of 'local integration'

space account for a settlement's genotype, which is its 'hidden' spatial structure of the public spaces shaped by buildings, land use demarcations, walls, and fences. These hidden spatial structures set the framework for what we can see, what we can access, and how we can move through and between all the physical obstacles placed in space.

In the following chapters, we will explain and demonstrate how the various spatial analysis methods are built up and the various calculation methods for space syntax. Examples from research and practice will be used. But before you go further, it is suggested to perform the exercises below.

1.5 Exercises

Exercise 1

Write a description of how you would explain to a stranger how to get from your home to the closest bus stop or railway station. Reflect upon what linguistic elements of your description refer to either extrinsic or intrinsic properties of space.

Exercise 2

Draw a Lynch-style visual form map of your home city, town, or village based on his five elements. Reflect upon the results: (a) Discuss the challenge in defining these elements for your case study. (b) Which of Lynch's five elements can be regarded as purely intrinsic? (c) Which of Lynch's elements can also show extrinsic properties of space?

Exercise 3

Draw a Spacematrix map of your home city, town, or village. You can use Google street maps' satellite images or Baidu Maps' satellites images (for those who cannot use Google) and street viewer as help. Try to classify the building types using the matrix of Fig. 1.3.

Exercise 4

Undertake a manual MXI analysis of your home city, town, or village. Use Google street view or Baidu street view as an aid. Indicate with colours the location of the following areas: mono-functional dwelling areas, mono-functional work areas (business parks, industrial areas), mono-functional amenities (leisure activities), bi-functional areas with two functions, and multi-functional areas with all three functions.

Exercise 5

Undertake a comparative street function analysis of a historic neighbourhood and recent neighbourhood of a city or town you know well. Use Google or Baidu street view as an aid. Indicate with colours the following elements of the street network: pedestrian and bicycle streets; balanced use between vehicles, pedestrians, and bicycles; streets and roads dominated by vehicles; and roads only for vehicles. Describe the difference between both neighbourhoods based on your analysis. How do you experience both neighbourhoods?

Exercise 6

Get a map of your neighbourhood and highlight the distributed and non-distributed streets. How many circular routes can you identify in your neighbourhood? What is the percentage of X- and T-junctions in your neighbourhood?

Exercise 7

The image below illustrates a scouting camp within total eight tents. Out of the eight tents, there are five normal tents, one tent for the leader, one kitchen tent, and one bathroom tent. Each night the camp is installed in different places. Figure 1.22 shows three different camp configurations. Describe and explain the phenotype and genotype of these three different camp arrangements.

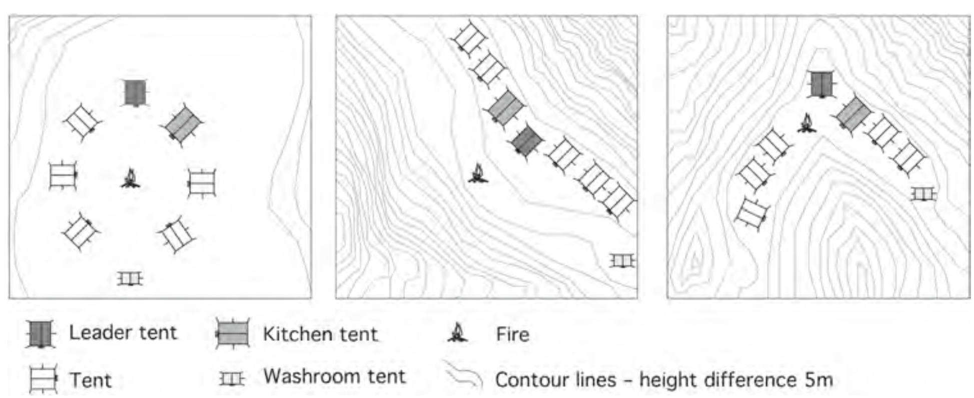


Fig. 1.22 Three different camp configurations

1.6 Answers

Exercise 7

The scouting camp's spatial organisation has the same genotype regards the location of the leader and kitchen tents in relation to the other tents and the bathroom tent. The phenotype of the scouting camp differs from each other, with a circle shape in the left figure, a linear shape in the middle figure, and a 'V' shape in the right figure.

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Analysing Linear Spatial Relationships: The Measures of Connectivity, Integration, and Choice

2

Contents

Abstract

In this chapter, we first explain the concept of an axial line and how the axial map is applied in space syntax. We then discuss the static measure of 'connectivity' with its 'one-step' to 'n-step' logic, including its meaning for axial integration analysis. We further present the segment integration analysis. Using the street segment as the basis for analysis allows one to apply three types of distances and three types of radii in space syntax. We then present the most-often used space syntax measures in more depth, namely angular choice and angular integration with metric radius, and introduce the

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mathematical formulae on how to normalise both measures. Real-life applications illustrate and underpin the usefulness of these measures and their meaning for urban analysis, such as why and how they allow us to identify urban societal processes and their added value at both a citywide scale and a neighbourhood scale. Finally, we critically reflect on the measures, including their potentials and misfits. Exercises are provided at the end of the chapter.

Keywords

Street network analysis • Graph theory • Connectivity • Integration • Choice • To-movement • Through-movement

Key concepts

Graph theory • Axial map • Segment map • Topological step • Topological distance • Geometric distance • Angular distance • Integration • Angular choice • To-movement • Through-movement

Learning objectives

After studying this chapter, you will be

- able to draw an axial map;
- able to carry out an n-step analysis and interpret its results;
- able to process from an axial map the measures of axial integration, segment integration, and choice with different radii for the same and different measures;
- able to normalise space syntax numerical values;
- able to undertake and interpret correlations between the same measures with different radii and between different measures;
- able to generate a four-pointed star model based on Hillier's fifty-cities approach; and
- able to critically reflect upon all obtained analytical results.

2.1 The Linear Urban Space

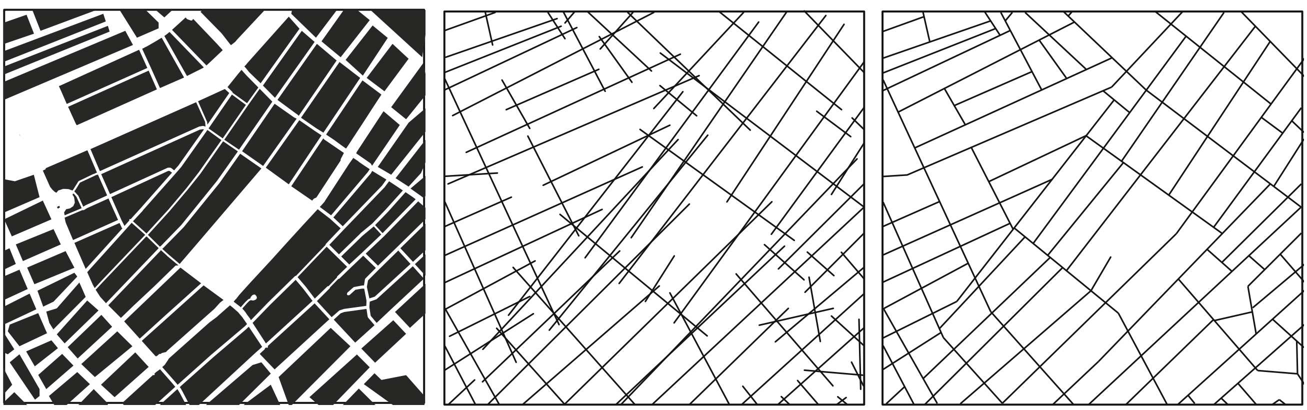
Independent of cultures and architectural styles, all cities have in common is that they consist of a set of private and public spaces. Public spaces are accessible for all and open up for movement from everywhere to everywhere else in the built environment. Private spaces have restricted access and are mostly inside buildings or can be private gardens. Private spaces are connected to public spaces in different degrees of depth, and the way all public and private spaces are interconnected conditions the possibilities for people's socio-economic activities.

The urban street network is constituted by public spaces. Puckett (2009) states that the street structure affects how human beings navigate and orientate themselves in urban space. When, for example, escaping from a threat, a network-structured street grid offers more escape possibilities than a tree-structured grid (Marshall 2005). In a network-structured street grid, the choices are many, whereas they can be quite limited in a tree-structured street grid, in particular for dead-end streets (see Chap. 1). In panic situations, rational thinking is reduced, and thus visual orientation has a high priority when people have to escape (Puckett 2009, p. 22). For example, in the 2004 tsunami in the city of Banda Aceh, Indonesia, mortality rates were ten times higher in neighbourhoods with a tree-structured street grid compared to neighbourhoods with a network-structured street grid (Fakhurrazi and van Nes 2012). Therefore, the axial sightline matters for human navigation in panic situations as well as in daily life. Seemingly, people follow their nose in the way they orientate through built environments (Dalton 2001). Therefore, it is worth focusing on the role of the axial sightline as a basic element for the analysis of the street network.

Urban public space is mostly 'linear'. Except for squares, the streets, roads, paths, avenues, pavements, or boulevards are linear items. Therefore, each spatial element of the street network can be represented as an axial sightline indicating movement paths. The axial line is a sightline with an underlying movement logic. To produce an axial map, all roads, streets, paths, subways, bridges, and tunnels are modelled in the same way using an axial line. The road width per se is not taken into account and is only indirectly measured in that the length of the axial line picks up the width of the street. For two streets with the same length, the wider street will have the longer axial line compared to the narrower street. As a basic tool, space syntax applies the axial map as the minimal set of longest straight sightlines indicating movement interconnecting all open spaces (Yamu and Voigt 2011; Yamu et al. 2021). In other words, the axial map represents urban space that is possible to visually overlook and physically access (Marcus 2007). Marshall claims that the axial line reflects the geometry of bounded space (Marshall 2005). An axial map is the geometric model of an urban street network that can translate into a topological graph (see Chap. 1).

Because the space syntax analysis utilises a graph-theory approach, the axial analysis examines the movement routes' degrees of (inter)connectivity. For a strategic city model, whether a street incorporates a tram or bus line or is pedestrianised or only accessible for public transport is not at stake here. All streets and roads are treated in the same manner and fashion for generating an axial map. Metro lines, railways, and light rail tracks are not taken into account in the axial map when they are separated from a street or road network. Human movement for metro and train services are regulated by introduced frequencies and predefined routes. Nevertheless, the location of public transport stops and stations in the street network is of interest. How these are accessible to their surroundings matters for making public transport accessible.

Figure 2.1 illustrates an example of how urban space can be abstracted and represented with a set of axial lines (b) and segments (c) for the Ferdinand Bolstraat area in Amsterdam (a). For each public space, an axial line is drawn. Thus, an urban street network is represented by the longest and fewest set of axial lines interconnecting with one another. With the axial map, we abstract and simplify reality. For the segment map, the axial map is broken up into segments at each street intersection.



(a) Figure-ground diagram (b) Axial representation (c) Segment representation

Fig. 2.1 A figure ground diagram (**a**), an axial (**b**), and a segment (**c**) representation of the Ferdinand Bolstraat area in Amsterdam

The basis for drawing an axial map can be any kinds of urban maps, as long as the public open spaces are visible. At present in the era of digital services, Google Maps, Bing Maps, and similar products can be used as base maps. Historic maps have to be digitalised to create, for example, discrete space syntax models through time. Once a digital version of an urban map is available, the axial map can be drawn using a variety of software, including Geographic Information System (GIS), Adobe Illustrator, AutoCAD, or Vectorworks. In general, any software can be used that allows one to draw and export .dxf files or interchangeable formats such as .mif files. The advantage of GIS is that the map is georeferenced, which is useful for later correlations with socio-economic data.

An axial map should always be drawn on a separate layer. When drawing an axial map, some simple rules have to be followed. All streets, roads, paths, etc. are equally represented as a set of the longest and fewest number of axial lines. At every direction change, make sure that the individual axial lines (in the latter, we will also call them 'axes') overlap well. Even though the axial stubs look 'ugly' at the junctions and in the bends of curved streets, it is better than to have an axial map with streets that are disconnected where they should not be.

Figure 2.2 shows some typical beginner's errors. The first error is to draw too many axial lines for a street. When the street is straight or its width varies, it is the longest through vision that is represented as one continuous line. Yet another new beginner error is to draw too many axes in curved streets. The second error is that streets are poorly linked because the connecting axes lack the axial stubs. Streets with a large-radius bend need to have long axial stubs to ensure that they are connected when importing the axial map into the space syntax software. The third error is to represent squares as 'objects'. The axes from streets connected to squares need to be drawn over the squares until they reach a physical obstacle like a building or a fountain.

Roundabouts can be represented in several ways. The only exception is when there is an object blocking the through vision, like a column or a tower (see below in Fig. 2.2). The same accounts for complex highway junctions. In most cases, a single axis can be used for highways with several lanes. The advantage is less time used for 'unlinking' (see explanation below) the highways from the local streets. A spaghetti junction can be presented either as two single axes crossing each other or by representing each fly-over with axes. The advantage of representing a spaghetti junction with two axes crossing each other is that there is no need to unlink these lines. All roads are in some way connected to each other.

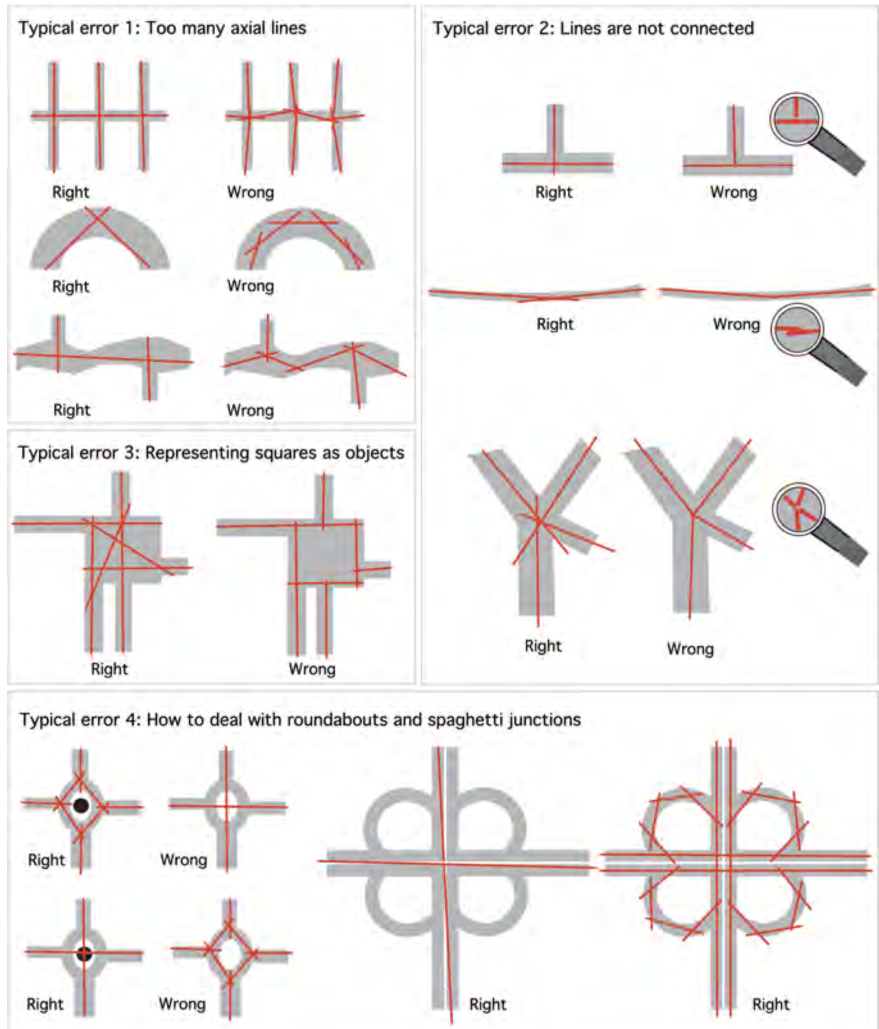


Fig. 2.2 Some typical beginner's errors and general advice for drawing an axial map

However, axial maps can be drawn in different resolutions with more or less detail. This depends on the scale level you are interested in, the focus of movement—for example, car versus pedestrian movement—and the (research) question under scrutiny. The quantum of the information influences the drawing and analysis of the axial map. An axial map can be of low, medium, or high resolution. A low-resolution model includes only the major relationships between aspects of the built environment. A medium-resolution model extends this by adding more pragmatic relations of the built and unbuilt environment. This can be, for example, a column or water feature in a public space that is taken into account. The major difference in the high-resolution axial map to all others is that the sidewalk and street crossings will be the focal point for drawing the axial map. This kind of axial map is used to generate local pedestrian models.

Another important feature in space syntax is to 'unlink' crossing axial lines that should not be connected. In reality, urban space often consists of complex overlapping axial lines that might not connect to each other, even though they look like they would in the plan. Overpasses, underpasses, tunnels, and stairways are good examples. If an axial map links overlapping lines that do not in reality connect, the analysis would be skewed and inaccurate. To deal with these conditions, it is possible to 'unlink' overlapping lines that do not share links in reality in the space syntax software (Space Syntax Ltd 2004).

In the following, we introduce some simple static spatial analysis techniques to illustrate the various degrees of connectivity a particular street has to its vicinity. In mathematics, connectivity is one of the basic concepts of graph theory. In space syntax, connectivity is applied to explain the number of connections each street has to its direct neighbouring streets. These simple static spatial analyses can be done manually as well as by using software.

2.2 Connectivity

Connectivity is a static local measurement, and it accounts for all direct connections each street has to other streets in its immediate vicinity. A street with many connections to its side streets has a high connectivity value, whereas a street with a few connections has a low connectivity value. These values can be visualised using a colour range. For example, the degree of connectivity for each street in the town of Mannheim in Germany is visualised on a map in Fig. 2.3. The axial lines marked in red and yellow are the streets with the highest numbers of connections to adjacent streets. All the streets with dark blue colours have only one or two connections in their vicinity. Streets in the city centre have high connectivity values. One of Mannheim's main shopping streets, Kurpfalzstraße, is the street with one of the highest connectivity values. This north–south-orientated street runs through the middle of Mannheim's city centre. Likewise, Kurpfalzstraße's side streets also have high values. The street with the highest connectivity (in the north of the city) is a local residential street. Its side streets have very low connectivity.

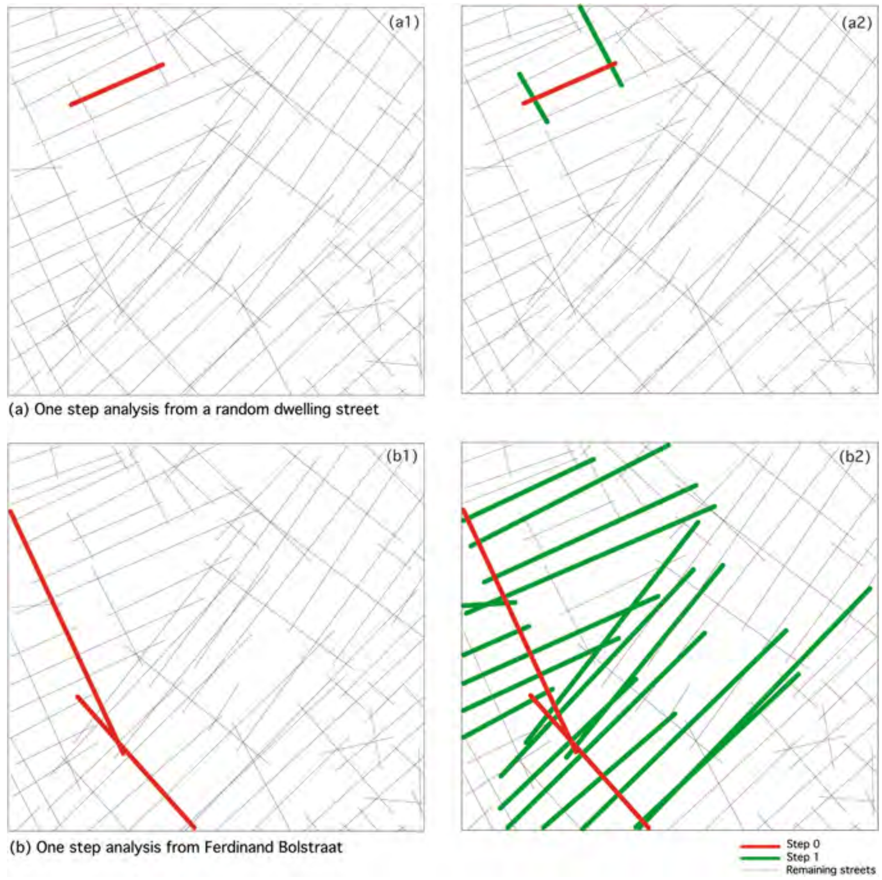
Fig. 2.3 Mannheim's connectivity graph

Connectivity analysis is thus very simple. It is about counting the number of connections each street has to its adjacent streets. In the following, we will demonstrate some more advanced connectivity analyses.

2.2.1 One-Step Analysis

This type of analysis is also a connectivity analysis, and it demonstrates how directly a street or road is connected to its vicinity. Figure 2.4 depicts a one-step analysis from a random residential street (a) and shopping street (b) as the origin in the Ferdinand Bolstraat area in Amsterdam. They are indicated in red. The residential street has two direct connections, whereas the shopping street has 25 direct connections to other streets. These connected streets are coloured in green. The shopping street consists of two axial lines with the reasoning that the street is curved. The shopping street can also be represented as one curved street segment.

Fig. 2.4 Examples of one-step analyses in the Ferdinand Bolstraat area in Amsterdam



The higher the number of axial lines directly connected to the street under scrutiny, the more this street is connected to its surroundings. The one-step analysis is useful for understanding the degree of connectivity of chosen streets to their vicinity.

Main routes are defined as routes people choose to travel through and between urban areas (van Nes 2009). For a city, main routes can be identified by highlighting all long streets whose endings abut long streets at an angle close to 180° Herein, Figuradeiro (2005, p. 165) defines a continuous line with the following rule of thumb: Streets that are connected to each other with an angle of 145–215° or streets that deviate less than 35° from a straight line are considered as 'continuous' lines. This insight builds upon the line of thought of Klaus Humpert that pedestrians have an 'ideal movement line' to reach their end point. According to Humpert (2007), if the ideal movement line deviates from the end point by more than 20°–30° off the existing movement line, the pedestrian re-orientates his/her direction. This is how path branching develops. Most old boulevards, main streets, and main distributors tend to have long visual sightlines indicating movement paths. Figure 2.5 illustrates a one-step analysis for main routes in the Pijp and Bijlmermeer areas in Amsterdam.

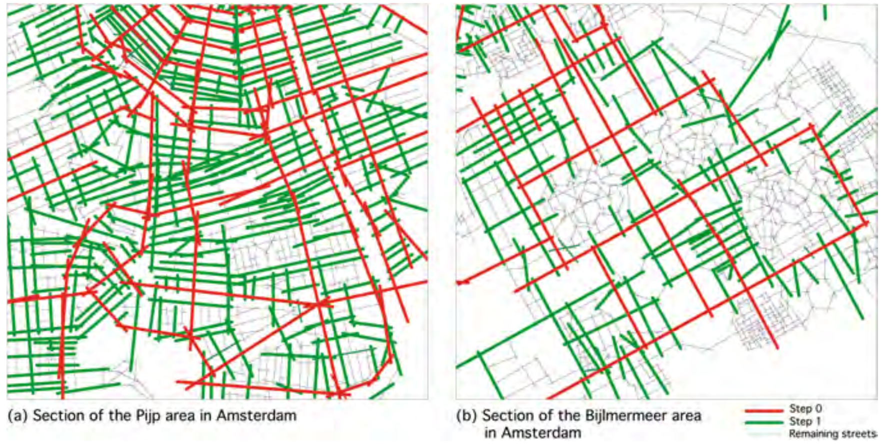


Fig. 2.5 One-step analyses of the main routes in the Pijp (**a**) and Bijlmermeer (**b**) areas in Amsterdam. The Pijp neighbourhood is a nineteenth-century built-up polder area, and Bijlmermeer is a modernist neighbourhood, planned and built in the 1960s

For both the Pijp and Bijlmermeer areas, we marked all of the longest sightlines indicating paths in red (step zero). All connecting streets to the indicated streets in red are marked in green. These represent the one-step analysis for the main route network. All remaining streets are indicated in grey. From the one-step analysis, we see that the number of green axial lines connected to the main route network is high in the Pijp area. Further, Pijp's main route network itself has a high density. Therefore, this neighbourhood is a topologically 'shallow' system because it is well interconnected. All destinations from all origins can be easily reached. Thus, the number of remaining streets indicated in grey is low. For this area, by changing the direction only once or twice, a main route can be reached.

In contrast, for the Bijlmermeer area, the main route network is more fragmented and has a lower density than the Pijp area. Undertaking the one-step analysis, the axial lines in green also depict a fragmented pattern. The number of remaining axial lines is higher than in the Pijp neighbourhood. Compared to the Pijp area, the Bijlmermeer area is a topologically 'deep' system. It requires a high number of direction changes to reach the main route network.

This analysis demonstrates the interconnective relationship between main routes and local street networks. Historic and pre-war urban areas have a distinct street hierarchy established, and the main route system can be easily identified on a normal street map. For a traditional European city, the main routes often form a 'deformed wheel'. The main route network functions as the urban backbone, and major streets lead through urban local centres, whereas for a number of modernist areas, the main route network bypasses the local centres and they become suburban, poorly accessible pockets.

2.2.2 Two-Step Analysis

This type of analysis allows one to depict the local catchment area for two direction changes in the network from a chosen set of axial lines. The visualised 'two-step grid' shows the degree of accessibility to the surrounding neighbourhood. This analysis can be manually carried out by indicating in a colour the chosen streets under scrutiny (step zero) . In the next step applying the one-step analysis logic, all connecting streets are marked in a different colour (step one)—here coloured in green. Now from these streets again, all connecting streets are marked in another colour (step two).

In our examples for a residential and a shopping street in Fig. 2.6, the streets located two topological steps or two direction changes away from the origin streets are marked in blue. The sum of all axial lines of step one and step two comprises the catchment area for the chosen streets indicated in red. For the shopping street (Fig. 2.6), the local catchment area of the two-step analysis covers most of the street network in comparison with the one-step analysis (Fig. 2.4).

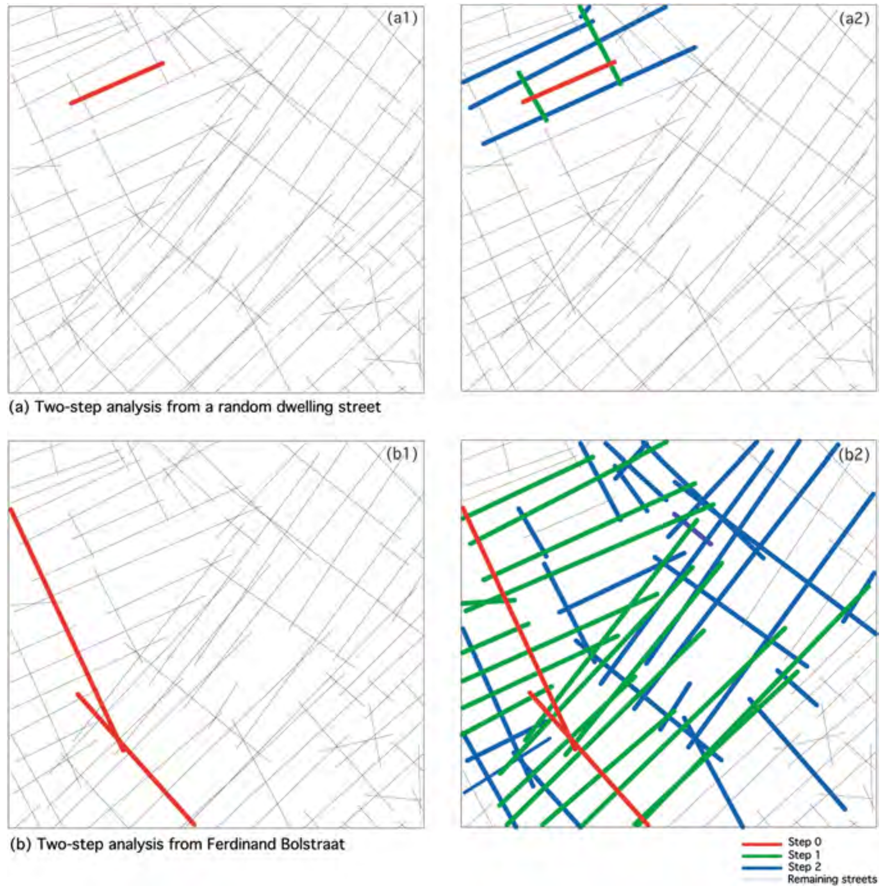


Fig. 2.6 Examples of how to conduct a two-step analysis for a residential street (**a**) and a shopping street (**b**) in Ferdinand Bolstraat in Amsterdam

Streets covering most of an area's street network with a topological 'two-step grid' (Hillier 1999, p. 119) within short metric distances are often an area's vital local shopping streets. For Hillier, for the disposition of shops, the density of the streets inside the two-step grid within short metric distances is what matters, not the length of the axial lines. This simple static spatial analysis can be applied for testing the degree of connectivity and therefore the accessibility a local shopping street has in its neighbourhood.

However, two types of urban patterns for shopping areas can be distinguished in Fig. 2.7: (left) a linear pattern and (right) a cluster pattern. For a linear pattern, the shops are aligned alongside a street with high connectivity to its vicinity with a short metric distance. Shopping in such a shopping area is mostly convenient and efficient on foot, bicycle, or public transport. In city centres, this type of street is often pedestrianised as an integral part of a pedestrian zone. This linear urban pattern type often appears in traditional, naturally growing cities and neighbourhoods.

For the cluster pattern, the shops tend to be located in modernistic areas where the buildings are not grouped as urban blocks. The shops are clustered in a designated area with short metric distances between the shops. This area is highly accessible by car. Independent of their size, these shopping areas tend to provide an open square with some benches. The larger ones have copied the narrow labyrinthine street pattern of an old historic town centre. Some shopping areas have only indoor facilities (and these often translate into shopping malls and shopping centres). These indoor spaces are only accessible during the shops' openings hours. This shopping experience for the clustered pattern of shops is mostly car-based because the shopping tour begins and ends at the car's parking spot.

Our example in Fig. 2.7 depicts Ferdinand Bolstraat and the Oostpoort shopping centre in Amsterdam to illustrate both types of urban patterns for shopping as active land use. Ferdinand Bolstraat is a local shopping street for the large and densely populated Pijp neighbourhood inside the ring road of Amsterdam. Moreover, this shopping street is also the main route running through the Pijp neighbourhood towards the city centre. Large numbers of cars, trams, bicycles, and pedestrians frequent this linear shopping street.

Compared to Ferdinand Bolstraat, Oostpoort has a low density of axial lines in its vicinity. This indicates larger block sizes and therefore a pedestrian-unfriendly environment in the vicinity of the shopping centre. Inside the shopping centre, some artificial short blocks are made. The spaces between these blocks are only accessible to the public during the shopping centre's opening hours. The Oostpoort shopping centre is located close to regional highways (van Nes 2005).

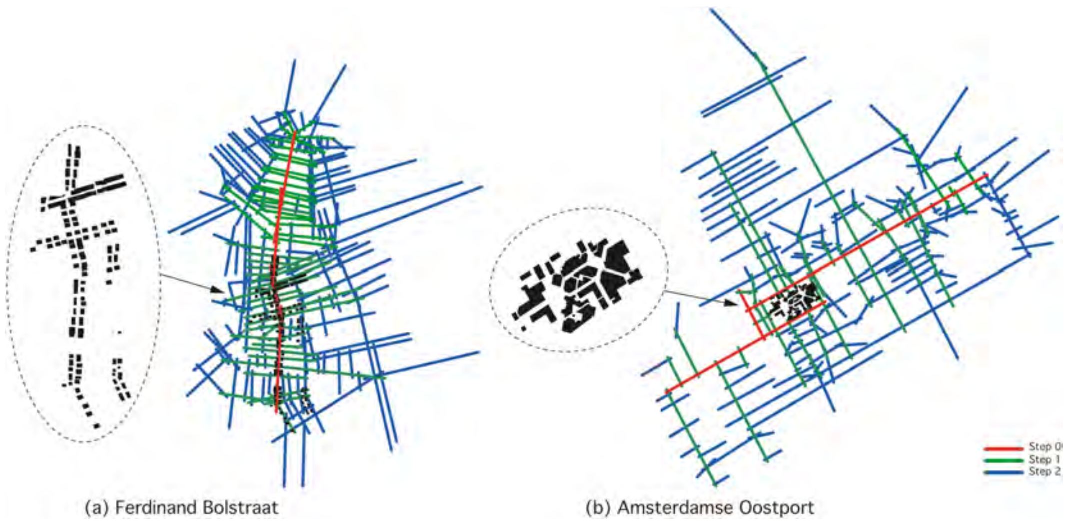


Fig. 2.7 Spatial features of an urban linear (**a**) and cluster (**b**) pattern for shopping

The higher the street network density for the two-step grid for a shopping street, the higher the number and variety of shops. The types of shops might change in line with how society changes, whereas some types of shops might disappear due to online shopping, new types of shops or commercial activities will emerge on their spots as long as there is no economic regression. Aside from the influence of online shopping on current land uses, the rule of thumb is that diverse active land use emerges along streets with many connections to their vicinity. In contrast, clustered shopping areas, shopping outlets, and shopping malls are connected to the regional scale, but they serve both the local and regional scales. A clustered shopping area is also connected to surrounding residential areas to reach local and regional customers. A shopping mall's location is often adjacent or in close proximity to the main routes in a city. On a citywide scale, emerged historic main streets and shopping streets have a high number of connections to other streets. Thus, their location is central to the urban system. The more the local shopping streets are, the more they depend on a strategic spatial position in the neighbourhood. A two-step analysis shows in what way shopping streets and shopping areas are centrally located. Figure 2.8 shows the public realm of the Oostpoort shopping centre (left) and Ferdinand Bolstraat (right) in Amsterdam.

Fig. 2.8 Images of the public realm of Oostpoort shopping centre (left) and Ferdinand Bolstraat (right)

2.2.3 Three-Step and N-Step or Point-Depth Analyses

To recapitulate, the one-step and two-step analyses demonstrate how a particular street or road is connected to other streets or roads in its direct vicinity. For the analysis, the number of syntactic steps from a particular axial line or street segment can be increased. Figure 2.9 shows how to conduct a three-step analysis using our previous example of a residential and shopping street. The three-step analysis for the shopping street shows that the 'three-step grid' covers almost every street in the neighbourhood, whereas for the residential street the third syntactical step is the shopping street itself.

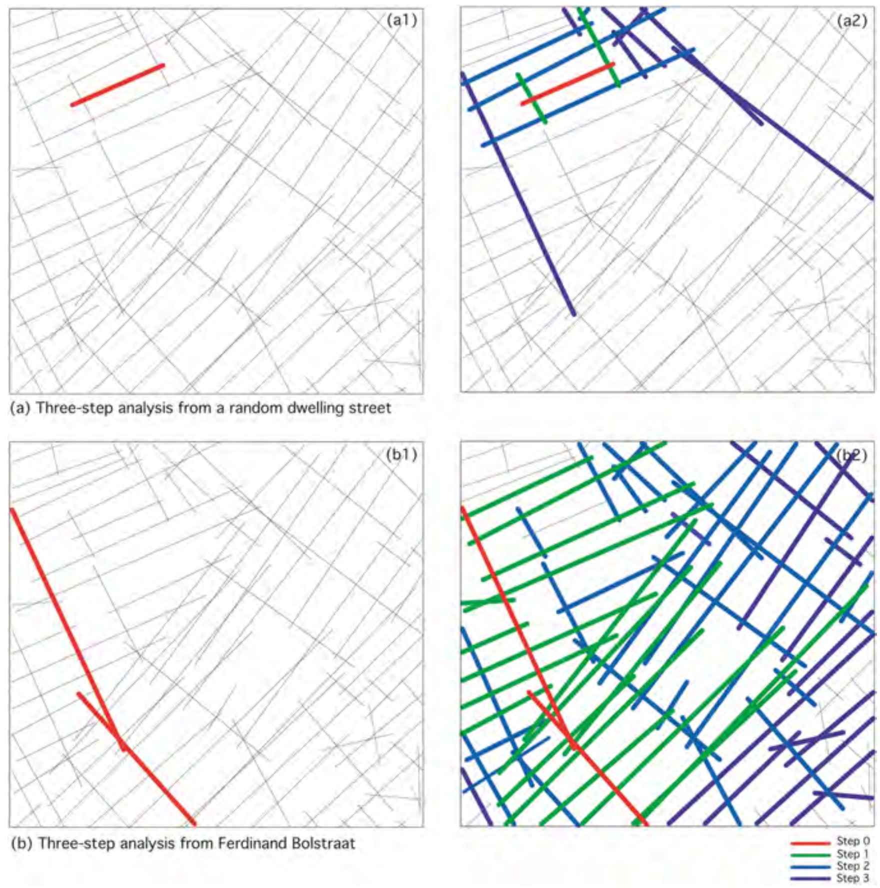


Fig. 2.9 Examples of how to conduct a three-step analysis for a residential street (**a**) and a shopping street (**b**) in Ferdinand Bolstraat in Amsterdam

An n-step analysis, also called a point-depth analysis, illustrates how topologically deep all streets and roads are in relation to one particular street. The scheme in Fig. 2.10 illustrates an n-step analysis with six syntactic steps. For each direction change away for the street under scrutiny, the syntactic step value (step 0, 1, 2, … n) increases. The length of the axial line or sightline influences the depth value, and each axial line has a single value attribute. The n-step analysis can be applied to an individual street, several streets, or a whole main route network simultaneously. N-step analyses are mostly applied to public transport stops, railway stations, and shopping streets to measure the ease of reach of these amenities from a location in the city and between them. For a public transport network, n-step analyses can measure how well the network of public transport stops covers the city in terms of direction change. This analysis can also be utilised for testing the degree of ease of reach to hospitals, schools, service centres, etc. Figure 2.11 shows an n-step analysis from all railway stations in Rotterdam. As can be seen from the figure, the areas in south-west Rotterdam have poor rail accessibility.

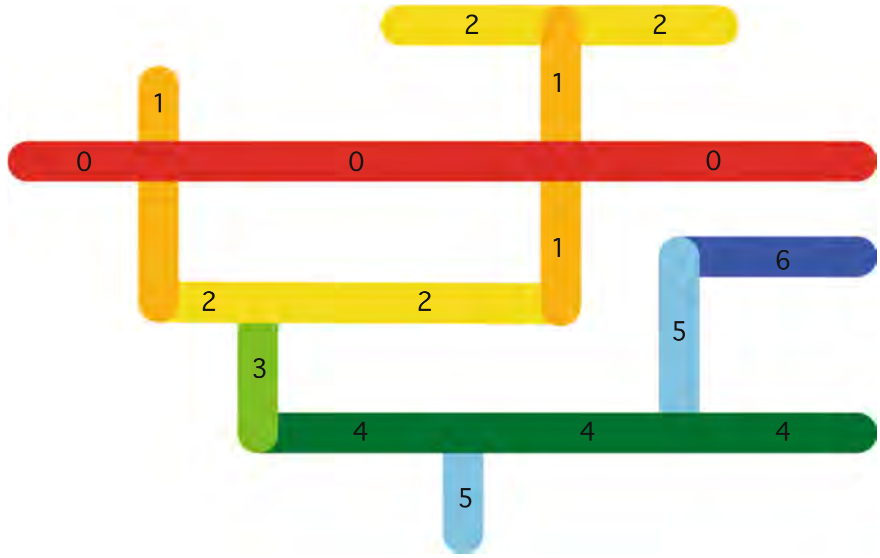


Fig. 2.10 Scheme of how topological depth is calculated from a chosen street (step 0)

Fig. 2.11 N-step analysis from all railway stations in Rotterdam

2.3 Global Axial Integration Analysis

'Global integration' describes how a street relates to all other streets in a predefined spatial system. This can be a neighbourhood, a quarter, a district, a village, a town, a city, or a region. In the context of globalisation, the concepts of 'global' and 'integration' are sometimes used to refer specifically to the integration of international economies through trade, foreign investment, and capital flows and to social issues such as migration, the spread of technology, and the transnational circulation of ideas, languages, and cultures (Bhagwati 2004). This must not be conflated with the meaning of the space syntax term 'global integration'. 'Global' in the space syntax jargon defines using a system-wide radius for spatial analysis. Therefore, global integration is, for example, citywide integration.

Global integration analysis estimates the degree of accessibility a street has to all other streets in the urban system taking into consideration the total number of direction changes of the urban entity (Hillier 1996). Mathematicians call this 'to-movement'. A global integration analysis calculates how spatially integrated a street axis, i.e. axial line, is relative to all other streets in the system. The fewer the changes of direction, i.e. syntactic steps, from a street to reach all locations in the system, the higher the global integration value of the street. In contrast, streets from which many direction changes have to be taken to reach all other locations in the urban system tend to have low global integration values. They are spatially segregated. In short, the longer the axial line and the higher its connectivity to other axial lines, the higher its integration value and vice versa.

Figure 2.12 shows town X with its morphological footprint (a), its unprocessed axial map (b), and its axial integration analysis results (c). Remember that the axial map is the set of fewest sightlines indicating movement paths. Each axial line represents a public urban space that connects to other public urban spaces. It is thus possible to calculate how each axial line is interrelated to all other axial lines in the given system. In other words, the topological depth of each axial line in relation to all other axial lines is calculated. A syntactic step is taken for each direction change. For the axial integration analysis, the values are coded in colour (c) where the red axial lines are the most integrated axes and the dark blue axial lines are the most segregated. The same colour scheme is also applied to the nodes of the justified graph (d). The justified graph illustrates how the system can be experienced from the most integrated street. Applying the logic of an axial map as the map with the fewest lines for the graph, "the lines are represented as nodes and the intersection of lines as connections between the nodes"

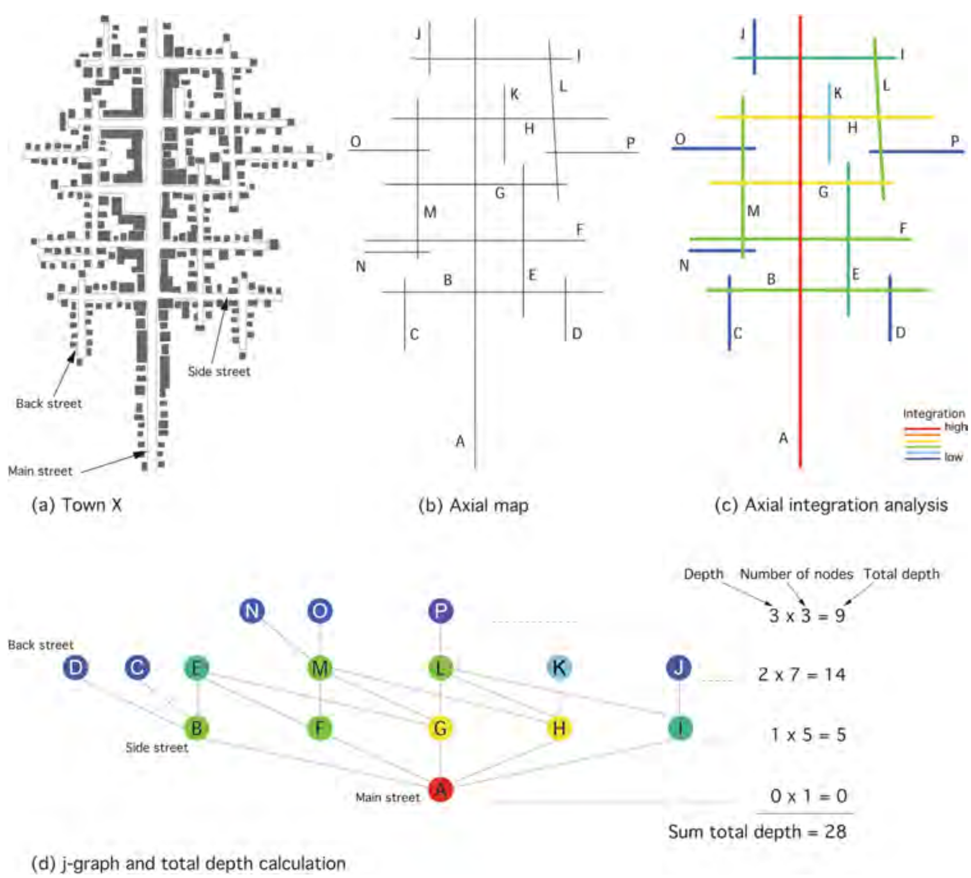


Fig. 2.12 Calculating total depth for town X with the main street A as the root node

(Turner et al. 1993, p. 425). The justified graph shows how the individual components of a system are connected to each other in an abstract manner.

In the following, we show how to calculate the global axial integration for town X (Fig. 2.13). The dead-end street, indicated with a C, is chosen as the root node or starting point or step 0. First, we calculate the total depth from the root node to all other streets. The total depth is defined by the number of spaces that must be passed through a chosen or given starting point in a system. Total depth is calculated by the sum of all possible steps from a given starting point. In other words, the total depth sum is calculated by first multiplying the number of spaces by the number of the respective topological depths and then summing up all values for each topologic depth. For our example in Fig. 2.13, the total depth is the sum of 1 root node (0 × 1) + one direction change for one space (1 × 1) + two direction changes for 3 spaces (2 × 3) + three direction changes for four spaces (3 × 4) + *n* direction changes for *n* spaces.

The total depth sum of the justified graph (j-graph) in Fig. 2.13 has the numerical value of 50. From total depth, the mean depth can be derived. Mean depth is equivalent to total depth relativised to the number of axial lines or nodes of the system and represents the average number of steps needed to reach any of the axial lines in the system. In the next step, mean depth is normalised and then the effect of the system's size is relativised. This allows all urban systems to be compared with each other.

In general, the mean depth values for cities vary with different cultures. Karimi (1998, pp. 269ff) and Hillier (2001, p. 02.9) point out that the topological mean depth for most European cities is a value around 3, for US cities it is around 2, while for Arab and Persian cities it is around 5. The orthogonal grid of most postmodern North American cities is a topologically shallow system, while labyrinthine Arabic cities are known to be topologically deep systems. The reasons for these local variations of the street network are culturally driven and demonstrate how local cultural traditions influence the built form differently.

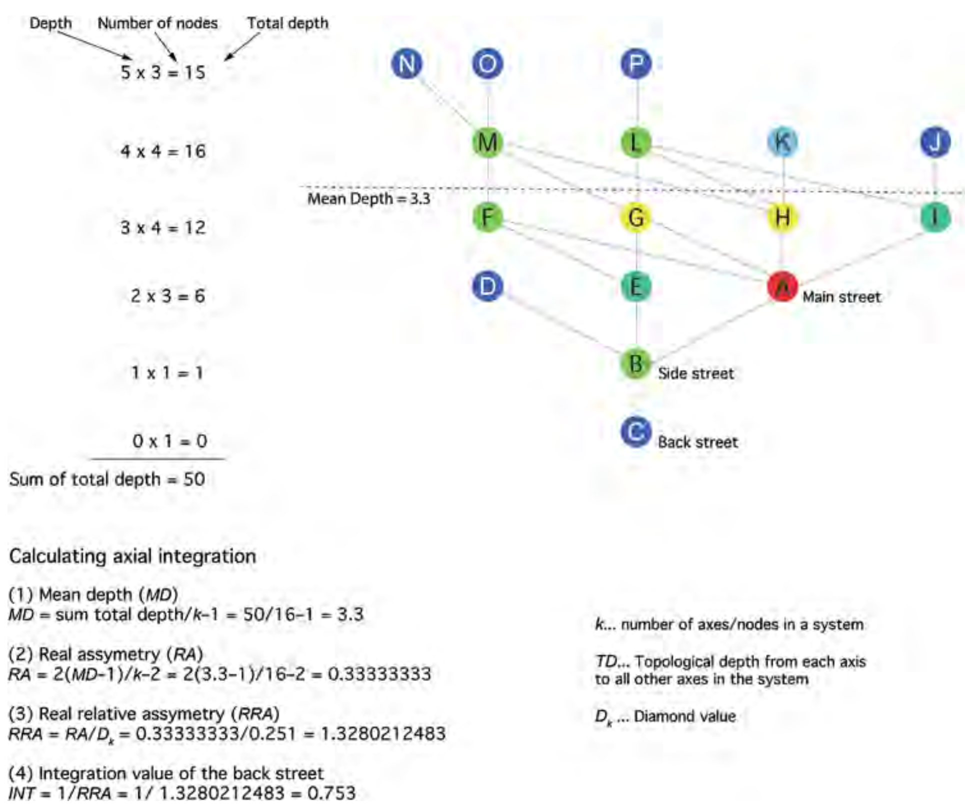


Fig. 2.13 Calculating the global integration of the cul-de-sac street C of town X

For an in-depth understanding, and if you like mathematics, we elaborate in the next chapter how to calculate spatial integration. For the non-mathematically interested readers, we suggest moving to Sect. 2.3.2 “Global spatial integration and segregation”.

2.3.1 The Mathematical Formulas for Calculating Global Integration

The mean depth is equivalent to the total depth relativised to the number of axial lines or nodes of the system and represents the average steps needed to reach any of the axial lines in the system. For our example, we calculate mean depth (MD) for the cul-de-sac indicated with ‘C’ in Fig. 2.11 as

$$MD_C = \frac{1}{(k-1)} \sum_k d_{Ck} \tag{2.1}$$

where k stands for the number of axes in the system, and d stands for the total depth. $\sum_k d_{Ck}$ stands for the total depth sum from the root node C to all other spaces in town X.

In addition, the relative asymmetry can be calculated. The mean depth provides the basis for the relative asymmetry, which provides a normalisation of the mean depth measure between zero and one. “This will indicate a space from which the system is shallow, that is, a space which tends to integrate the system, and high values indicate a space which tends to be segregated from the system. Relative asymmetry (or relative depth) can therefore be thought of more simply as the measure of integration” (Hillier and Hanson 1984, p. 109). Relative asymmetry is calculated as

$$RA_c = \frac{1(MD_C - 1)}{(k-2)} \tag{2.2}$$

The interpretation of spatial integration is sensitive to the scale of the axial maps because their diamond values are dependent on the size of the spatial system at issue (Krüger and Vieira 2012, p. 194). The effect of relative asymmetry depends on the size of the system. Therefore, real relative asymmetry provides a relativisation that allows comparison of depth between different sized spatial systems. In line with Hillier and Hanson (1984, p. 110ff), “real relative asymmetry is used to eliminate the considerable effect that size can have on the level of relative asymmetry values in the real system”. Real relative asymmetry is calculated as

$$RRA_C = \frac{RA_C}{D_k} \tag{2.3}$$

where D_k stands for the diamond value that eliminates the effects that size can have on the relative asymmetry value. Adding the diamond value to the calculation of axial integration is a normalising measure of a particular node of a graph with n nodes. It is a kind of ‘centrality measure’ that is obtained if that node were the root of a standardised graph in a diamond shape with the same number of nodes (Krüger and Vieira 2012, p. 195).

Figure 2.14 illustrates a simple experiment with a diamond-shaped graph for a particular street or node in a graph. In our example, the diamond shape $D_k = D_{10}$. We assume for our sample spatial system that it consists of 10 streets represented by 10 nodes in the justified graph.

The topological depth of the node at the bottom is 4 because at the broadest part of the diamond, there are four spaces. This system in Fig. 2.14 has 5 levels. The k stands for the total number of spaces, and the n represents the broadest part of the diamond, or the level of depth with the highest number of points. Here in this simple example the node in the equation below has the value 4, taken from the number of spaces at the step of the broadest part of the diamond. When calculating the integration values for every single street, the D_k value varies from street to street.

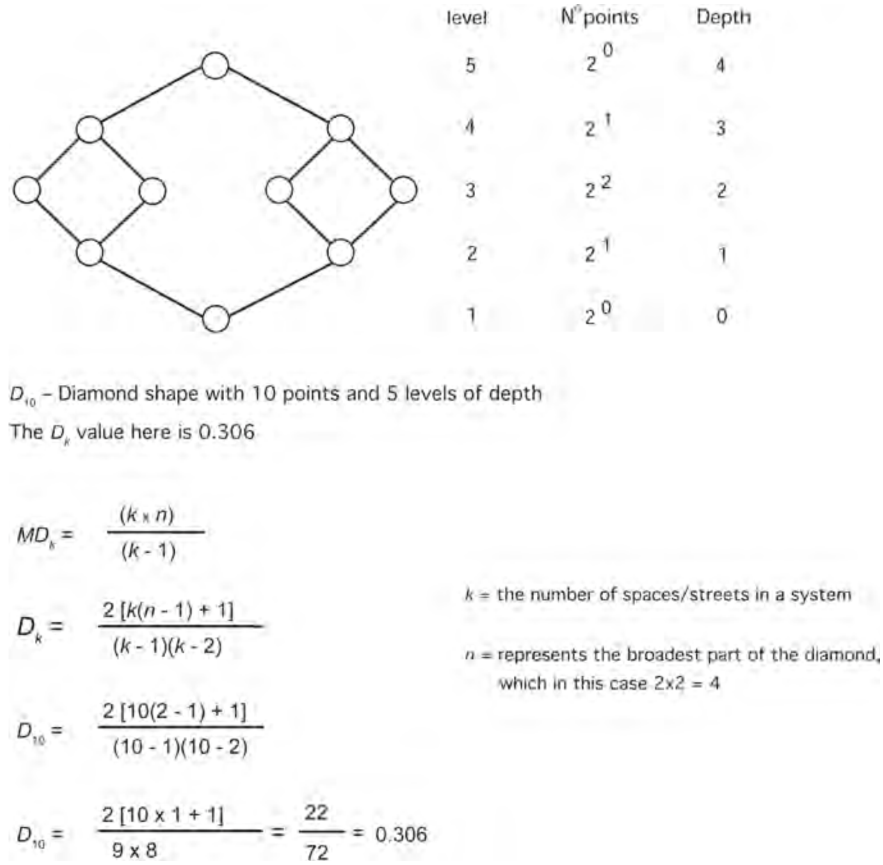


Fig. 2.14 How to calculate diamond values

The diamond value allows one to compare the integration value of an axial line of a particular city with the integration value of an axial line in another city. Thus, spatial systems can be compared. Further, it allows one to study the changes in the integration of a street in the same city over time. Hillier and Hanson explain that the diamond value is dependent on the total number of spaces in a system (Hillier and Hanson 1984, p. 112). For example, town X comprises 16 axial lines and thus its diamond value is 0.251 given the dead-end street root node (Fig. 2.12).

High real relative asymmetry values mean greater depth, and this implies less activity and greater segregation. In order to operate with high values for integrated streets and low values for segregated streets, global integration is the reciprocal of real relative asymmetry. The global integration value is calculated as follows:

$$\text{Global integration} = \frac{1}{RRA_c} \tag{2.4}$$

Integration enables the measurement of the relative accessibility of a space within a system. Hillier and Hanson describe integration as a global measure of depth, relativised in such a way that differently sized systems can be directly compared to one another (Hillier and Hanson 1984).

A highly integrated street has a high integration value, and a highly segregated street has a low integration value. For the cul-de-sac street C from Fig. 2.12, the global integration value is 0.753. This value does not tell us anything unless we compare it with other streets of the same system. Figure 2.15 shows the calculation of the main street of town X. If the total depth sum starting from the main street is calculated, we arrive at a numerical value of 28. This means that the main street has a shorter topological distance to all other streets in comparison to the cul-de-sac street in Fig. 2.12. The global integration is almost three times higher for the main street than for the cul-de-sac street in town X, namely 2.027 compared to 0.753.

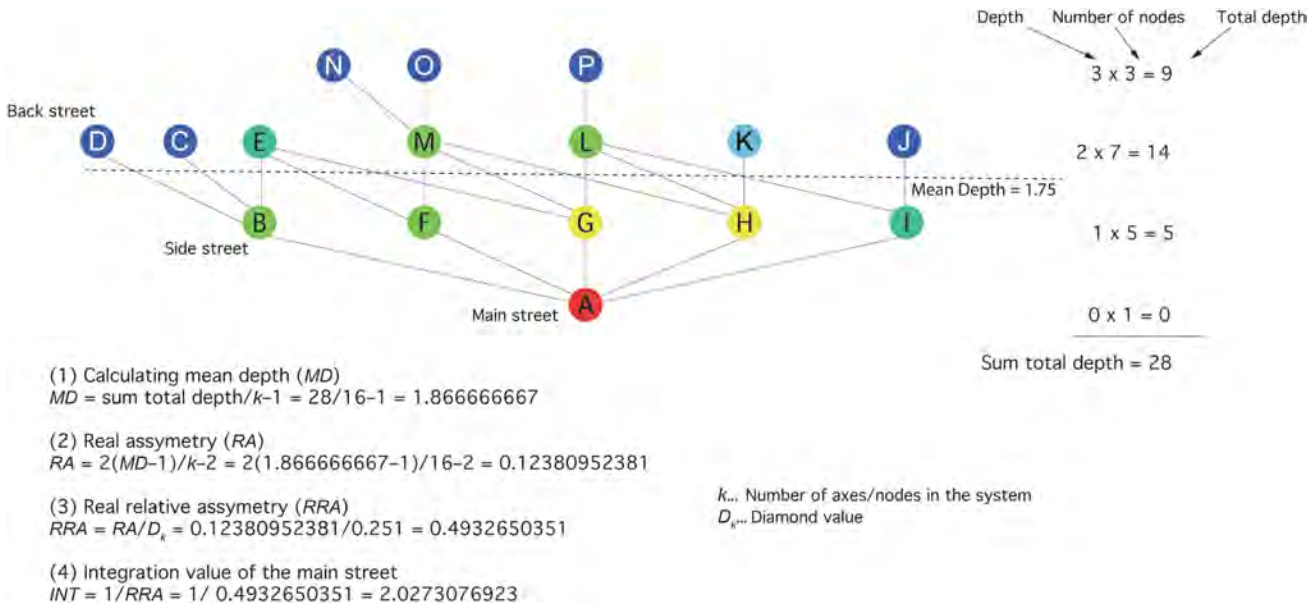


Fig. 2.15 Calculating the global integration for the main street of town X

2.3.2 Global Spatial Integration and Segregation

The more integrated a street is, the shorter is its topological distance to all other streets in the urban system. Vice versa, the more segregated a street is, the longer its topological distance is to all other streets in the urban system. In Fig. 2.16, we compare the justified graphs of our example from town X for the dead-end street with the main street. For the justified graph with the root note ‘dead-end street’, the structure depicts a more tree-like structure, and for the ‘main street’ it takes on a more bush-like structure. The bush-shaped justified graph is topologically shallower than the tree-shaped graph. If most of the spaces are located many syntactic steps away, it is more likely that the space under scrutiny will have a low integration value. In this case, it is a segregated space, and the tree-shaped justified graph is topologically deep. For our example town X, all measures can be calculated manually. With the space syntax computer application Depthmap[1] (Turner 2007), large cities’ and regions’ axial maps can be computed.

We have demonstrated how to understand integrated and segregated urban street spaces with spatial configurational relationships by applying the measure of global integration. Main urban centres have the highest global integration. Through empirical data collection, the flow of human movement and the location of various functions and activities can be registered for spaces along the axial lines and can be compared with their values of different measures (see Chap. 5).

We can apply the measure of integration to measure urban change from different time periods. In the case of Berlin, the fall of the Berlin Wall after the revolution of 9 November 1989 radically changed the street network. The erection and fall of the Berlin Wall completely changed possible movement routes from everywhere to everywhere else in the city. The wall blocked and divided the main, historic streets, thus altering pedestrian and vehicular movement in the streets of former East and West Berlin. After the fall of the Berlin Wall, the street network re-established its old configurational order with regard to the historic street network. Herein, the global integration analysis shows how the Berlin Wall affected Berlin’s urban centres and individual streets by means of their spatial integration.

[1]A short history of computer applications for urban studies: Axman (Dalton 1988), Axwoman (Jiang et al. 2000), Meanda (Dalton 2001), Mindwalk (Figueiredo and Amorim 2005), Place Syntax for QGIS (Ståhle et al. 2005), Depthmap (Turner 2007) Urban Network Analysis Toolbox for ArcGIS (Sevtsuk 2010), Space Syntax application for QGIS (Gil et al. 2015) and Form Syntax as a plug in for GIS (Ye and van Nes 2016) for a synthesis.

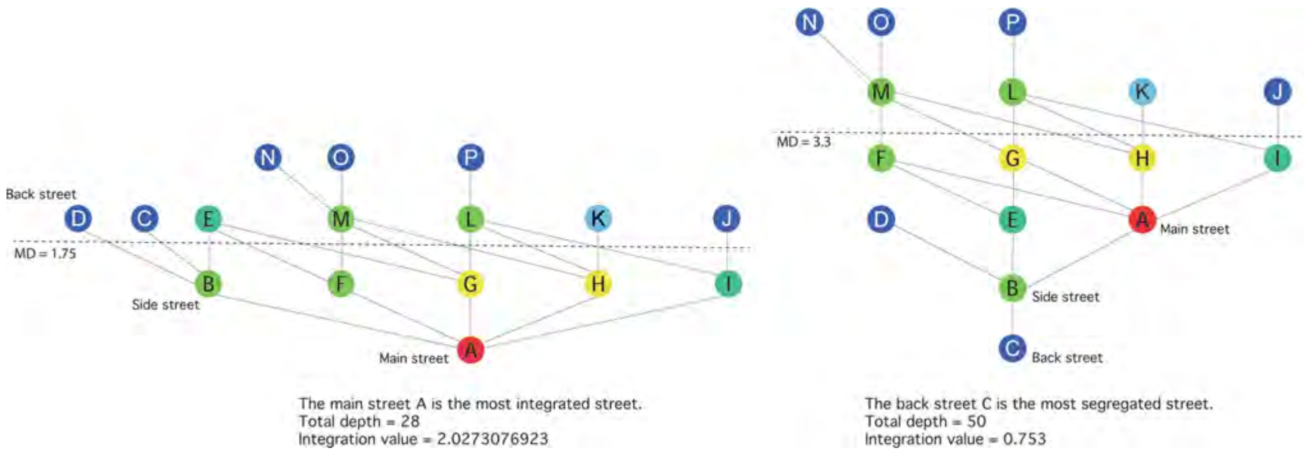
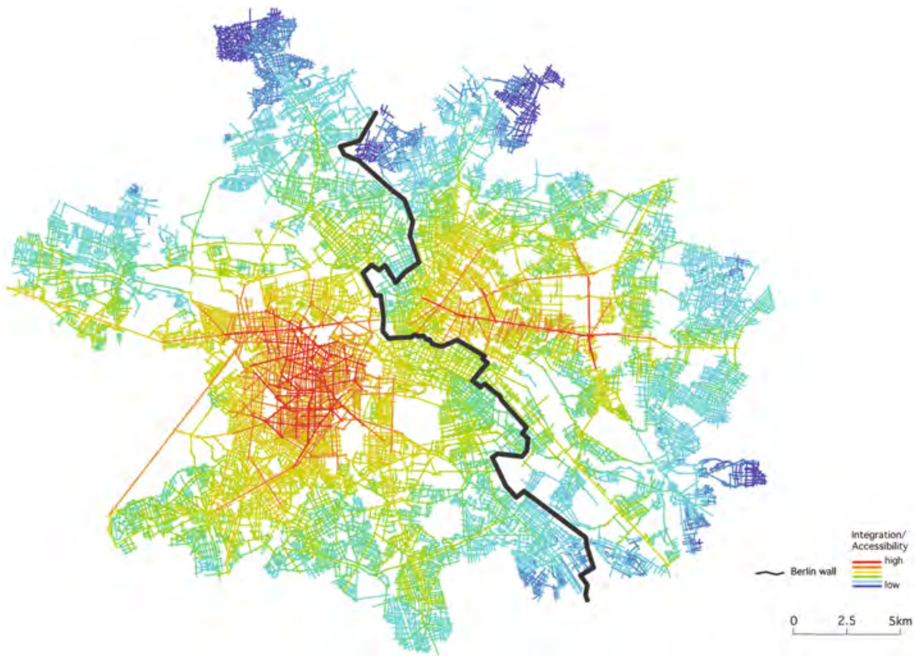


Fig. 2.16 Comparison of two justified graphs with the root nodes of a dead-end street and the main street

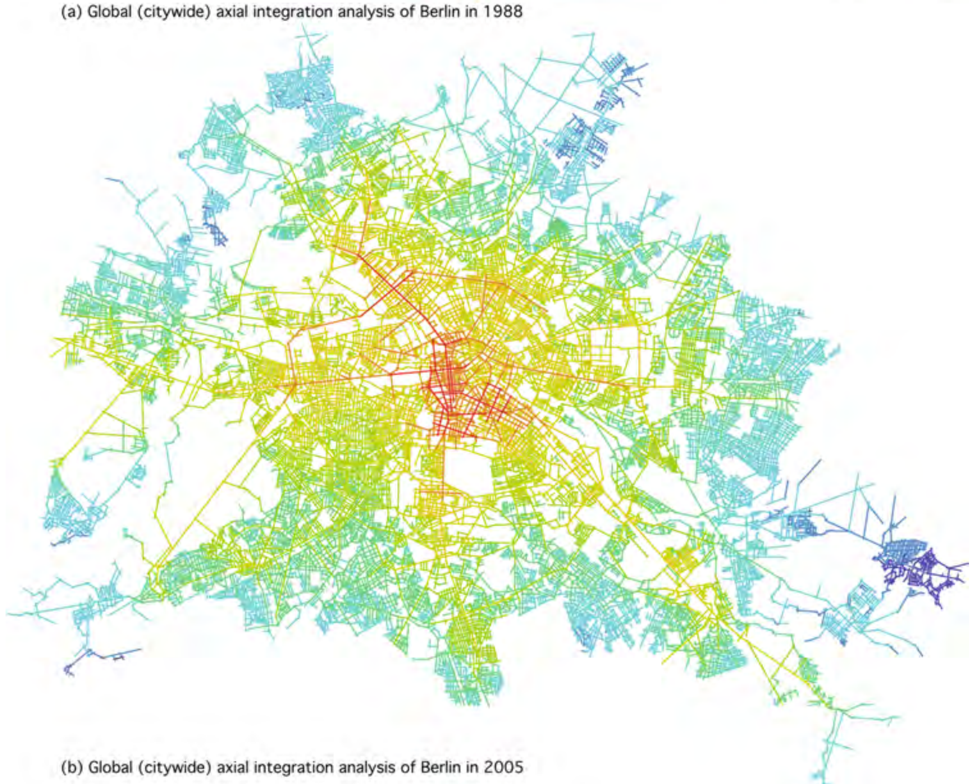
Figure 2.17 illustrates the urban change of Berlin by applying the measure of integration in 1988 and 2005. The 1988 integration analysis depicts Kurfürstendamm and Tauentzienstraße as the most integrated streets in West Berlin and Alexanderplatz as the most integrated for East Berlin. Alexanderplatz is located at the intersection of the highly integrated streets Frankfurter Allee and Greifswalder Straße, and this was the urban centre for East Berlin. Kreuzberg and Wedding are segregated areas in the analysis, indicated by green and blue axial lines, suffering from the isolated position caused by the Berlin Wall in West Berlin. The integration analysis of reunified Berlin in 2005 reveals that the central urban core has shifted to Friedrichstraße. Friedrichstraße and Potsdamer Platz were the most integrated areas of unified Berlin as far back as the 1930s, but during the era of the wall they were segregated areas. The globally, i.e. citywide, integrated Friedrichstraße is currently Berlin's high street, comparable to Oxford Street in London.

Active land use like shops is sensitive to shifting centralities, and Berlin is clearly an example of this. Friedrichstraße and Potsdamer Platz are currently Berlin's urban main centres, and the former urban main centres of Alexanderplatz and Kurfürstendamm have lost their highly central position in the urban system since the fall of the wall. Accordingly, the two centres around Alexanderplatz and Kurfürstendamm flourished during the period of the wall, while the other two centres around Friedrichstraße and Potsdamer Platz faded away during this period and flourished again after the wall came down. At present, Kurfürstendamm is a high-end luxury shopping street. Interestingly, luxury brands are often located in streets with high connectivity to their vicinities. These luxury brands avoid streets with the highest integration values, with the purpose of reducing the flow of random customers from mainstream society. Most of the mainstream customers just come and look, but cannot afford to buy. Desyllas (2000) investigated how land values changed in Berlin before and after 9 November 1989, and he showed that real estate prices increased in areas where the integration values of the street network increased after the fall of the wall. Figure 2.18 shows impressions from Berlin.

The Berlin example showcases the twofold challenge with global integration analysis. First, the urban fringe and the suburbs are highlighted as very segregated areas close to the system's boundary, which is referred to in the analysis as the so-called 'edge effect'. This will be explained in the next section. Second, many cities consist of several centres, ranging from the city's main centre to local neighbourhood shopping streets. Global integration analysis highlights the city's main centre whether the centre is a car-based shopping mall or a pedestrian-friendly high street with adjacent streets. Local sub-centres tend to be poorly highlighted in a global integration analysis.

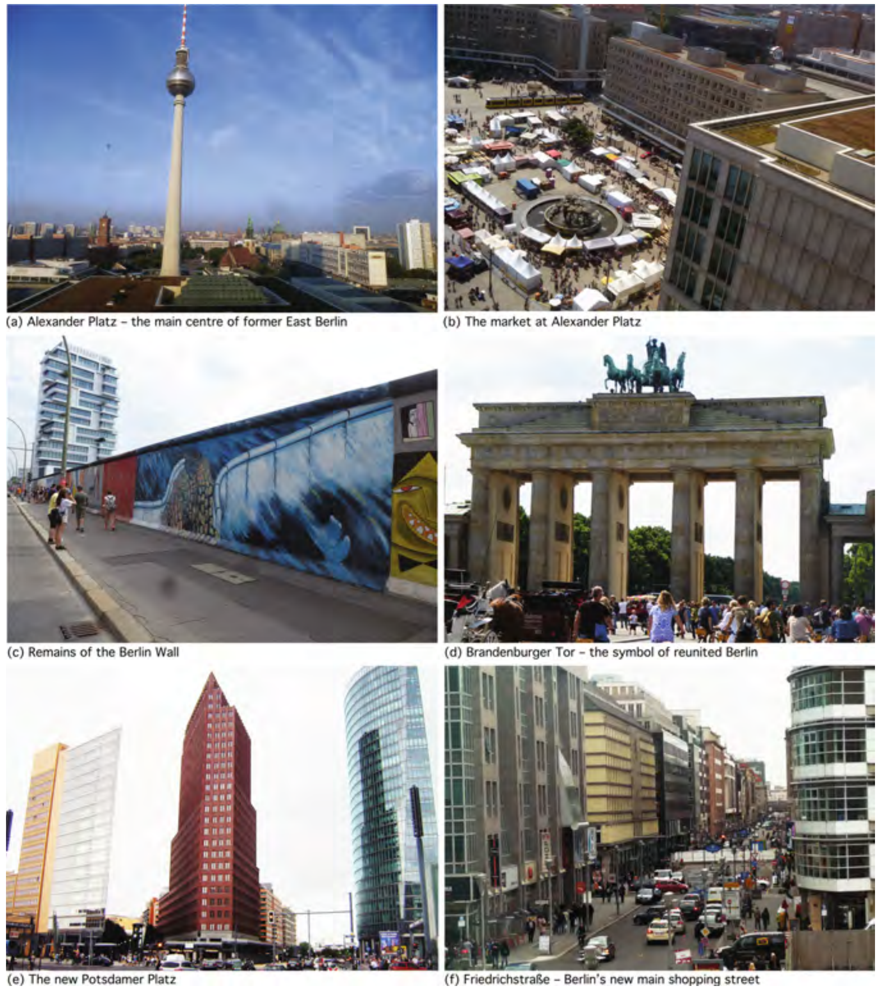


(a) Global (citywide) axial integration analysis of Berlin in 1988



(b) Global (citywide) axial integration analysis of Berlin in 2005

Fig. 2.17 Global integration analysis of Berlin in the area of the Berlin Wall in 1988 **(a)** and in reunified Berlin in 2005 (**b**)



(a) Alexander Platz – the main centre of former East Berlin
(b) The market at Alexander Platz
(c) Remains of the Berlin Wall
(d) Brandenburger Tor – the symbol of reunited Berlin
(e) The new Potsdamer Platz
(f) Friedrichstraße – Berlin's new main shopping street

Fig. 2.18 Impressions from Berlin: Friedrichstraße, Alexanderplatz, Potsdamer Platz, Brandenburger Tor, and the Berlin Wall

2.4 Local Integration Analysis

Many urban neighbourhoods and suburbs have their own local shopping areas. These local urban centres are poorly highlighted in a global integration analysis, and local urban shopping areas often have low global integration values but high local integration values. There are two options for measuring the local integration of these centres: (a) a global integration analysis of only the urban centre under scrutiny, and (b) a local integration analysis of the entire city. This section will examine the latter in detail.

In general, the key to assessing local integration is in calculating the average mean depth value of all streets within a certain syntactic radius, for example, a radius of three. For the topological radius, integral numbers have to be chosen because the radius number represents the number of syntactic steps—one cannot take a fractional topological or syntactic step like 2.5. For example, two syntactic steps include one direction change including the starting point (root node) for a radius of two. Three syntactic steps are two direction changes including the starting point for a radius of three. For a radius of four, all streets beyond three topological steps away from the street representing the root node have to be excluded.

Town X has a low average mean value of mean depth 2.525 for the whole system due to its orthogonal street network and is thus a topologically shallow system. Figure 2.19 illustrates the local integration radius of three for town X. For our example (a), we chose the main street as the root node as indicated in red. Thus, the axial lines indicated with an N, O, and P are not part of the integration radius three analysis. In example (b), we considered the cul-de-sac as the root node as indicated in red. For the integration radius three analysis, only five axial lines are considered. Figure 2.19 (c) depicts a local integration radius three analysis for the entire town X. Thus, for each axial line, the integration radius three values are calculated. When comparing the local integration values of all streets, street M has the highest local integration value followed by the main street for town X (Fig. 2.20).

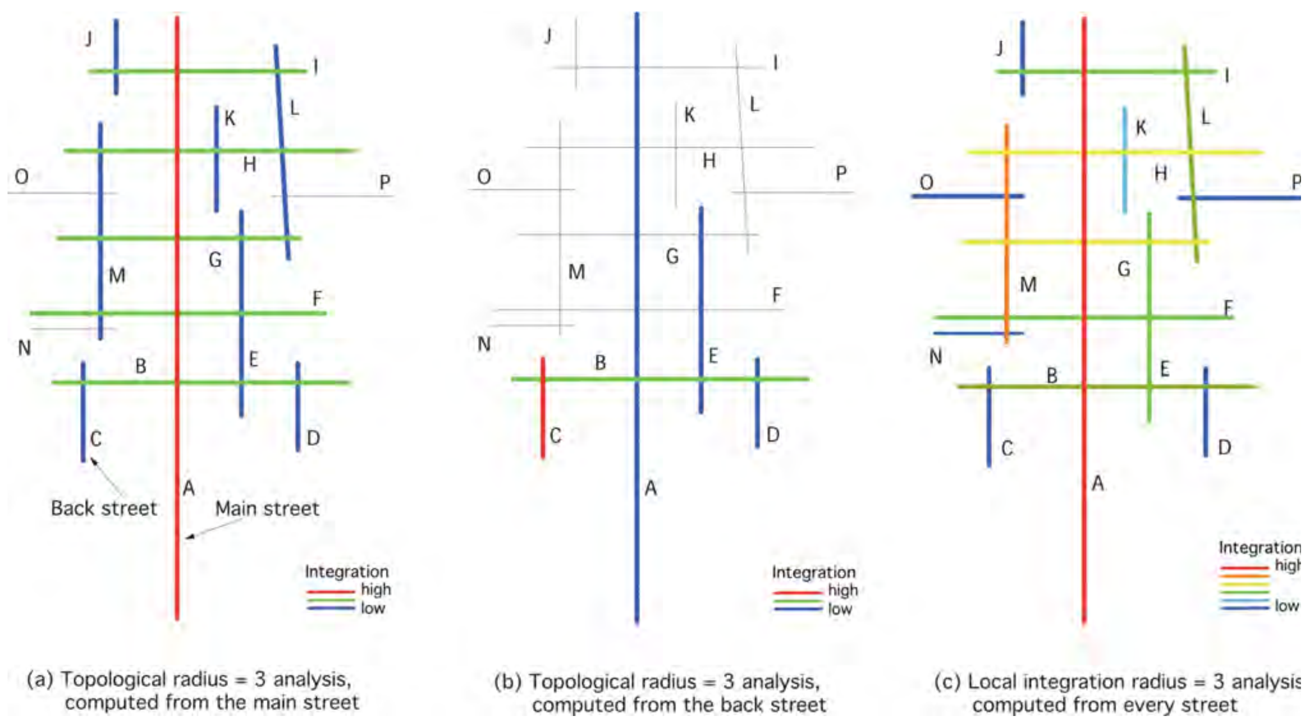


Fig. 2.19 The principle of local integration

In Fig. 2.20, we show a comparison of how global and local integration is calculated for town X with street M as the root node. In the global integration analysis, the sum of the total depth is 34, while for the local integration analysis it is 13. None of the urban spaces beyond the second syntactic step from the street for which the local integration is calculated are taken into account. This is also highlighted in the justified graph. Global and local integration analyses differ from each other by the total depth sum value and the diamond value in calculating the real relative asymmetry. Due to the lower number of spaces taken into consideration for the local integration analysis, the diamond value differs for the entire system. A description of how and why the diamond value is calculated is explained in Sect. 2.3.1. For street M, the diamond value is 0.267.

In Fig. 2.21, we show justified graphs with the main street and cul-de-sac street as root nodes. The local integration value for the main street A is 2.6022857143, and for the dead-end street C it is 0.7039999998. Street M's local integration value is 2.754 (Fig. 2.20). The main street has a lower local integration value compared to street M, which means that street M is locally more highly integrated than the main street.

Global and local integration allows one to measure the spatial impact for an entire city before and after urban interventions. Hillier (1998) and Hillier et al. (1998) state that pedestrian flow rates through cities correlate with local integration values, while vehicle flow rates correspond with global integration values. Furthermore, a local integration analysis indicates the local shopping areas in a city. In order to illustrate the differences between local and city scale centres, we use the Norwegian capital of Oslo as a case.

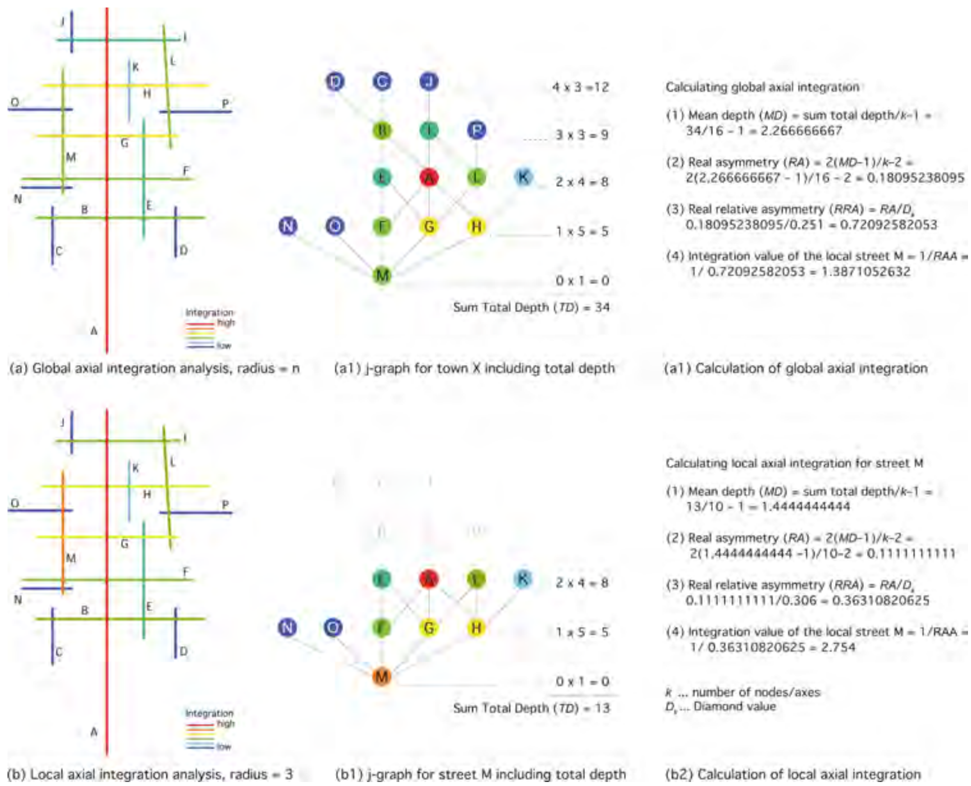


Fig. 2.20 Calculating the global (**a**) and local (**b**) integration of street M for town X

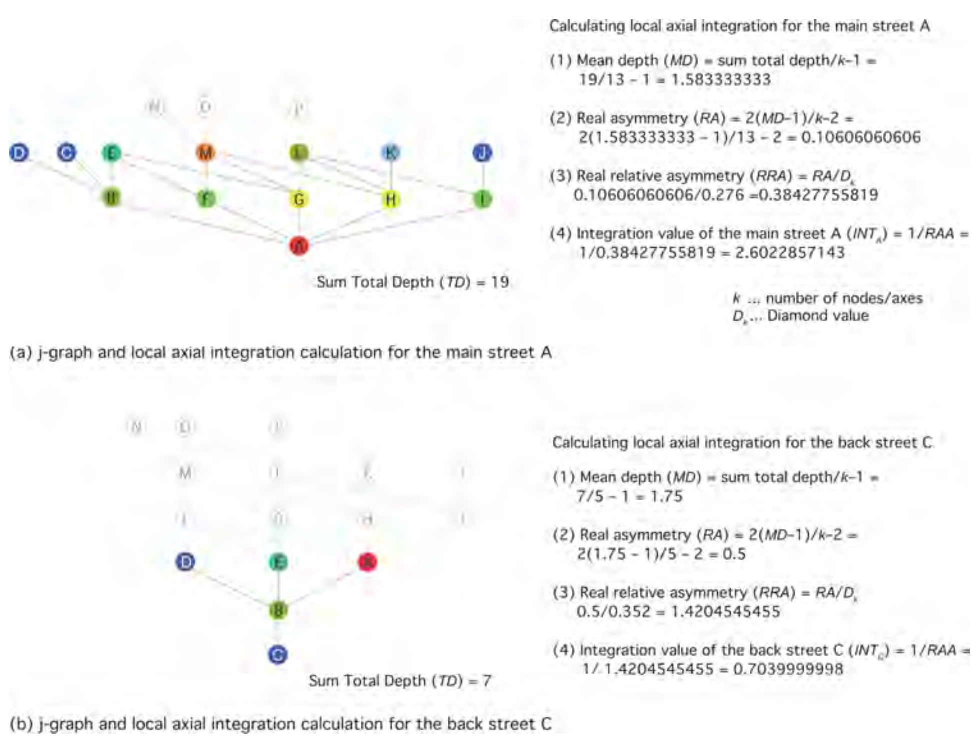


Fig. 2.21 Calculating local integration for the main street (**a**) and dead-end (cul-de-sac) street (**b**) of town X

Figure 2.22 shows a global (a) and local (b) integration analyses of Oslo. The most globally integrated axial lines are the outer ring road followed by the middle ring road. Both ring roads serve vehicular movement. In particular, the outer ring road is a busy car-based road. At every junction, a car-based shopping mall is located. The locally highly integrated streets are Oslo's most pedestrian-friendly and vital shopping streets, and these streets have mixed land use with individual small shops, cafés, and chain stores.

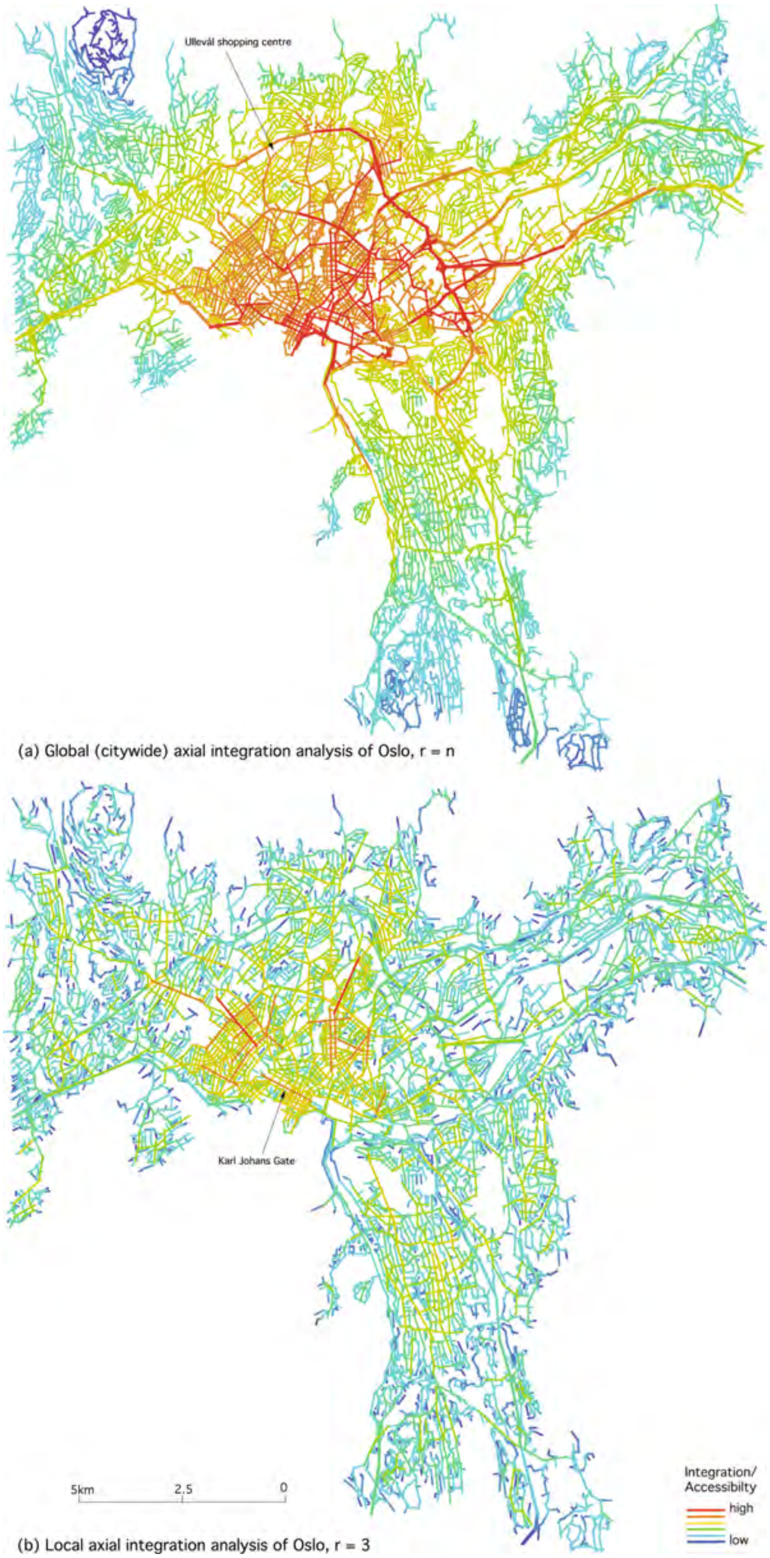


Fig. 2.22 Global (**a**) and local (**b**) integration analyses of Oslo

Oslo is known to be a compact city in comparison to other Norwegian cities. Due to a strict policy to protect agricultural land, Norwegian settlements tend to be scattered with batches of agricultural land in between. In Oslo, the Ullevål shopping centre was built in the 1980s after ring road 3 was finalised. Originally, there were no intentions to give planning permission for such a shopping centre. However, the market forces were stronger than the planning system, and currently car-based shopping centres are located at every junction of Oslo's globally integrated ring road 3. The locally integrated Karl Johans Gate is Oslo's pedestrianised main shopping street. This linear shopping street is well connected to its direct vicinity (Fig. 2.23).

Fig. 2.23 The Ullevål shopping centre is located adjacent to a highly integrated car-based ring road (left), and Karl Johans Gate in Oslo as an example of a locally well-integrated shopping street in Oslo (right)

Where the topography is hilly and streets are curvy, local shopping areas are poorly highlighted in the global and local integration analysis. This is because a curvy street is modelled with several shorter axial lines. Thus, to provide a solution for this challenge, we here introduce angular segment analysis.

2.5 Angular Segment Analysis

What angular segment analysis adds to integration analysis is that each street segment is weighted by the angle of its connection to other street segments. Each axial line is split into a number of street segments. The split of an axial line takes place at every junction, and the relationships between junctions in a street network are now taken into account.

The difference between axial and segment analyses is as follows. In the axial analysis, a curved street is modelled with several axial lines. In the angular segment analysis, a curve is modelled with several street segments derived from the axial line that snap to each other at the segment ends. Curves that are modelled with a number of street segments are processed and analysed as one spatial entity. When two or more axial lines intersect, it is defined as a junction. In the axial line representation of a curved street, a 'junction' occurs every time there is a change of direction.

However, the angular segment analysis quantifies how likely the selected street segment is to be part of a trip for all possible combinations of origin and destination in an urban system (Turner 2001). Angular segment analysis is further coined 'choice', 'angular choice', and 'potential through movement'. The empirical support for this analysis was initiated by the research of Ruth Conroy Dalton with her British Library hypothesis, and she showed how angles influence people's choices for the simplest route between their origin and destination. Conroy Dalton concluded that "people tend to conserve linearity through their routes with minimal angle deviation" (Dalton 2001, p. 47.11).

This means that for urban public spaces, the angular relationships between streets play a role in the way people orientate and navigate themselves in and through the built environment. When changing direction, people tend to choose routes where the angles between different streets and street junctions are close to 90° or 180°. Urban blocks with rare angles like 30 and 60° are presumably difficult for orientation, and people tend to get lost. As mentioned earlier, Figuradeiro's concept of continuous lines (2005) has been one step towards adding angular weighting into space syntax. Defining streets that deviate less than 35° from each other as one continuous line contributes to the identification of the main routes through the city.

Moreover, Conroy Dalton discovered that people tend to choose the longest street with the shortest angle towards their aimed direction. In other words, people choose the straightest possible route to avoid the complexity of wayfinding through urban street grids (Dalton 2001). From an urbanism perspective, the same tendencies can be identified in cities as in Conroy Dalton's British Library example. Figure 2.24 shows a map from Delft with two different routes between home and work for one of the authors' previous home addresses. The longest street with the lowest angular deviation from the destination is chosen at the beginning of the journey. It is only at the end of the journey that the route choice becomes slightly fragmented on account of a bridge over a canal. In general, the longest route with the lowest angular deviation wins over the shortest route with a larger angular deviation (Fig. 2.24).

Fig. 2.24 Bicycle route from home to work in Delft

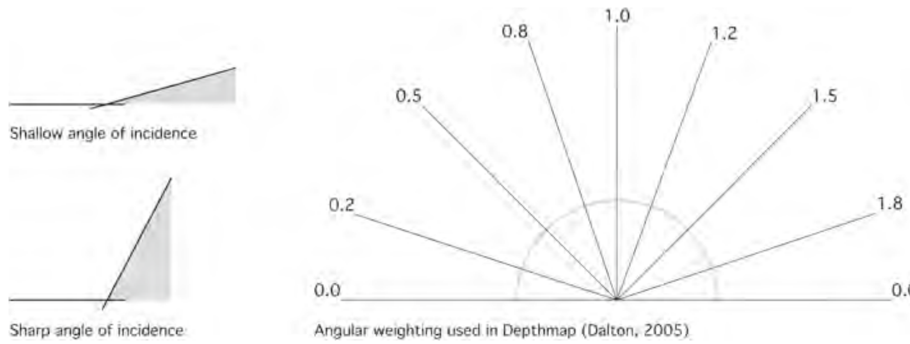


Fig. 2.25 Angular weighting of street segments (redrawn; original: Dalton 2005)

Figure 2.25 illustrates the angular weighting used in the computer application Depthmap. Shallow angles of incidence of nearly 180° are weighted with the numerical value zero, and sharp angles close to 90° are weighted with a numerical value of one.

Integrating angles into the calculation of street systems is based on two major factors. First, orientation in built environments is easier for people when the street network is not dominated by 'strange' angles. Second, people linearise routes when taking shallower turns towards their goals. For angles between street segments in cities, people tend to round angles to 90°. The subject memory of turns is better for right angles, thus when there is a doubt, a turn is rounded to 90° for better placement of oneself for choosing a route for a trip in the urban network (Turner 2001) . In general, there are three types of turns for people with regard to cities: no turn, fork, and right angle (Dalton 2001).

In general, segment analysis is about the absolute change of direction (Turner 2000) when moving from origin A to destination B. The basic underlying idea for angular segment analysis is the minimal change of direction. The distinction is between minimum angular path (MAP) (Turner 2000) and the minimum distance path (MDP) as a Euclidean measure between two locations in the urban system. A tourist will mostly follow the minimum angular path, and a local will mostly follow the shortest Euclidean distance.

The major impact of angular segment analysis is that it allows one to use the way people orientate and navigate themselves to visualise the potential choice of routes in a network. This includes people's cognitive assumptions regarding the network in terms of angles or linearising routes. In Fig. 2.26, we illustrate, based on a simple example, two different routes between two locations in the network. The dotted line route has the highest number of angular deviations, but the shorter Euclidean distance between both locations. Conversely, the solid line has the fewest angular deviations, but the longer Euclidean distance between both locations.

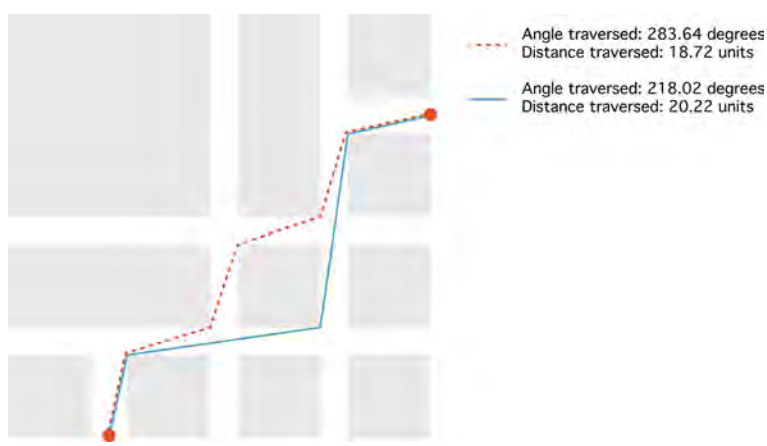


Fig. 2.26 The Manhattan grid—minimum angular path versus Euclidean path (redrawn; original: Turner 2000, p. 4)

For the operationalisation of angular segment analysis, the axial lines are broken into (axial) segments. Figure 2.27 shows three different basic spatial representations of the street and road networks for a particular case (a). In the axial representation (b), the given case consists of four axes. When breaking the axial map into a segment map, the case consists of six segments (c).

Recently, for analysing large metropolitan areas, whole regions, or even whole countries, the road centre line map is applied. Herein, Turner (2007) has demonstrated the applicability of road centre line maps in addition to axial maps for segment analysis. Drawing an axial map is time-consuming. Using a road centre line file can save a lot of time, but only if all road centre lines are well connected, there are not several road centre lines stacked on top of each other, and all roads, streets, and paths are indicated. Cleaning up and complementing a road centre line file can be very time consuming. However, which approach to use depends on your research or project focus. When you are working on a metropolitan or regional scale, then the case-based routes are easy to aggregate from the road centre line. Sometimes a so-called 'hybrid model', a combination of road centre lines and an axial map, is used. When working on a small town or neighbourhood level, the time used for making a hand-drawn axial map can be the same as the time used for cleaning up a segment map aggregated from the road centre line. Moreover, the hand-drawn axial map contributes to greater accuracy than the road centre line map.

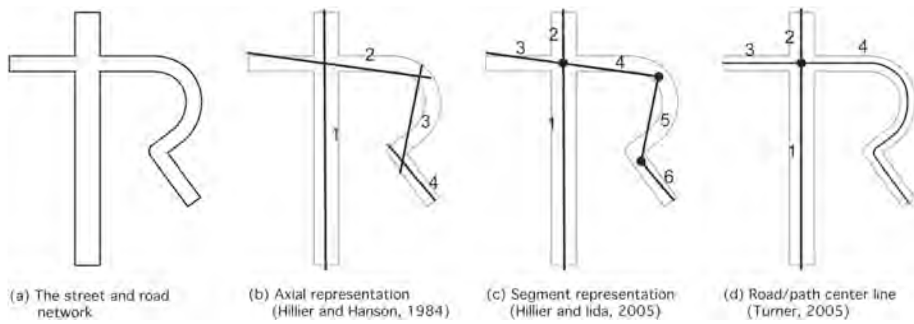


Fig. 2.27 The various spatial representations of the street and road network

Here in our case, the road or path centre line consists of four segments (Fig. 2.27d). The continuous line nr. 4 thus has both a length and a curvature. In the case of the road centre line map, the segment is represented as one segment between two junctions (Bruyns et al. 2019). Turner verified (2007, p. 533) "that the road-centre line maps and space syntax axial line maps may be analysed in comparable fashion when using angular segment analysis". For the objectivity of the spatial analyses, the segment length thus has to be taken into consideration when processing the road centre line map. The same spatial structure is shown when breaking road centre lines maps or axial maps into segment maps and when segment length is used for the analysis (Turner 2007).

For angular segment analysis, the total segment depth is calculated "by the sum of the angle turns from the starting segment to any other segment within the urban system" (Turner 2005, p. 145). In Sect. 2.2, we used only topological steps in the one-, two-, three-, and n-step analyses for visualising topological step depths. For every direction change away from a line, a topological step is taken. Now we add the angular weighting between the lines into the step-depth analysis. The sharper the angular turn from a segment, the higher the step is weighted.

Figure 2.28 illustrates how various types of step depths (or direction changes) are calculated from a particular street segment or axial line for an organic street pattern (a) with a radius n. Example (b) shows an axial step depth starting from the red street axis, example (c) shows a segment step depth from the red street segment, and example (d) shows an angular-weighted step depth analysis from the red street segment with a black frame.

For the axial depth calculation, the axial map is the basis. As mentioned earlier, the axial map represents the longest sightlines indicating paths, and each direction change is one topological step. This refers to the axial topological depth calculation (see Fig. 2.10). The segment depth calculation considers every junction at which a syntactic step is taken. Here in Fig. 2.28, we see that the red axial from example (b) is split into two street segments due to a junction (c). For the angular-weighted step depth calculation in example (d), it is important to know that the closer the connecting street segment to the previous street segment is to 180°, the closer the numerical weight value is to 0. Street segments with a zero degree of angular deviation from the red segment in example (d) have zero values in the angular step depth analyses. Therefore, these segments are coloured in red. An angle of 90° has the numerical weight value of 1 and is in our example coloured in yellow. A sharp angle of 40° has a weighted value of 1.6 and is indicated in light green. For an explanation of the angular weighting, see Fig. 2.25. The colour codes allow for visualisation and comparison of different step depths.

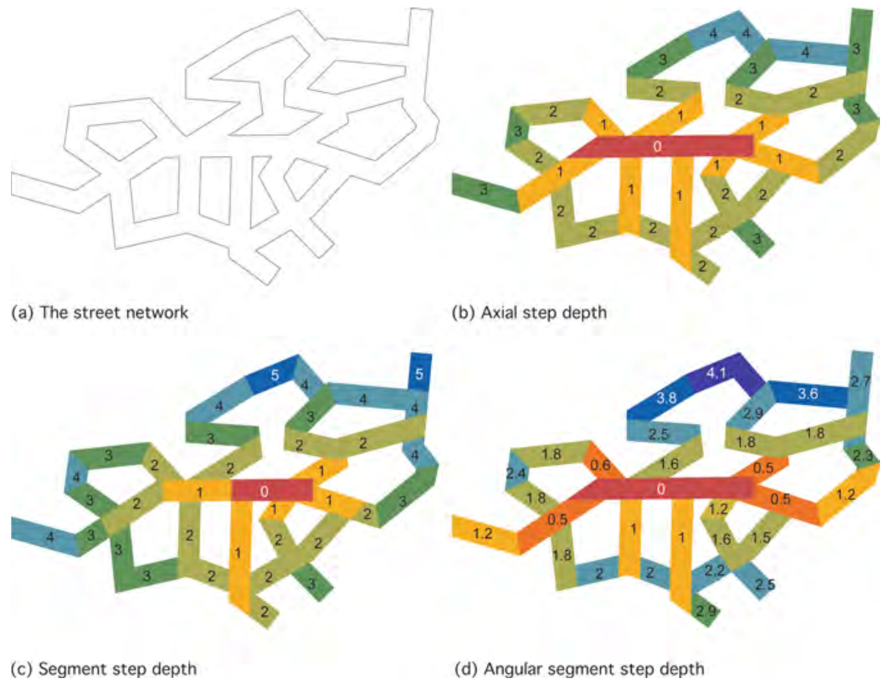
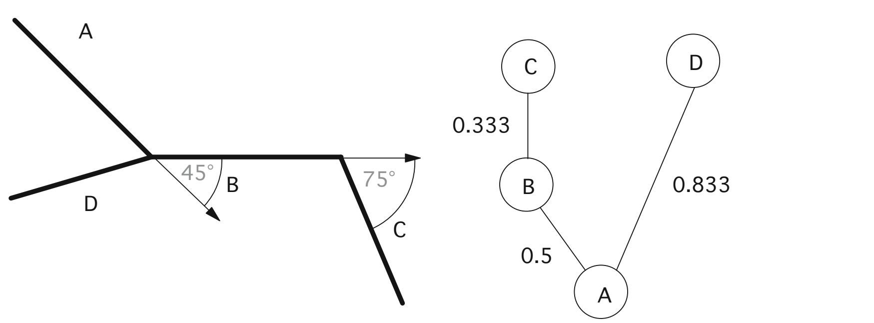


Fig. 2.28 Basic principles of axial (**b**), segment (**c**), and angular-weighted segment (**d**) step depths for street network (**a**)

For the angular segment analysis, all changes of directions, i.e. turns, are weighted according to their angle of incidence. The first step to calculating angular choice is to calculate the mean angular depth from each segment to all others. In Fig. 2.29, we show how angular mean depth is calculated. Our example depicts four street segments connected to each other at different angles. The angular segment depth value from street segment A to B is 0.5 because the angle of incidence is 45°. The angular segment depth sum from A to C is 0.833 and is calculated from the sum of the depth of the segments A to B with an angle of 45° and B to C with a total angle of 30° (75°minus 45°). The angular segment depth from street segment A to D is also 0.833 because the angle of incidence is 75°. The numerical depth values are shown in the justified graph in Fig. 2.29 (right) along with the calculations of the angular mean depth or choice for street segment (A).



$$\text{Angular mean depth of segment (A)} = \frac{\text{Sum of the angular weigths from segment (A) to (B),(C) and (D)}}{\text{total number of segments - 1}}$$

$$= \frac{\text{(B) 0.5 + (C) 0.833 + (D) 0.833}}{3} = 0.722$$

Fig. 2.29 Angular relationship of four street segments (right) and the justified graph with the angular weighting to all the other lines from segment A (left) (redrawn from Turner 2005, p. 148)

The use of the segment as a unit and the calculation of the angular mean depth of the segments was the first step to further developing the advanced calculations of the angular choice and the angular integration analyses. Before we go further, some clarification is needed for various types of *distances* and various types of *radii*.

With regard to distances, space syntax is mostly dealing with *topological* and *geometric* distances. *Metric* distance is seldom used. Topological distance is about direction changes. In global axial integration analyses, only topological distances are used. Here, the globally highest integrated street has the fewest total number of direction changes to all other streets, and the most segregated street has the highest number of direction changes to all other streets. Likewise, segment integration analysis measures how integrated a street segment is in relationship to all others in terms of the fewest number of turns. The measure of integration depicts 'to-movement' potentials.

Geometric distance also takes into account the angular deviation of the direction change. A geometric distance refers to Euclidean geometry and the Manhattan distance (Fig. 2.26) with a least angular path. Thus, a geometric distance can be represented in degrees. Breaking up the axial map into segments is essential for being able to calculate geometric distances. The angular mean depth and the angular choice analysis contribute to identifying the main route network of cities and regions because these main routes have the fewest total numbers of angular deviations to all other streets in the system. Angular choice analysis highlights a route hierarchy and a route choice because these routes link how people orientate and navigate through the urban system.

Metric distance involves calculating the shortest distance from everywhere to everywhere else. Metric distance analysis measures how metrically integrated a street or road is in relationship to all others.

The application of these three types of distance in space syntax has been correlated with pedestrian flow data and location patterns of shops. Crowded shopping streets tend to be located on the most angular integrated street segments of the main route network (Turner 2005, p. 149f). The angular segment analysis (least angle) seems to be the best predictor of movement, followed closely by integration analysis (fewest turns). Metric distance is a distant third (Hillier 2005; Hillier and Iida 2005; Hillier et al. 2007).

With regard to a radius, in space syntax we are dealing with *topological*, *geometric*, and *metric* radii. The topological radius is about taking the number of direction changes into account. In the global axial integration analyses, we use radius n, and in the local axial integration analyses we use radius 2 for American cities, 5 for Persian and Arab cities, and 3 for the remaining cities. All these numbers represent the number of direction changes from each line when processing the local integration analysis.

The geometric radius is about taking the angular deviation into account in the local and global segment integration analyses. Here, we calculate how integrated each street segment is when changing a direction like 90°, 180°, etc. A main route tends to have low values for each angular step depth, and thus a main route segment tends to have a much larger extension than a local street segment. A serpentine road or street tends to have a short extension on a geometric radius due to a very sharp angular deviation for each direction change.

The metric radius is about taking metric distances into account. Here, we calculate how integrated a line is within a certain metric distance, for example, 400 and 5,000 m. Adding the metric radius to the various angular segment integration and choice analyses shows a higher degree of correlation with socio-economic data than only the topological radius (Hillier et al. 2012). Since 2012, the metric radius has been the most used in the various angular choice and angular integration analyses.

Since the introduction of angular weighting for analysing spatial interrelationships on the segment level, various calculation methods have been developed. In articles and papers published since 2001, there exist several concepts regarding angular analyses. The most used concepts are angular choice, angular segment, local angular integration, global angular integration, angular total depth, segment integration, and angular mean depth. Two measurements have been established—angular integration and angular choice—both with various metric radii. The angular choice is used to calculate the angular mean depth of every street segment to all others with a high and low metric radius, whereas the angular integration adds the segment length and replaces mean depth with angular mean depth in the integration formula (see Sect. 2.5.4).

2.5.1 Radii Used in Segment Analysis

One of the criticisms of space syntax was that it does not take metric properties into account in the analysis of the mobility networks (Ratti 2004, p. 501). Indeed, space syntax originally only worked with topological distances (number of direction changes) and geometric distances (degree of angular deviation). Metric distance was added to the angular segment analysis after 2004.

Ansii Joutsiniemi (2005) highlights that metric properties matter, especially on a local scale. For illustrating the differences, Fig. 2.30 shows the principles of topological radius, metric radius, and geometric radius and their different analytical results, including explanations. We showcase this with a street grid example combining an orthogonal street grid and a deformed street grid.

When applying the topological distance radius 3 (= 2 direction changes and 3 syntactic steps) to the chosen street segment indicated in red, all streets in the orthogonal grid can be reached within two direction changes. The deformed grid has a low catchment area for the same topological distance (Fig. 2.30b). When applying a radius with metric distance of two units for the same street segment in red (example a), both the orthogonal and the deformed street grids have nearly the same catchment areas (Fig. 2.30c). For the application of a radius with geometric distance (Fig. 2.30d), a radius of 180° is applied. When the angle is sharp (below 90°) the value is high, and when the angle is shallow (above 90°), the value is low.

In this example, for every direction change from the chosen street segment marked in the black frame, the angular deviation is added up until 180° is reached. The catchment area of the red segment is larger in the upper part of the red line than the lower part of the deformed street grid. This is due to the different angular relationships between the segments between the upper and the lower parts in relation to the chosen starting segment. In the lower part, the first step from the segment has a sharp angle, which gives a high value on the first step. Main routes tend to have very shallow angles. Here in our example, the segments connected to the segment in the black frame have an angle of zero. Therefore, these segments get low values and are coloured in red.

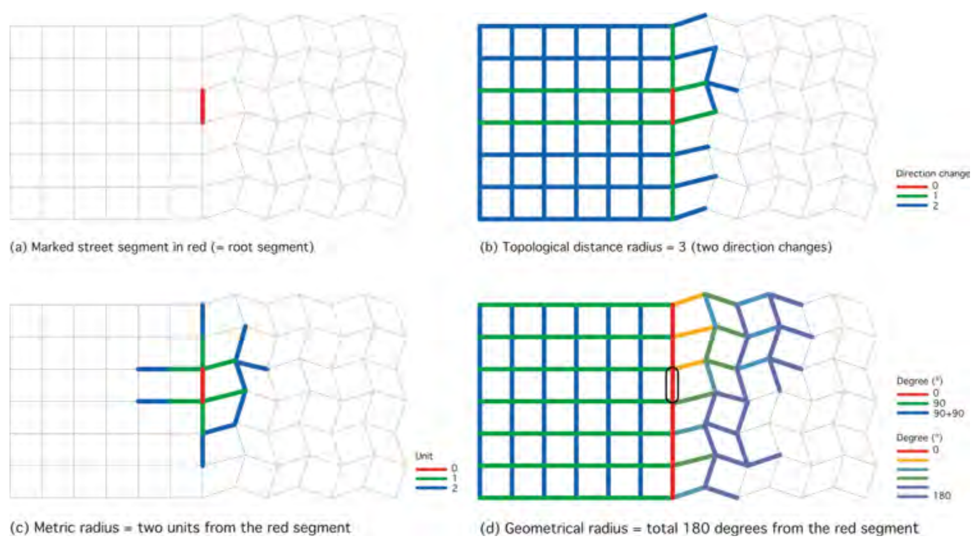


Fig. 2.30 The principles of topological (**b**), metric (**c**), and geometric (**d**) radii

Adding a metric radius to the angular segment and angular choice analyses provides a much more fine-grained analysis than the axial analysis. In Fig. 2.31, we apply the same metric radius of 900 m to topological, metric, and geometric distances in Amsterdam. All distances are based on the segment map.

The topological distance (the number of direction changes) is a segment integration analysis with a metric radius of 900 m (image (a)). The Pijp area has the highest integrated streets, and the area is perceived as the main centre of Amsterdam for the locals. This area is known to be highly vital and a lively local centre for the entire city. Pijp offers a large variety of shop types and has crowded streets throughout the day. All locations within Pijp are easily accessible by bicycle, tram, and car and partly on foot.

The metric distance with a metric radius analysis of 900 metres (Fig. 2.31b) reveals that the metric centre does not always overlap with a city's economic centre or where the vital centre tends to be. In Amsterdam, the results from the metric distance with metric radius shows a patchwork of local neighbourhoods with a particular local identity. In particular, the neighbourhoods Geuzenveld, Appollobuurt, Van der Pekbuurt, Watergraafsmeer, Diemen, Duivendrecht, and Slotervaart are highlighted in red. These spots are not vital local centres; rather, they are neighbourhoods with a clear identity and a name.

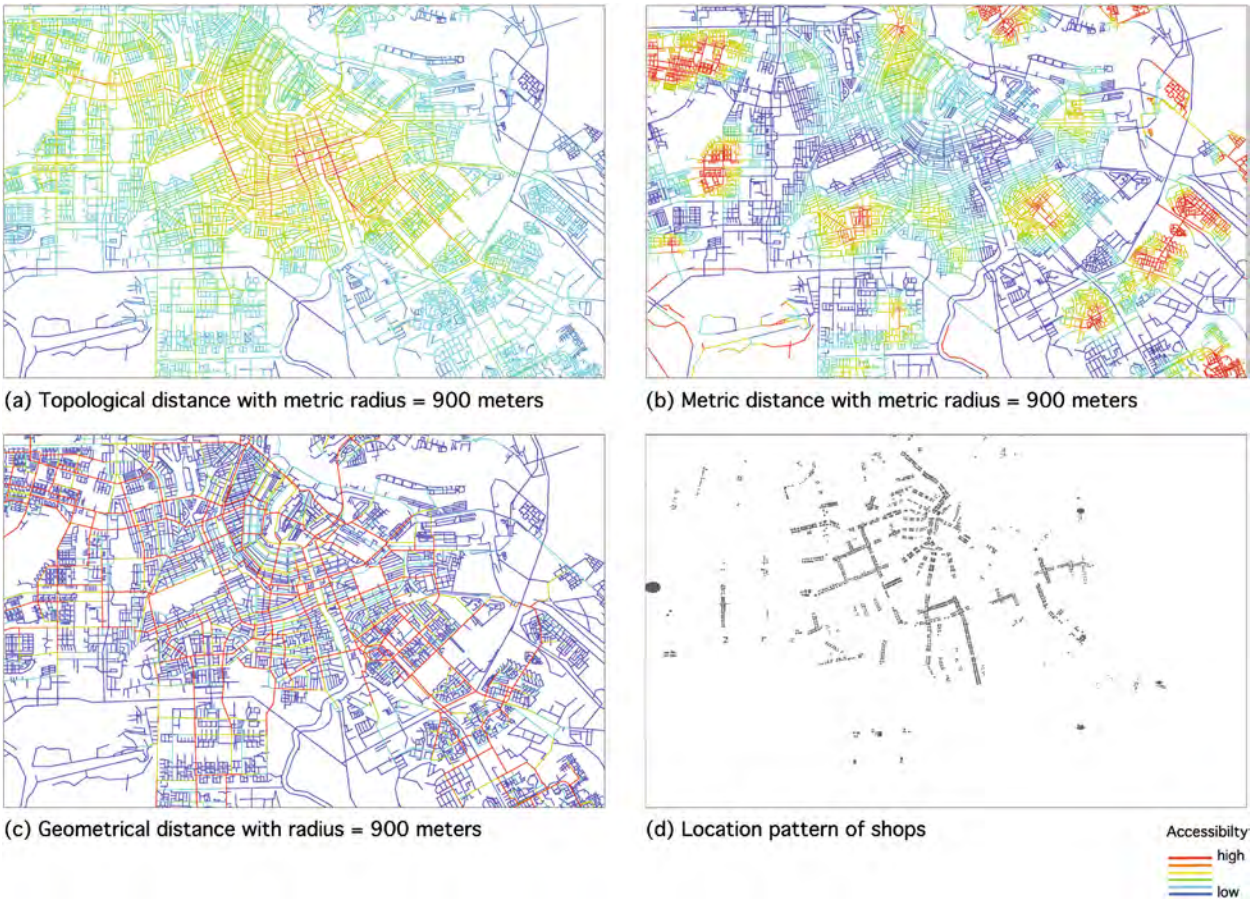


Fig. 2.31 Applying the same metric radius to different distances on Amsterdam: (**a**) topological distance with a metric radius of 900 m, (**b**) metric distance with a metric radius of 900 m, (**c**) geometric distance with a radius of 900 m, and (**d**) the location pattern of shops

The geometric distance (the degree of angular deviation) with a metric radius of 900 m (Fig. 2.31c) highlights the main route network. These main routes have the fewest angular deviations to all other streets within a radius of 900 m. This geometric distance analysis is the logic of the angular choice analysis. Amsterdam's location pattern of shops (Fig. 2.31d) and tramline routes follows the street segments with the highest values in the angular choice analysis with a metric radius of 900 m (Fig. 2.31c).

Following this, we apply the most used analyses to Amsterdam (Fig. 2.32). For the axial integration analysis (a) and angular choice analysis (b), we apply a topological radius of 3. Here, we calculate how integrated every axis or street segment is when changing directions three times from them (according to the latest developments in space syntax; see for further explanation Yamu et al. 2021). In both analyses, Amsterdam's oldest city centre around the Berlage stock exchange (inside the black circle) is poorly integrated.

In Fig. 2.32 we show the latest calculations based on segments within a metric radius. Image (c) shows an angular integration and image (d) shows an angular choice analysis, both with a radius of 400 m. Now, the streets inside Amsterdam's oldest centre have the highest integration values in both analyses. This area is neither highlighted in the global and local axial integration analyses nor in the global angular segment analysis with various topological radii. This is because the area around the old Berlage stock exchange building was originally developed with short metric accessibility to other functions. Today, it is Amsterdam's tourist centre where everything is accessible on foot.

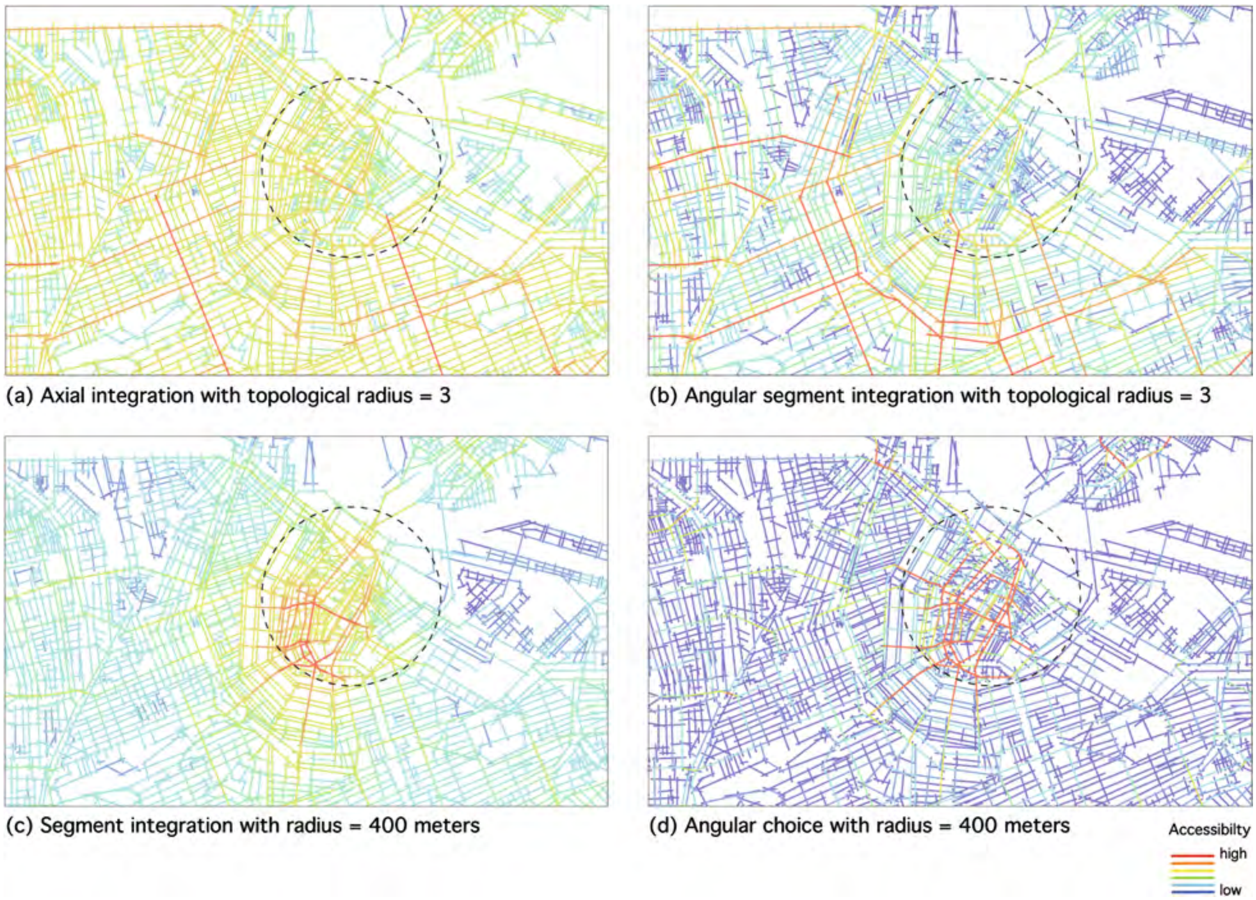


Fig. 2.32 Various local measurements of Amsterdam, with the location of the oldest centre of Amsterdam around the old Berlage stock exchange indicated in the black circle

Metric radius matters for the angular segment integration analysis as well as for the angular choice analysis. Other radii, for example, of 800 or 1200 m highlight various local urban centres. An indication of the size of the local catchment areas is often given by the various values of the metric radii. Most commonly, a radius of 4,000–8,000 m is used as a high metric radius and a radius of 400–800 m is used for a low metric radius. For axial maps that are scale free or non-georeferenced, the local or low radius tends to be 10% of the global or radius n, also called the high radius.

Adding metric radii (e.g. 400 m or 800 m) to the angular choice analysis allows a more sophisticated spatial analysis of urban networks compared to axial analysis with its topological radii (e.g. radius 3 or radius 5). To show what metric radii add to space syntax on a local scale, we show in Fig. 2.33 five different spatial analyses of Friedrichstraße in Berlin including a non-processed axial map with the distribution of shops (f). Images (a), (b), and (c) show the results from the segment analyses. Image (a) is the angular choice analysis with a topological radius of 3. Here, Friedrichstraße is a part of the main route system. Image (b) shows an angular choice analysis with a metric radius n. Here the northern part of Friedrichstraße is highlighted in red. At present, Berlin’s largest shopping malls are located at this spot. Image (c) shows an angular choice analysis with a low metric radius. Now the central and southern parts of Friedrichstraße also get higher values. The local shops serving the neighbourhood are located there. The segment length is included in the analyses in images (b) and (c), whereas it is not taken into account in image (a).

The segment analyses with segment length and with metric radii show more sophisticated results than the axial global (Fig. 2.33d) and local (Fig. 2.33e) integration analyses. In the axial analyses, Friedrichstraße gets the same value for its whole length, whereas in the segment analyses various parts of the street are highlighted depending on the radius. Seemingly, the size of the metric radius indicates where the customers for the shops come from, whether it is only from the immediate vicinity or the whole city.

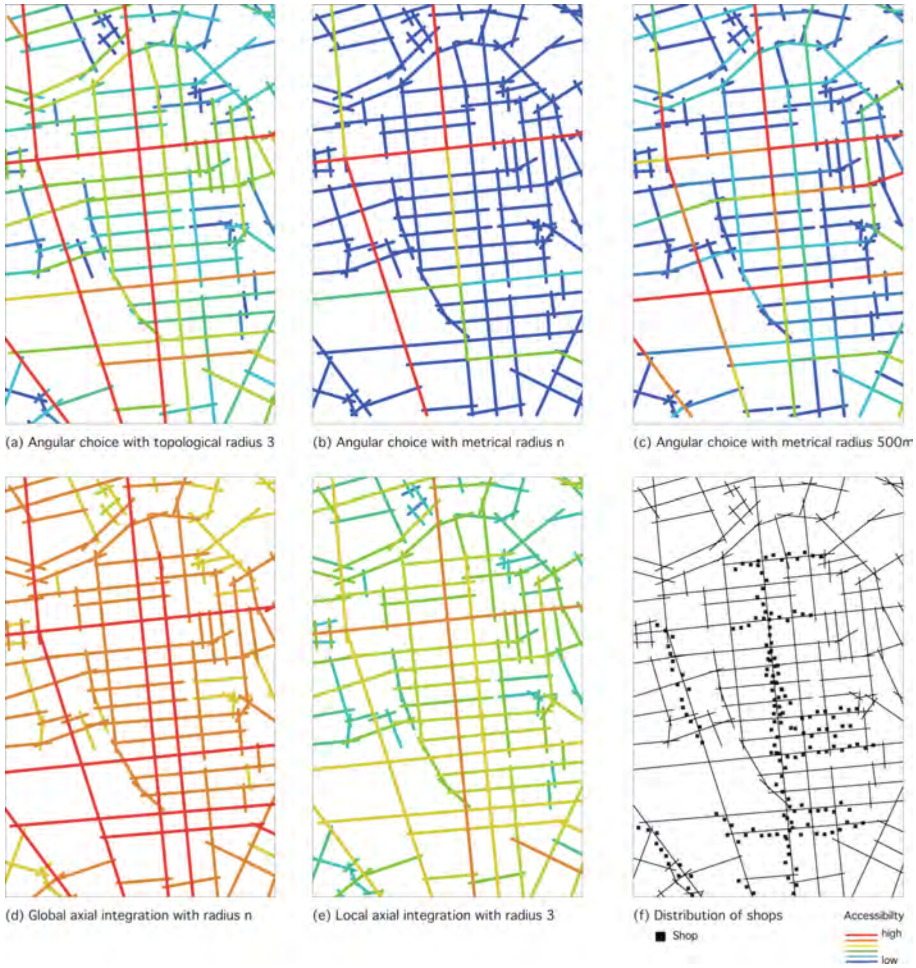


Fig. 2.33 Angular segment (**a**, **b**, **c**) analysis and axial analysis (**d**, **e**) with the location pattern of shops (**f**) for the Friedrichstraße area in Berlin

In experiments testing various types of distances with various types of radii and correlating the results with socio-economic data, two types of spatial analyses are most commonly used—angular choice and angular integration with a low and a high metric radius. These measurements will be discussed in the next sections.

The most used metric radii when having a georeferenced axial map or road centre line map are 400–800 and 5,000–8,000 m. The first set of radii concerns walkable distances or local accessibility, whereas 800 m refers to a 10 minute walk. The latter set of radii concerns car-based distances or citywide accessibility. In general, we apply the 10% rule, which means that the low radius is 10% of the value of the high radius. When the segment map is not georeferenced, we apply a 10% rule retrieved from the system's coordinates for a local radius. Radius n stays the same. The system's coordinates are often determined by the space syntax software.

2.5.2 Angular Choice: Main Routes Through Cities and Regions

The angular choice analysis depicts the 'through-movement' potential and therefore an urban route hierarchy. When applying various metric radii for the angular choice analysis, the following results are obtained. For a small metric radius, the local main routes of local centres of a city are highlighted. This applies, for example, for radii of 400, 800, or 1,200 m. The higher the applied metric radius, the more the main routes running through and between neighbourhoods in a city are highlighted. In the radius n analyses, the highway network tends to get highlighted.

According to Hillier et al. (2007), cities have a dual nature with a foreground (citywide or 'global') and a background (local) street network. The foreground network links urban centres at all scales and levels. It gives a city's street structure a so-called 'deformed wheel pattern' consisting of radials and orbitals. This structure can even be seen in cities having an orthogonal street grid. The main route network through urban areas shapes the deformed wheel's armature. In this way, accessibility from the city's edges to its centre and the natural interface of co-presence through movement from centres to edges is made efficient and possible. The foreground street network works independently of cultures. Correspondingly, cities have a background network for residential areas, which reproduces cultural patterns. Different cultures have different local radius measures, which are the conservative components of the city. The background local network is mostly shaped by the way different cultures influence urban space, including both the metric and geometric properties of the network. However, local residential areas tend to also have a localised foreground structure (Hillier et al. 2007, p. 4).

However, we can observe that all cities and towns are made up of a very large number of short streets and a very small number of long streets and roads (Figueuredo and Amorim 2005, p. 163). This can be identified across scales and gives a city's street network and a regional road network a clearly fractal structure (Czerkauer-Yamu 2012; Yamu and van Nes 2017, 2019). In addition, Claudia Yamu says that the fractal structure of the urban street network and the metropolitan road network incorporates an intrinsic hierarchy and both are therefore rather consistent with fractal ordering principles (Yamu and Frankhauser 2015; Yamu et al. 2016; Yamu 2014). Hillier explains that the foreground network is largely composed of longer streets and roads that connect to other streets and roads at highly obtuse angles. The longer the street line, the more likely it is to end with a nearly straight connection. Main routes through cities on all scales tend to consist of a set of longer lines connected to each other with almost 180° angles (Hillier and Iida 2005). Herein, angular weighting contributes to highlighting the main routes in the angular choice analysis (van Nes and Yamu 2018). Conversely, the background network is largely made up of short streets that tend to intersect with other streets at nearly right angles. The shorter the street, the more likely it is to end at a right angle. Most quiet residential streets tend to be metrically short (Hillier et al. 2007 pp. 2ff).

According to cognitive science, human beings seem to choose the straightest routes to avoid route complexity (Dalton 2001). Figure 2.34 shows two street examples from the city of Cologne, Germany, including a short residential street connecting with an angle of 90° to its adjacent street (left) and a long main route connecting to the next street at an angle of almost 180°. Both examples are taken from the same neighbourhood.

Fig. 2.34 It shows a short background network street (left) and a long foreground network street (right) in the city of Cologne, Germany

In Fig. 2.35, we illustrate the foreground and the background network for the city of Amman in Jordan (left) and Banda Aceh in Indonesia (right) through an angular step depth analyses taken from the main route network. The main routes are identified by applying an angular choice analysis with radius n. These main routes are coloured in red. From the main route network, a radius of n degrees is used in the angular depth analyses. Applying both analyses, we can see how the background network is connected to the main route network in terms of the total number of angular deviations.

For Amman, the analysis depicts a typical Middle Eastern city with a well-integrated foreground network and a segregated background network. The background network is represented in dark blue. The various local neighbourhoods (marked in blue and turquoise) are not visible from the main route network. This complies with the local culture and religion in that the domestic spaces and the streets these spaces are connected to are more protected from random through travellers than in cities in Europe, North America, East Asia, or Central and South Africa.

Fig. 2.35 Foreground and background networks for Amman in Jordan (left) and Banda Aceh in Indonesia (right)

In contrast, Banda Aceh is an Islamic city located in Indonesia. Its street pattern was mostly developed during the Portuguese and Dutch colonial rule from 1600 to 1940. For Banda Aceh, a majority of the background network is easily accessible from the foreground network. The foreground network has a high density. The city incorporates both types of structures: a tree structure and a network structure. The tree structure in the west of the city is poorly accessible from the main route network. This part of the city was developed in the time period dominated by the Islamic culture. The city's network structure in the east was developed under colonial rule.

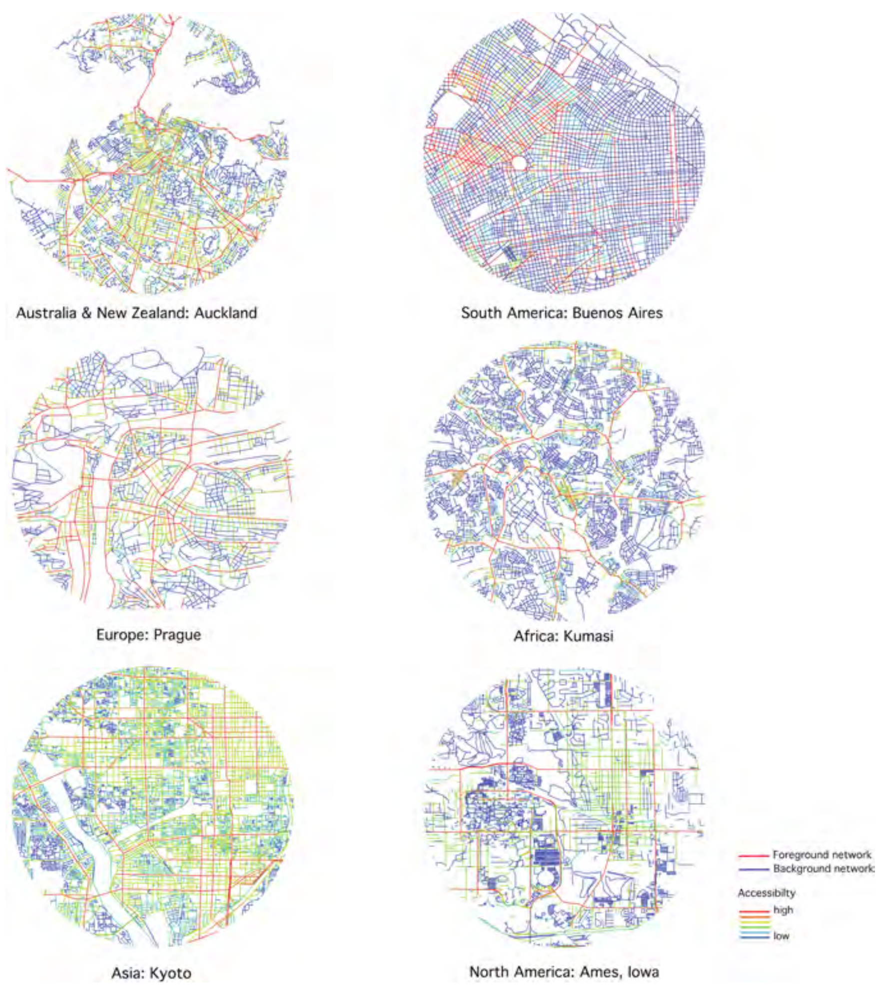


Fig. 2.36 Foreground and background networks for six cities from six different continents

Moving on, we present six further city examples from six different continents with different urban typologies on how foreground and background networks establish themselves (Fig. 2.36). Again, we applied angular step depth analysis from the main routes. The established foreground and background networks vary from city to city and culture to culture. Likewise, the colour scale of the background network varies for each city. For some cities, the background network is better connected to the foreground network than for others.

The cities of Kyoto, Ames in Iowa, and Buenos Aires have an orthogonal grid structure. However, the way the background network is connected to the foreground network is different. Kyoto has a far more accessible background network than Buenos Aires and Iowa. The cities of Prague, Kumasi, and Auckland have a main route network forming a 'deformed wheel' pattern. In Kumasi, the new bypass road (or ring road) has become a part of the foreground network. In Auckland centre and Prague, the background network is well connected to the foreground network. A feature in most European cities is that in the pre-war urban areas, the background network is well connected to the foreground network. In the post-war or modernist urban areas, the background network is poorly connected.

Following up the discussion about the foreground and background networks, we demonstrate in the following what different citywide and local radii mean for urban centrality. We apply the angular choice analysis to the two Dutch towns of Lelystad and Hilversum.

The new town of Lelystad was founded in the late 1960s and is located on reclaimed land from the Zuiderzee (english: Southern Sea). Car lanes, bicycle lanes, and pedestrian sidewalks are separated from each other. Figure 2.37 shows an angular choice analysis applied to an axial segmented map for the street network with (a) radius 6000 m and (b) radius 600 m.

For the angular choice analysis with a radius of 6,000 m, all main routes between various local centres are highlighted in red to green. These routes have predominantly vehicular traffic. Lelystad's main shopping mall is located in the geometric centre of the town where the density of these main routes is the highest. In contrast, the angular choice analysis with a radius of 600 m depicts the local centres of Lelystad. Streets indicated in red are locations where small neighbourhood supermarkets and corner shops are located. However, the vitality of these local centres is very low. In addition, Joris van Casteren (2008) states that a criticism directed at new towns is that they tend to be 'dormitory towns'. Analysing new towns using angular choice with metric radii can shed some light on this discussion.

When applying the same analysis to the historic town of Hilversum close to Amsterdam, a different spatial structure can be identified (Fig. 2.38). Hilversum is one of the oldest settlements in the Netherlands, founded in 1424. Angular choice analysis with a radius of 6,000 m depicts a deformed wheel structure constituted by the main road system. In contrast, the angular choice radius of 600 m highlights the town's local shopping streets, indicated in red and orange. Both analyses depict all of Hilversum's central shopping streets. As mentioned earlier, optimal locations for shops are streets that are accessible within a short metric distance to the neighbourhood's residents and close to streets with citywide through- and to-movement potential. The variations of shops in local shopping areas tend to be higher in historic towns compared to new towns. Often, newer Dutch towns have a small neighbourhood supermarket, mostly used by the neighbourhood's residents. In contrast, historic Dutch towns have a good variation of shops in strategic locations in streets that can be easily reached from the main route network.

Overall, the main route network in newly built neighbourhoods is separated from the local centres, whereas it is integrated in historic towns. Results from various space syntax analyses indicate that spatial conditions for generating vital urban areas with a high diversity of active land use are as follows: (1) there is a topologically and geometrically well-integrated street network from a local to a global scale; (2) main routes have high accessibility values for angular choice global radius analysis; (3) main routes are running through neighbourhoods instead of running around them; (4) main routes are directly connected to a majority of local residential streets; and (5) the same main routes are running through or are well connected to a locally integrated centre of a town or city.

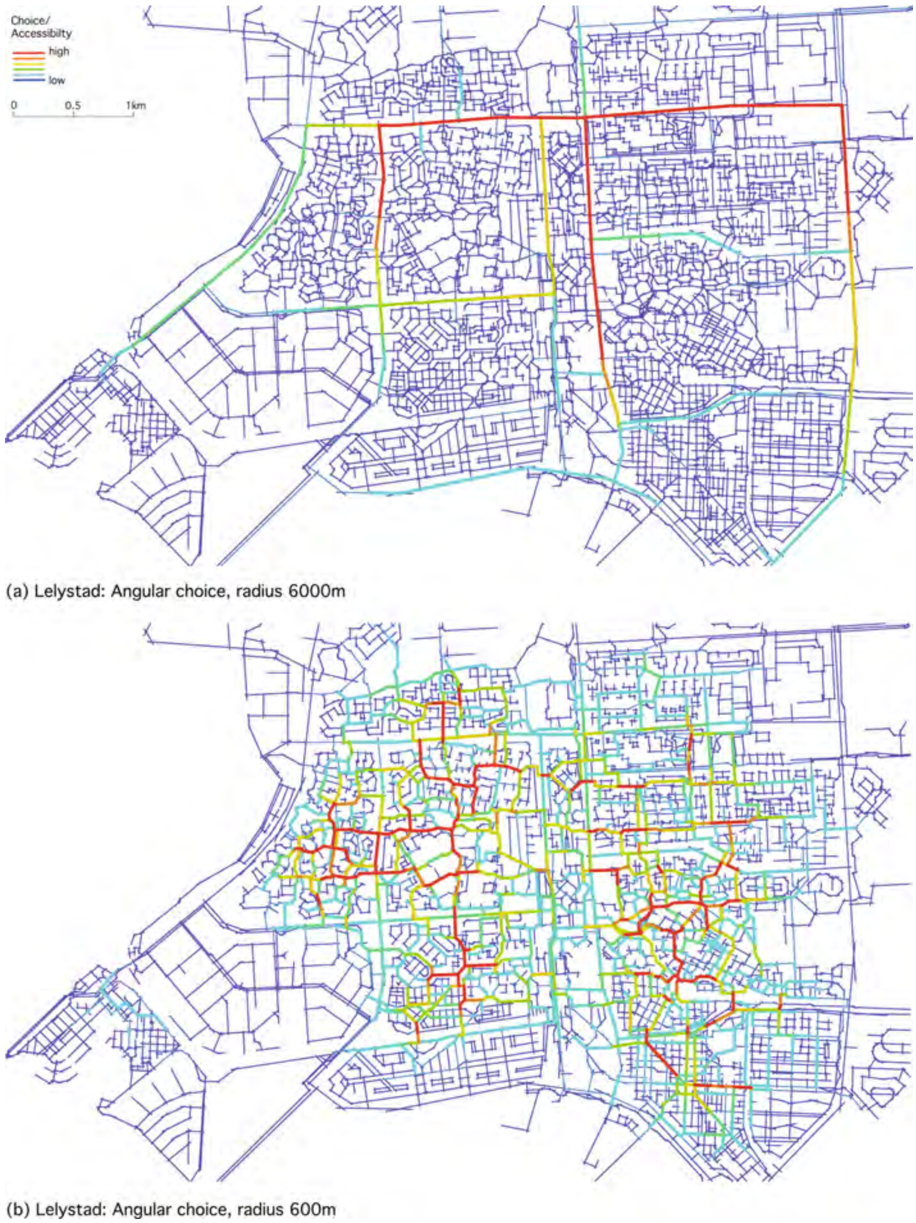


Fig. 2.37 Angular choice analysis for the town of Lelystad with (**a**) a radius of 6,000 m and (**b**) a radius of 600 m

2.5.3 Angular (Segment) Integration: The Location of Urban Centres

The angular segment integration shows the accessibility of a street segment in relation to all other street segments in an urban system in terms of direction changes. For this kind of analysis, the street segment's connectivity represents the 'to-movement' potentials for the city or town under scrutiny. As mentioned earlier, connectivity is the basis for integration and is the underlying logic for segment integration analysis. Segment connectivity consists of counting the number of connections from a street segment to all other adjacent street segments. The unit of segment connectivity is the individual street segment, which is a street section from junction to junction (Hillier and Sahbaz 2005, p. 455f). Segment connectivity is the basis for calculating angular integration by means of mean angular depth.

Fig. 2.38 Angular choice analysis for the town of Hilversum with (**a**) a radius of 6,000 m and (**b**) a radius of 600 m

(a) Hilversum: Angular choice, radius 6000m

(b) Hilversum: Angular choice, radius 600m

Figure 2.39 illustrates how segment connectivity is calculated. For our example (a), the chosen street segment on a throughway has six connections, thus its connectivity is six. The street segment from example (b) has a connectivity of three with one direction change from the throughway and a connectivity of one with two direction changes away from the throughway. For example (b), it is possible to hide away in the cul-de-sac or to escape via the adjacent T-junction.

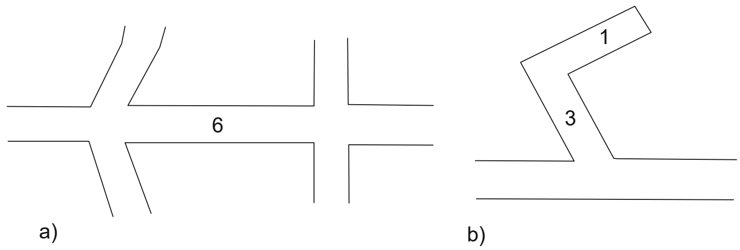


Fig. 2.39 Segment connectivity for two different sets of streets: (**a**) represents a through carry way in traditional urban areas with two X-junctions and (**b**) represents a cul-de-sac with an adjacent T-junction

The usefulness of segment connectivity analysis is to highlight potential escape routes for criminal activities or exit routes when fleeing from natural hazards like tsunamis. Connectivity is a local static measure. In general, main streets tend to have high segment connectivity, while dead-end streets tend to have low segment connectivity (Hillier and Sahbaz 2005, p. 456). In studies on urban safety and crime, all possible escape routes, for example, back paths and footpaths through parks are taken into account in the segment connectivity analysis (Hillier and Sahbaz 2005; López and van Nes 2007).

Angular segment integration analysis seeks to measure the to-movement potentials on a neighbourhood and a citywide scale. The same mathematical logic is applied to angular segment integration analysis as in the axial integration analysis. The only difference is that it is the segment that is the unit for analyses, segment length is taken into account, the topological mean depth calculation from the axial analyses is replaced with the angular mean depth or angular choice analysis, and that metric radii can be added. In order to show the principle difference between segment integration and angular choice analyses, Fig. 2.40 shows two different types of j-graphs on how to calculate the choice (C) and the segment mean depth (MD) relationship from segment A.

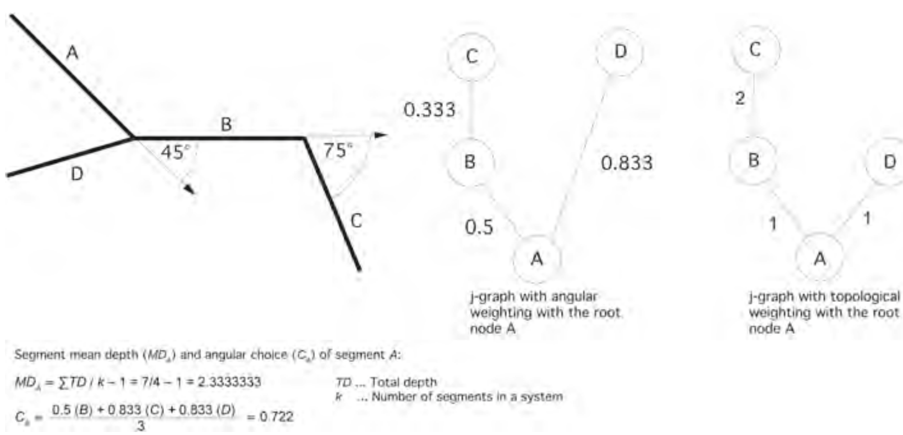


Fig. 2.40 Two different types of j-graphs for calculating the mean depth from segment A to segments B, C, and D

Fig. 2.41 Angular (segment) integration analysis for the town of Lelystad with (**a**) a radius of 6,000 m and (**b**) a radius of 600 metres

Again, we use the Lelystad and Hilversum cases to show how various metric radii highlight the various to-movement potentials on different scale levels. Figure 2.41 shows an angular (segment) integration analysis with a high metric radius of 6,000 m and a low metric radius of 600 m for Lelystad. The to-movement potentials on a citywide scale are in a different location than on a neighbourhood scale. The main shopping centre is located along the streets with the highest values for the angular (segment) integration analysis with a radius of 600 m (a) and outlet shops, furniture shops, and car dealers are located along the roads with the highest numerical values for the angular (segment) integration analysis with a radius of 600 m (b).

Conversely, in Hilversum the streets with high numerical values for the high metric and low metric analyses overlap in the city centre (Fig. 2.42). Large and small enterprises are located in the city centre and along the integrated main streets leading to the city centre. Hilversum offers a large variation in the types of shops in comparison with Lelystad.

(a) Hilversum: Angular (segment) integration, radius 6000m

(b) Hilversum: Angular (segment) integration, radius 600m

Fig. 2.42 Angular (segment) integration analysis for the town of Hilversum with (**a**) a high metric radius of 6,000 m and (**b**) a low metric radius of 600 m

For an in-depth understanding, and if you like mathematics, the next chapter explains more elaborately how to calculate angular choice. For the less-interested readers, we suggest moving on to reading Sect. 2.5.4 "Normalising the angular integration and choice values: NACH and NAIN".

2.5.4 A More Elaborate Explanation for How to Calculate Angular (Segment) Integration and Choice

The basis of the space syntax method is the axial map, and the basic premise is to calculate the topological depth from one axis to all others, in other words, the total number of direction changes from one axis to all others. The integration (*I*) of an axial line (*i*) is a function of its depth related to all other axes. The calculation behind the integration of an axial line is (Rashid 2017 p. 64):

$$l_i = \frac{2\left(n\left(\log_2\left(\frac{n+2}{3}\right) - 1\right) + 1\right)/(n-1)(n-2)}{2\left(\left(\frac{\sum_{j=1}^{n} d_{ij}}{n-1}\right) - 1\right)/(n-2)} \tag{2.5}$$

where n is the number of segments and d_{ij} is the shortest distance (least number of direction changes) between two segments i and j. The greater the number of steps (d_{ij}) between street axes, the lower the integration values become. The choice of a street axis shows how likely one is to pass through that axis when moving around in a built environment. Choice measures the degree of betweenness and measures the through-movement potentials. The formula of choice (C) of a street axis (i) is as follows (Rashid 2017, p. 64):

$$C_i = \sum_J \sum_K g_{jk}^{(i)}\,\mathrm{lg}_{jk}^{(j<k)} \tag{2.6}$$

where $g_{jk}^{(i)}$ is the number of shortest paths between segment j and k containing i, and g_{jk} is the number of all shortest paths between j and k (Rashid 2017, p. 64).

In the segment analysis, the axial lines are broken up where they cross each other (D'Acci 2019) or at each junction. The segment integration of a street shows how easy it is to get to that segment from all other segments. It calculates the to-movement potentials. Segment integration can be compared across systems. It measures how close each segment is to all others in terms of the sum of angular changes that are made on each route (Hillier and Iida 2005, pp. 475–490). Here, too, a radius of 500 m is taken for the local scale, and a radius of 5,000 m is used for the city scale. The choice takes the angular deviation of each topological step into account.

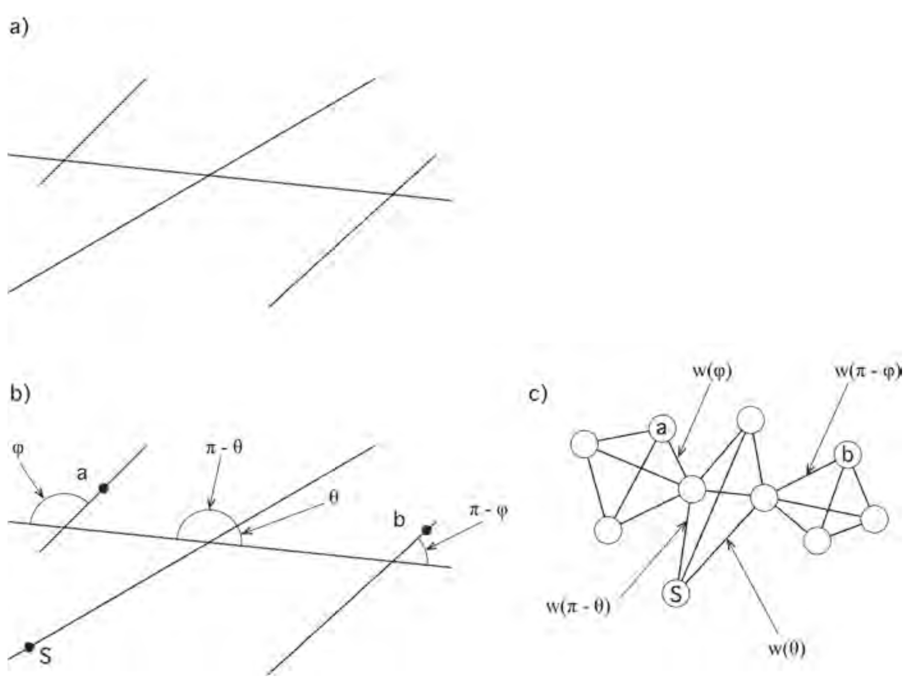


Fig. 2.43 It shows an axial map (**a**) and how a segment map is made (**b**), and **c** shows the representation of the spatial interrelationships of the segments in an unjustified graph Hillier, Bill (Image redrawn from Hillier and Iida 2005, p. 559)

Figure 2.43b illustrates how the segment network is disaggregated at the intersections of axial lines. The distance is measured by taking the 'shortest path' from every line to all other lines. The angle between segments is now taken into account. The calculation between node *S* to node *a* is thus (π − θ) + w(φ). As Hillier and Iida write,

> The following weight definitions are used to represent different notions of distance: Least length (metric): The distance cost of routes is measured as the sum of segment lengths, defining length as the metric distance along the lines between the mid-points of two adjacent segments. The distance of two adjacent line segments is thus calculated as half the sum of their lengths. Fewest turns (topological): Distance cost is measured as the number of changes of direction that have to be taken on a route. In the example shown in Fig. 2.43b, c, w(θ) = w(π − θ) = w(θ) = w(π − θ) = 1 (however, w(0) = 0). Least angle change (geometric): Distance cost is measured as the sum of the angular changes that are made on a route by assigning a weight to each intersection proportionate to the angle of incidence of two line segments at the intersection. The weight is defined so that the distance gain will be 1 when the turn is a right angle. In other words, 'w(θ) ∝ θ, (0 ≤ θ < π,w(0) = 0, w(π/2) = 1'" (Hillier and Iida 2005, p. 559).

The angular segment choice is calculated by counting the number of times each street segment falls on the shortest path between all pairs of segments within a selected distance (termed the 'radius'). The 'shortest path' refers to the path of least angular deviation (namely, the straightest route) through the system (Hillier and Iida 2005, p. 475). The angular integration of a segment x is

$$AI_X = \frac{1}{n}\sum_{i=1}^{n} d_\theta(\pi X, i) \tag{2.7}$$

where n is the number of segments and $d\theta$ is the angle between any two segments on the shortest path on segment x (Rashid 2017, p. 66). When adding the length l of the segments, we get the following formula for the angular integration of a street segment with segment length:

$$AI_X^l = \frac{\sum_{i=1}^{n} d_\theta(X, i) l(i)}{\sum_{i=1}^{n} l(i)} \tag{2.8}$$

The issue we are dealing with is to calculate how easy it is to get to a street and how likely one is to pass through a street (D'Acci 2019) within certain metric radiuses.

2.5.5 Normalising Angular Integration and Angular Choice Values: NAIN and NACH

The first generated axial maps were not georeferenced because earlier versions of the space syntax computer application dealt only with topological distances. When the metric radius was introduced, the Depthmap software generated a unit system when loaded into the computer application for maps that are not georeferenced. For the georeferenced maps, the software identifies the real metric units.

Since 2012, normalised angular integration (NAIN) and normalised angular choice (NACH) have been applied (Hillier et al. 2012). At present, the computer application Depthmap allows normalising angular segment choice and angular segment integration analyses with metric radii directly in the software after processing the graph. Figure 2.44 depicts (a) a NACH analysis with global radius n and (b) a NAIN analysis with global radius n for Greater Vienna.

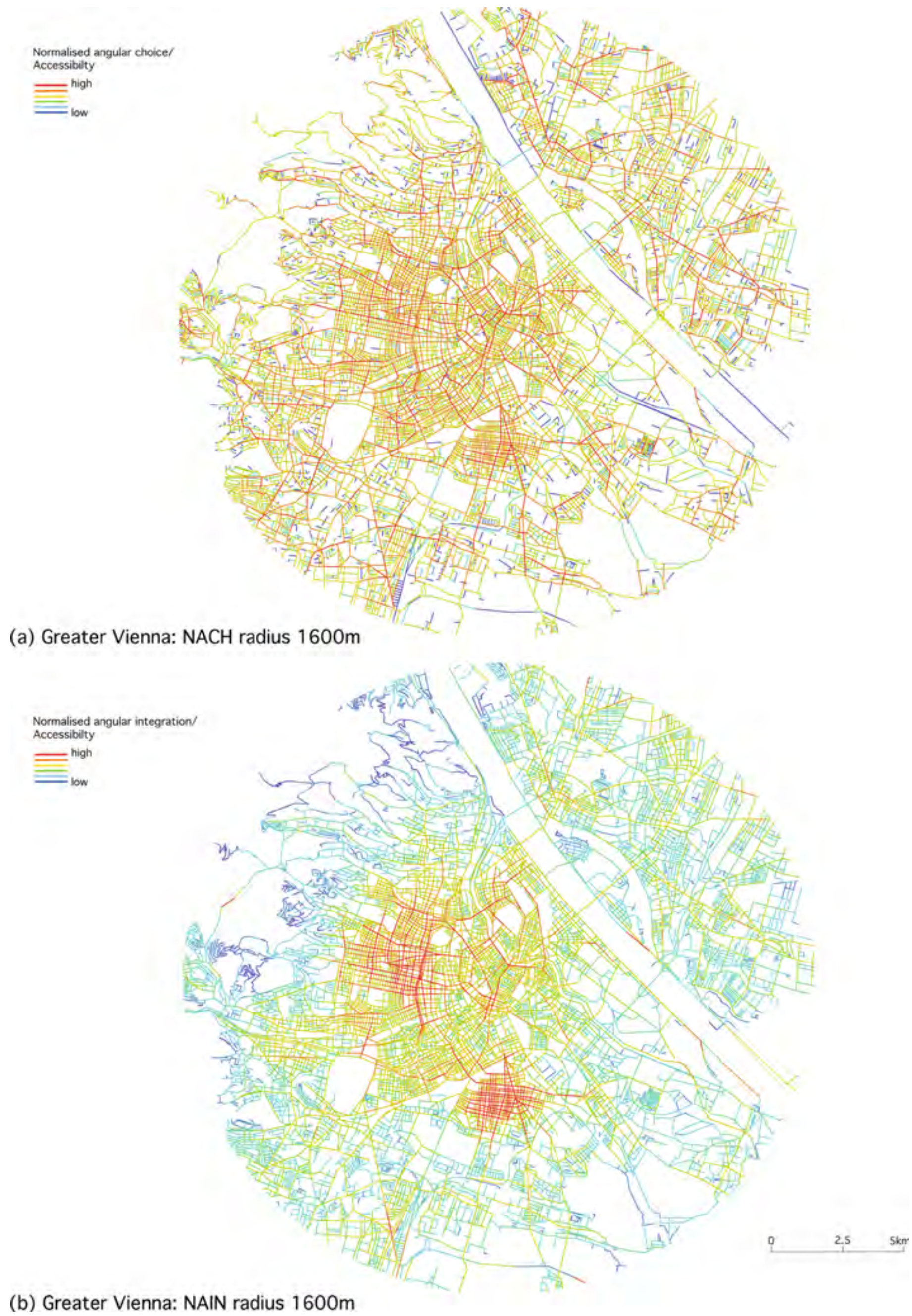
Fig. 2.44 Normalised values from the angular segment analysis: (**a**) NACH radius n and (**b**) NAIN radius n for Greater Vienna

NAIN shows the to-movement potentials of various scale levels, whereas NACH shows the through-movement potentials. Economic centres tend to locate themselves in areas with streets that have high NAIN values, and preferably along streets with high NACH values for catching the through travellers.

NACH radius n depicts the deformed wheel pattern of the main route network. As can be seen in the NAIN radius n analysis, the main centre of Vienna is the historic core extended by the inner-city districts as being highly central (Fig. 2.44).

In contrast, the NACH radius 1,600 m highlights the most vital main route network on a local neighbourhood level. The NAIN radius 1,600 m shows the to-movement potentials for various neighbourhoods. All of these local centres tend to have a very high pedestrian inter-accessibility (Fig. 2.45).

Fig. 2.45 Normalised values from the angular segment analysis: (**a**) NACH radius 1,600 m and (**b**) NAIN 1,600 m for Greater Vienna



For normalising the values, the following equations can be best used for NACH and NAIN for a radius r:

NACH = log (Choice (r) + 2)
NAIN = log (Integration (r) + 2)

These normalisation formulas are robust and work well for all types of built environments. The usefulness of NAIN and NACH is when comparing different cities with one another, in particular when the axial maps are not georeferenced. The numerical values of the NAIN and NACH analyses of Vienna in Figs. 2.44 and 2.45 were normalised with these two mathematical formulae. When all the maps are georeferenced with the same type of units, there is in principle no need to normalise the values.

Currently, there are experiments going on to develop more advanced normalisation formulas for NACH and NAIN. Both radius n and various local metric radii can be applied (Hillier et al. 2012, p. 191):

$$\text{NACH} = \frac{\log(\text{Choice}(r) + 1)}{\log(\text{Total depth}(r) + 3)} \tag{2.9}$$

$$\text{NAIN} = \frac{\sqrt[1.2]{\text{Node count}\ (r)}}{\text{Total depth}\ (r)\ +\ 2} \tag{2.10}$$

Both equations were developed and tested through the comparison of 50 different cities and large neighbourhoods. The chosen cities had a large variation in geographical location, cultural background, and spatial layout (from strict orthogonal to an organic labyrinthine network) and size (from less than 1,000 up to 250,000 segments) (Hillier et al. 2012).

The following cities were chosen:

(1) USA: Manhattan, Chicago, Chicago centre, Denver, Charleston, Las Vegas, Atlanta, New Orleans, Hollywood, and Washington;
(2) South and Central America: Santiago, Mexico City (central areas), Rio de Janeiro, Brasilia, Recife, Teotihuacan, Uberlandia, Sao Paulo, Petropolis, and Ouro Preto;
(3) Europe: Barcelona, Mytilene, Nicosia, Nicosia in walls, Venice, Athens, Hamburg, Canterbury, Munich, Antwerp, London, Madrid, Alkmaar, Amsterdam, Rome, Bath, Apt, and Gouda;
(4) Middle East: Hamedan, Shiraz, Istanbul, Jeddah, Ahmedabad, and Konya;
(5) Asia: Tokyo, Beijing, Kyoto, Suzhou, Hong Kong, Xangai, and Shanghai;
(6) Australia and New Zealand: Auckland.

In addition, Hillier et al. (2012) tested four different neighbourhoods in London as reference cases: Clerkenwell, Barnsbury, Brompton, and South Kensington. The reason for this choice was that dense movement has been observed in these areas. The collected empirical movement data were tested against various spatial calculations. The two different normalisation equations for angular segment integration and angular choice seem to work well for a cross-comparison of different cities and urban areas.

2.6 Four-Pointed Star Model

In 2012, Bill Hillier and his colleagues experimented with combining various normalised measurements, such as combining the mean NACH or mean NAIN with the max NAIN or max NACH (Hillier et al. 2012, p. 170). For comparing the 50 cities with each other, they applied these four measures in a four-pointed star model by using Z-scores or standard scores. The Z-score is a value's relationship to the average of a group of values, measured in terms of standard deviations from the mean. A positive Z-score indicates that the value is above the mean, and a negative Z-score indicates that the value is below the mean. In this way, Bill Hillier, Tao Yang, and Alasdair Turner made it possible to compare cities with one another for describing the degree of integration of their foreground networks in relation to their background networks.

As the results show, various cultures influence the relationship between the background and the foreground network. Arab and Persian cities have low values for the correlations between these four measures, whereas Greek cities have high values. Chinese cities have a highly integrated foreground network, but a poorly integrated background network. European cities vary a lot on these scales. The essence is that the foreground network (identified by the NACH analysis) is needed to interconnect the various centres (identified by the NAIN analysis) in a city with one another.

For generating the four-pointed star model, the following equations for calculating the Z-scores are applied for both the NAIN and NACH values:

$$\begin{aligned} \bar{X}_{max} &= \frac{\sum_{i=1}^{50} X_{max}(i)}{50} \\ Z_{max}(i) &= \frac{X_{max}(i) - \bar{X}_{max}}{\bar{S}_{max}(i)} \end{aligned} \tag{2.11}$$

where $X_{max}(i)$ denotes the maximum value of the city i.

$$\begin{aligned} \bar{X}_{mean} &= \frac{\sum_{i=1}^{50} X_{mean}(i)}{50} \\ Z_{mean}(i) &= \frac{X_{mean}(i) - \bar{X}_{mean}}{\bar{S}_{mean}(i)} \end{aligned} \tag{2.12}$$

Table 2.1 Values from the 50 cities analysed by Hillier et al. (2012)

	NACH	NAIN
$X_{\max}$	1.5679	1.8705
X_{mean}	0.912	1.2206
S(X_{mean})	0.098	0.522
S($X_{\max}$)	0.0669	0.767

where $X_{mean}(i)$ denotes the mean value of the city i. where S is the standard deviation from the 50 cities, $x_{\max}$ is the maximum value, and x_{mean} is the average value for NACH or NAIN either from a city under scrutiny or from the 50 cities analysed by Hillier et al., (2012). Further, they compared the maximum NAIN and NACH as well as the mean NAIN and NACH of these cities. Because the 50 cities are representatives from America, Europe, the Middle and Far East, and Australia/New Zealand, the following values can be used based on these 50 cities (Hillier et al. 2012, pp. 164ff). Table 2.1 shows the various max and mean values from the 50 cities analysed by Hillier et al. (2012).

The sizes of the chosen 50 cities did not matter, and all of the radius n measures could be used (Hillier et al. 2012). Therefore, their mean values can be applied to other cities with the purpose of testing to what extent a particular city scores above or below the average in terms of to-movement (NAIN) or through movement (NACH) . The mean values represent the majority of streets in the city, which is the background network. Conversely, the maximum values represent the main route network, which is the foreground network. NAIN represents the to-movement potential where the max values often represent the main shopping streets, and NACH represents the through-movement potential, where the maximum values represent the main routes through or between various urban areas.

In the following, we will apply these mean values from the 50 cities for the four-pointed star model to our examples of the towns of Lelystad and Hilversum and the city of Vienna. In the Depthmap software, the column properties allow one to retrieve the max and mean values for NACH and NAIN.

For the Dutch town of Hilversum:

NAIN max = 1.4046

NAIN mean = 0.951158

NACH max = 1.56825

NACH mean = 0.603626

X_{mean} and the standard deviation values S are used from the comparison of the 50 cities. Thus, we get the following results:

$$Z(NAIN_{\max}) = \frac{(1.4045-1.8705)}{0.767} = -0.608 \tag{2.13}$$

$$Z(NAIN_{\text{mean}}) = \frac{(0.951158-1.2206)}{0.522} = -1.3871 \tag{2.14}$$

$$Z(NACH_{\max}) = \frac{(1.56825 - 1.5679)}{0.0669} = 0.0052 \tag{2.15}$$

$$Z(NACH_{\text{mean}}) = \frac{(0.0603626 - 0.912)}{0.098} = -3.147 \tag{2.16}$$

We applied the same logic to the town of Lelystad:

NAIN max = 1.56903

NAIN mean = 0.901995

NACH max = 1.65309

NACH mean = 0.552625

$$Z(NAIN_{\max}) = \frac{(1.56903-1.8705)}{0.767} = -0.8697 \tag{2.17}$$

$$Z(NAIN_{\text{mean}}) = \frac{(0.901995 - 1.2206)}{0.522} = -0.6104 \tag{2.18}$$

$$Z(NACH_{\text{max}}) = \frac{(1.65309 - 1.5679)}{0.0669} = 1.2734 \tag{2.19}$$

$$Z(NACH_{\text{mean}}) = \frac{(0.552625 - 0.912)}{0.098} = -3.6671 \tag{2.20}$$

Figure 2.46 shows a four-pointed star model of Hilversum and Lelystad. Each measure is a standard score (Z-score) varying about 0 with a negative minimum at the centre and positive maximum at the edge (Hillier et al 2012, p. 170). On the x-axis, we plot the mean NACH (top) and mean NAIN (bottom) values, and on the y-axis we plot the max NAIN (left) and max NACH (right). The four-pointed star diagrams for Hilversum and Lelystad depict how they spatially behave and score in comparison and in relation to the average of the 50 cities and how their values deviate from this average.

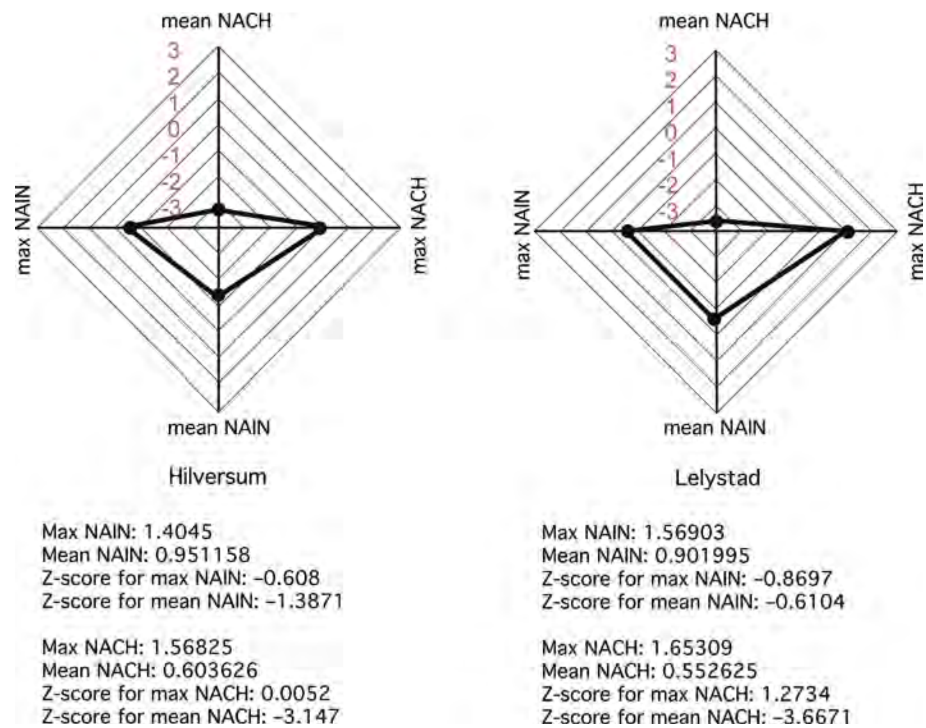


Fig. 2.46 Four-pointed star model of Hilversum and Lelystad

From the results for both Hilversum and Lelystad in relation to the 50 cities, we can see that the to-movement potentials (NAIN) score slightly below average for both the maximum and minimum values. For the through-movement potentials, both cities also score very low on the NACH mean values, which represents the background network. For the maximum NACH value, Lelystad is above average for the main route network, whereas Hilversum is close to the average. These results tell us first of all that Hilversum and Lelystad have very different spatial setups. Both town' background networks are highly segregated. Lelystad's strong foreground network suggests that all segregated neighbourhoods are held together by the main route network, which supports car-based movement.

Even though Hilversum and Lelystad have very different spatial patterns—new town versus historic town—the differences between them in relation to the 50 cities is not large. The local Dutch culture has influenced the spatial structure of the background network in the modern planned cities. This means that within neighbourhoods, the through-movement potentials are very low. All segregated neighbourhoods are connected to each other with a highly integrated main route network, mainly for vehicular movement.

Interestingly, Greater Vienna's four-pointed star model depicts a different spatial reality. All values are close to the average in comparison to the 50 cities. For the NACH values, the main route network has average integration values and is connected to the whole region around Vienna. For the NAIN values, the scattered former towns and villages around Greater

Vienna lower the NAIN values. If just Vienna's historic core is analysed separately, the NAIN values would be high. However, most towns and villages are well connected to the main route network. In other words, Greater Vienna has a balance between its foreground and background networks for through-movement and to-movement. This means that spatially Vienna's neighbourhoods are very pedestrian-friendly and well-connected to the foreground network. Vienna is known to be a city with a high quality of life (Mercer Quality of Living Survey, 2019). Seemingly, Vienna's high scores for quality of life are also spatially supported (Yamu 2020) (Fig. 2.47).

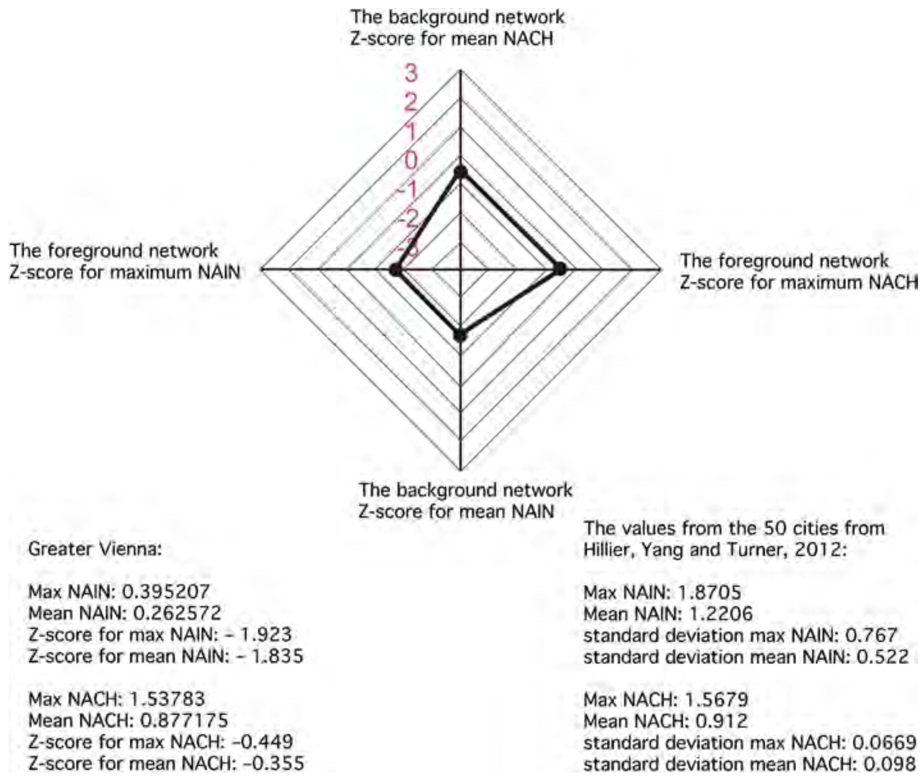


Fig. 2.47 Four-pointed star model of Greater Vienna

2.7 The Use of Scatterplots

Scatterplots are useful for identifying the type of relationship between two quantitative variables. For example, correlations between global and local integration values refer to the concept of the 'intelligibility' of an urban system. The closer the correlation coefficient is to one, the more orientable and thus intelligible the built environment under scrutiny is. A high number on the correlation coefficient means that when staying in a local area, the street pattern logic of a whole city can be understood. For example, when standing in a neighbourhood with a strict orthogonal street network, it can be easily understood that the whole city follows a similar logic, for example, Manhattan in New York. Thus, the concept of intelligibility also refers to cognitive mapping and to Lynch's approach (1960).

Scatterplots are also useful when correlating angular choice results with high and low metric radii because this can indicate the degree of street life in built environments. When the correlation coefficient is high, the locally integrated main routes are also highly integrated on a city scale. Conversely, when the correlation coefficient is low, the locally integrated main routes are located far away from the main routes on a city scale. Figure 2.48 shows the scatterplots for Lelystad and Hilversum. The correlation coefficient (R^2) for Lelystad is very low in comparison with Hilversum. In Hilversum centre, the streets have high values for angular choice analyses with both high and low metric radii, whereas the streets in Lelystad have high values either on a local or on a city scale.

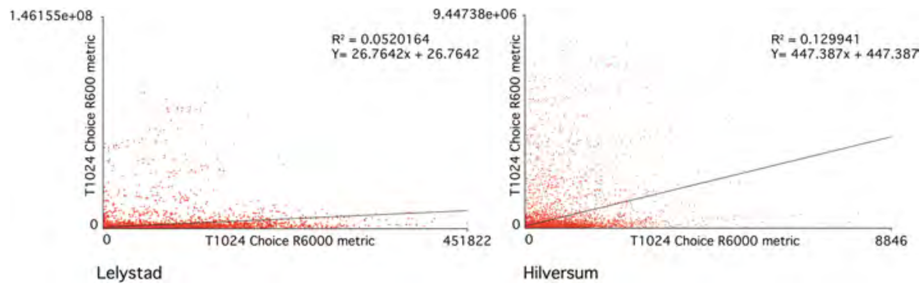


Fig. 2.48 Scatterplots for Lelystand (left) and Hilversum (right)

2.8 Conclusions: Common Errors and Mistakes When Analysing Linear Urban Space

Axial and segment analyses have undergone great changes since the 1990s. Software developments, computer capacity, access to big data over time, and criticism of weaknesses of earlier methods have contributed to methodological and analytical developments. Old axial analysis calculation models from the 1990s, such as radius–radius integration analysis and integration gradient analysis have been stepping-stones on the way forward for the constant improvement of the current calculation methods (Yamu et al. 2021). Over the past decade, the accuracy of the results from the segment-based angular choice and angular integration analyses with various metric radii has been established through the application of these measurements in research and consultancy wordwide.

However, a typical beginner's error when drawing an axial map is that the axial lines are not properly linked with each other. Often, a subset of axial lines is not connected to an axial line from the overall axial map. This can distort the results of the analysis on a citywide and local scale. Another beginner's error is that the axial map is drawn with polylines instead of single lines. A polyline axial map makes it difficult to run a depth analysis from a particular line. When some road or street links are missing in the axial map, this leads to incorrect conclusions from the space syntax analyses. The same accounts for forgetting to unlink axial lines representing bridges and tunnels. Wrong connections of axes and segments can distort the computed results. Furthermore, beginners tend to 'over-model', drawing too many axial lines for producing an axial map. By definition, an axial map is the minimal set of axial lines representing sightlines indicating movement paths. Practice is needed to produce an axial map with the minimal set of axial lines.

Another typical misuse of space syntax is to include light rail or metro lines in the axial map. Public transport travellers cannot make a decision to make a turn to a side street when travelling between public transport stops. Therefore, rails cannot be included. The best is to analyse the results from the space syntax analyses at the public transport stops. Where the results from the choice and integration analyses are high at all scale levels, there is a greater need for public transport facilities.

First of all, focus on the research question when making an axial map. When investigating pedestrian accessibility or anti-social behaviour in public spaces, the pedestrian movement routes on pavements, subways, paths through parks, etc. need to be represented as axial lines. Here, the highway network lacking pavements can be left out. When investigating larger metropolitan areas, the highway network needs to be added to the axial map. At present, the challenge is to develop well-functioning application software for generating axial maps from road centre lines in geographic information systems (GIS). Manually generating axial maps of large metropolitan areas is a monotonous and time-consuming task to undertake.

Another new beginner error can be the incorrect interpretation of the spatial analysis results. Therefore, we advise first drawing and analysing a neighbourhood or town you are familiar with. We suggest you to read the theory chapter and some of other literature related to your research topic on space and society.

2.9 Exercises

For most of the exercises, please use software. DepthmapX and "DepthmapX manual for dummies" can be downloaded from www.spacesyntax.net and www.github.com.

Exercise 1

Carry out a manual one-step analysis from the main routes from two different urban areas from a city or town.

Exercise 2

Carry out a manual two-step analysis from a shopping street and a residential street from your own neighbourhood or a neighbourhood you are familiar with. Compare the total number of axes that can be reached within a radius of 500 m starting from both streets.

Exercise 3

Carry out a manual n-step analysis from the main route system of your own neighbourhood. What is the maximum number of direction changes from the main route network to the local streets of your neighbourhood? What kinds of functions are located in the buildings of these streets?

Exercise 4

Draw an axial map from two neighbourhoods or towns you know. You can use any software that allows you to export a dxf. file or mif. file. Best is to use any geographic information system software because it allows the generation of a georeferenced axial map. For comparison, you can draw two axial maps, one from a modern or newly developed neighbourhood and one from a historic neighbourhood. This allows for a better comparison. Process the map and compute the connectivity and the global and local axial integration using Depthmap software. Reflect upon the results. Where are the local centre(s) located? Are there any differences between connectivity and global and local integration results?

Exercise 5

Carry out a step depth analysis using the Depthmap software from all public transport stops in your neighbourhood. Describe the degree of accessibility to the neighbourhood for these public transport stops.

Exercise 6

Correlate in the Depthmap software the local and global integration results of the two neighbourhoods from exercise 4. What is the value of the correlation coefficient? What is the degree of intelligibility of these neighbourhoods? What does this tell us about the neighbourhoods?

Exercise 7

Carry out angular integration and angular choice analyses with low and high metric radii of the neighbourhoods using the Depthmap software. Where are the main routes located? Are they going around or through the neighbourhoods? Describe the spatial features of the local centre(s) in these areas.

Exercise 8

Using the Depthmap software, correlate the angular choice values with high and low metric radii for both neighbourhoods. Describe and reflect upon the results.

Exercise 9

Normalise the obtained results from your angular integration and angular choice analyses for high and low metric radii. Generate a four-pointed star model for the neighbourhood using the values from Table 2.1. Explain and reflect upon the results.

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3 Orientation and Wayfinding: Measuring Visibility

Contents

Abstract

In this chapter, we explain how the analytical logic of space syntax is applied for visibility analysis. In the previous chapter, the focus was on presenting all public spaces as axial sightlines. The individual axial line is a one-dimensional (1D) representation of public space and is useful for analysing the interrelationship of public spaces on a citywide scale. At the neighbourhood scale, a two-dimensional (2D) representation of spatial elements can be useful. In particular, the public realm, such as public squares, parks, and wide streets, benefits from a 2D spatial analysis with a visual field using a raster-based as well as an all-line modelling approach. In order to explain visibility analysis in space syntax, we start with the well-known 2D geographical visibility analysis 'isovist' as a field of vision. We build upon and explain visibility point-depth analysis and visual graph analysis. Further, we demonstrate how the simple point-depth calculations contribute to a theory on space and urban centrality. In addition, we discuss 3D isovists. Furthermore, we also demonstrate and discuss the use of the all-line analysis. Finally, we expound upon agent-based modelling. Exercises are provided at the end of this chapter.

Keywords

Visibility • Wayfinding • Isovist • Visual graph analysis • All-line analysis • Agent-based modelling

Key Concepts

Orientation and navigation • Wayfinding • Convex space • Two-dimensional (2D) representation of space • Visual field • Through vision • All-lines

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Learning Objectives

After studying this chapter, you will

- be familiar with the concept of visual fields;
- have knowledge about how to calculate spatial integration for visual fields;
- be able to conduct an isovist analysis, visual graph analysis, and through vision analysis;
- have an understanding of the all-line axial map and how to create it;
- have knowledge about agent-based modelling using visual fields and be capable of creating an agent-based model; and
- be able to critically reflect on different concepts and analysis techniques related to visibility, orientation, and navigation, including wayfinding for different spatial settings.

3.1 Isovist Analyses

Visual orientation is decisive in how we orientate ourselves and thus navigate through the built environment. When manoeuvring through an area we are not familiar with, we aspire to get a visual overview of the spaces we are moving through. Often, a panoptical view field of 180° is appropriate for most people when cruising through cities. Contrarily, a guerrilla soldier on foot has to act fast in every spatial direction in each space. The soldier is in need of an immediate 360° overview in all directions of every space they enter. These 360° turns have to be made for every step the guerrilla soldier takes because the visual field can change significantly with every step taken. Likewise, a sniper with their static position has to regularly take a 360° overview of their location to ensure avoiding an ambush. The panoptical view from a certain location is called an 'isovist'.

C. R. V. Tandy is acknowledged to have coined the term 'isovist' in 1967 (Tandy 1967). The most well-known definition of an isovist is from M. L. Benedikt, who also introduced a set of analytical measurements of isovist properties. Benedikt (1979, p. 47) explains that an isovist is "(…) the set of all points visible from a given vantage point in space and with respect to an environment". An isovist can be briefly explained as a visual record of what can be seen in a 360° angle from a given location. The visual record is taken at average eye height. Isovists describe the space from the viewpoint of individuals as they perceive, interact with, and move through space (Turner et al. 2001). For landscape architecture, urban planning, and military science, a similar concept of 'viewshed' is applied.

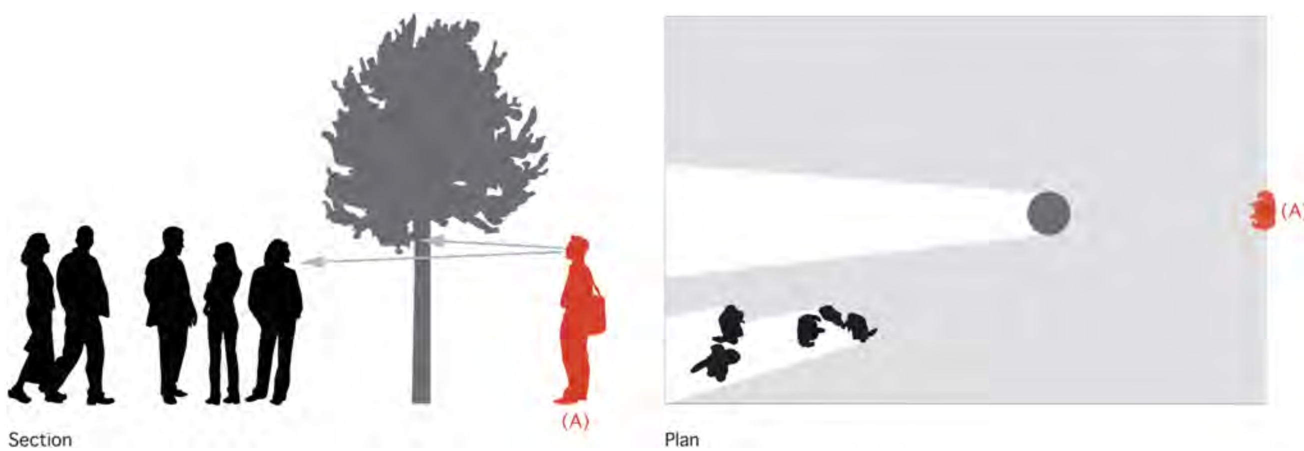


Fig. 3.1 The logic of a 180° isovist field from a person's location (A)

An isovist visualises the geometrical area of a person's panoptical view from a particular location in the built environment. The isovist's area is defined by subjects, objects, and vegetation in the open space under scrutiny. When moving through space, the shape and size of the isovist field changes with every newly occupied location. It is thus possible to visualise visual field sequences of particular movement routes through cities. Figure 3.1 illustrates a 180° isovist from a person's location in the public realm. The tree close to the person (A) influences their visual field and therefore impacts the isovist field. The same applies to the group of people in close proximity to the tree. Simply speaking, both block the individual's view.

This so-called one-point isovist analysis is mostly useful at a neighbourhood scale. Isovist analysis depicts the degree of visibility of the location of urban artefacts and visualises the visual field area and perimeter. In reverse, in Fig. 3.1 the one-point isovist field also indicates from which locations of the public space the person (A) is visible.

Isovist analysis is useful for testing the impact of new urban interventions and how they will increase or decrease the visual experience from a given location. Inversely, the isovist analysis also allows identifying optimal locations for, for example, a temporary concert stage in a public space. All kinds of obstacles such as vegetation, buildings, and light poles can partly block the view and therefore reduce the isovist field. Nothing is more annoying than staring at a light pole or tall person in front of you at a live concert in an urban square. In general, the applicability of isovist fields is manifold. Figure 3.2 depicts two different isovist fields for the same setting of park X.

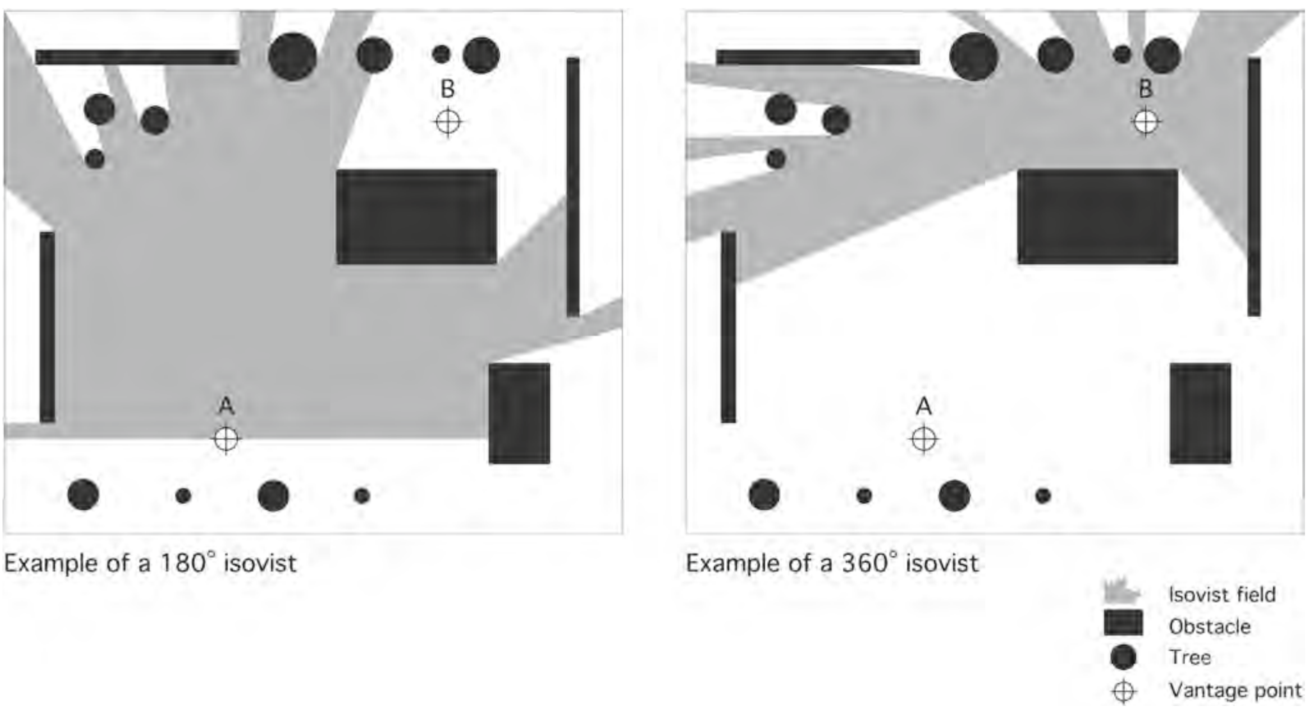


Fig. 3.2 Two different isovist fields from vantage point A applying a 180° view (image left) and from vantage point B applying a 360° view (right image) for our example of park X

An isovist visualises the geometrical area of a person's panoptical view from a particular location in the built environment. In Fig. 3.2, the visual field for vantage point A depicts what a person sees when entering the park, whereas the visual field for vantage point B depicts the view when the person turns around on their own axis. While the 180° isovist example illustrates an individual overview of a certain space, the 360° isovist depicts a low viewshed due to the hidden location of vantage point B behind the building. This hidden location is an example of spaces that are highly likely to be used for criminal activities. The person in location B makes sure that they can hardly be seen by other people in the park. For analysing surveillance of a given space, a 360° isovist is conducted. In our example, the individuals do not see each other (represented by vantage point A and B in Fig. 3.2).

Figure 3.3 illustrates four sequences of 180° one-point isovists for space X. None of the indicated four individuals can see each other. Red and yellow as well as green and blue isovist fields overlap. The higher the overlap of isovist fields from different strategic urban locations, the easier people navigate through the space. This is due to the provision of consistent visual information about the space they move through.

Isovist sequences are connected to Gordon Cullen's concept of 'serial vision' (1971). Cullen draws a panoptical view sketch from each strategic location along a chosen route in order to achieve visual coherence and organisation among the jumble of buildings, streets, and spaces that make up the urban environment. In many ways, Cullen's method is dealing with intrinsic properties of space, whereas an isovist analysis is dealing with extrinsic properties of space. Cullen is drawing the surface texture of the objects we see at every vantage point, whereas the isovist analysis is visualising the spaces between the objects.

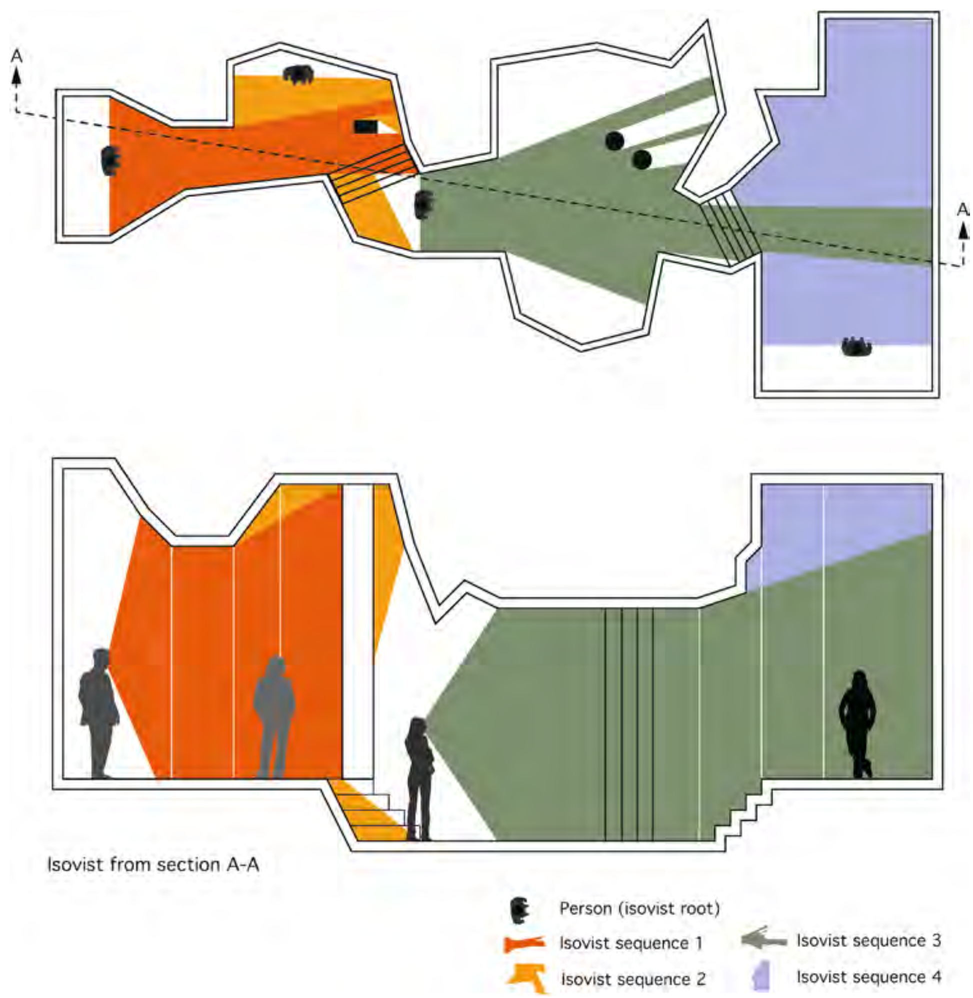


Fig. 3.3 Sequences of isovists for the ground map (above) and section (below) of an exemplary space X. Horizontal (above) and vertical (below) representations of a 2D isovist analysis

Isovists can be represented in several ways. Figure 3.3 shows a plan and a section of space X with the viewpoints of four people. In the plan, an isovist of 180° is used. In section a-a, an isovist of 120° is used. The persons have to move their eyes a little up and down to cover this view field. The isovists in section A-A can deal with height differences in public spaces. In addition, we applied serial vision to a route through the town centre of Haarlem close to Amsterdam (Fig. 3.4). The route is

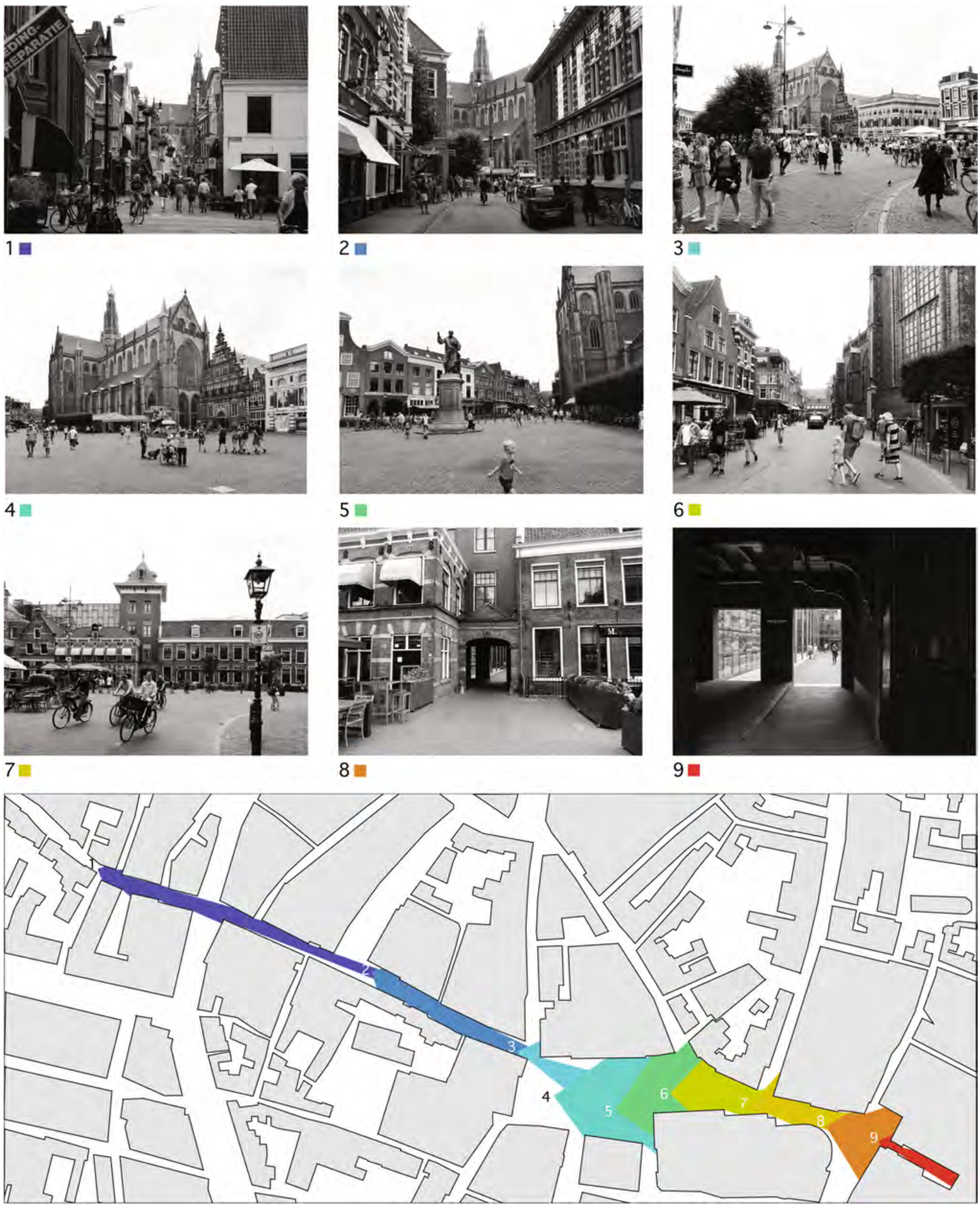


Fig. 3.4 A serial vision from a route in Haarlem applying 90° isovists

illustrated with photos taken from the isovists' vantage point of the analysis. Several 90° isovists were conducted. The photographs numbered 1–9 show how the impressions of the surface of buildings and public spaces can change from point to point. In particular in open spaces, such as the main square, the view field can change a lot after only a couple of meters. Therefore, the one-point and the serial vision route isovists can be useful in urban planning.

Two well-known urban projects for the application of isovist analysis are the redevelopment of Trafalgar Square in 2003 and the Millennium Bridge project in 2000 in London, both by the architect firm Foster+Partners. For both projects, isovist analysis was applied in a descriptive and predictive way. Trafalgar Square was an isolated island for pedestrians with two columns in its centre and surrounded by heavy vehicular traffic. The natural movement paths to enter and exit Trafalgar Square were blocked by fences and signs. An empirical data collection in the form of recording stationary activity and pedestrian movement showed that Londoners avoided the centre of Trafalgar Square and that tourists failed to make the journey between Trafalgar Square and Parliament Square. Some tourists tended to stand on a traffic island in the middle of the most trafficked road for taking pictures. According to the isovist analysis taken from that spot, pedestrians had the largest overview over the square and into the streets leading to the square. One could also see all the way to Buckingham Palace from that isovist root (Space Syntax Laboratory 2001). A set of space syntax analyses was carried out to test and validate urban design options to improve pedestrian accessibility to the centrally located fountains. At present, Trafalgar Square is a central meeting destination for Londoners and tourists alike (Fig. 3.5).

For the Millennium Bridge project, the isovist analysis was applied for proofing the optimal location for the new Millennium Bridge to decision makers. Further, the isovist analysis evidenced the vast visual field the bridge would cover when completed. The visual field included overviews over the Thames River, covering major tourist icons like Big Ben, Westminster Abbey, the Millennium Wheel, St. Paul's Cathedral, Tower of London, and Tower Bridge (Space Syntax Laboratory 1994). All these artefacts are recognised as defining the image and identity of London. Isovist analysis demonstrated how these artefacts are all visible from the location of the Millennium Bridge (Fig. 3.5).

Fig. 3.5 Impressions from Trafalgar Square (left) and the Millennium Bridge (middle and right) from 2015

For conducting an isovist analysis, the root of the visual field can be located at the most-used space to study the kind of overview a person has from it. Conversely, the root of the isovist can also be located at places with lower use to identify their spatial features (Trova et al. 1999). For public spaces, stationary social interaction, for example, where people stand and sit, correlates with the isovist field (Trova et al. 1999). The higher the density of people at a certain location, the larger the overall isovist field as the sum and overlap of all people's individual isovist fields.

Until now, the 2D isovist analysis has been mostly applied in urban research and practice. A 2D isovist analysis provides a quick and robust way to gain an overview of a given spatial situation in a time-efficient manner. However, 3D isovist analysis is at the forefront and can add value when, for example, working with 3D city models in virtual reality.

The added value of a 3D analysis using 'voxels' as compared to a 2D analysis using 'pixels' is in line with the thoughts of van Bilsen (2009) because it overcomes the following shortcomings: (1) The vertical dimension, e.g. building heights, is ignored in the 2D analysis even though it influences visibility measures, (2) walkable surfaces of cities differ in height such as on hills and bridges, (3) incomplete landmark analysis in 2D analysis if any, (4) a typology based on the full 3D environment is missing, and (5) a connection to cognitive pattern recognition which occurs in 3D analysis is missing.

In the development of 3D measures for visibility analysis, Fisher-Gerwitzmann and Wagner (2003) developed a tool that emerged from the concept of spatial openness. Following from this, Teller advocated sky-opening maps (2003), Bilsen and Stolk (2007) developed a framework for a 3D isovist-based visibility analysis, Morello and Ratti introduced an urban array of urban-visibility measures called the 'isovist matrix' (2009), Dalton et al. (2015) used information and data from a 3D scan to produce a 3D isovist for the built environment, and Kim et al. (2019) developed a 3D space syntax metric based on 3D isovist capture.

In this context, Dalton et al. (2015) compared the number of times people reported seeing specific content and the places this was displayed in a real built environment with a 3D spatial analysis model of a university campus. The registrations were correlated with the number of isovist values from a 3D scan. The results from the 3D visual graph analysis were compared to the 2D visual graph analysis. The values from the 3D isovist did not deviate much from the values of the 2D visual graph analysis. Departing from this insight in the following, we will explore 2D visual graph analysis (VGA) (Fig. 3.6).

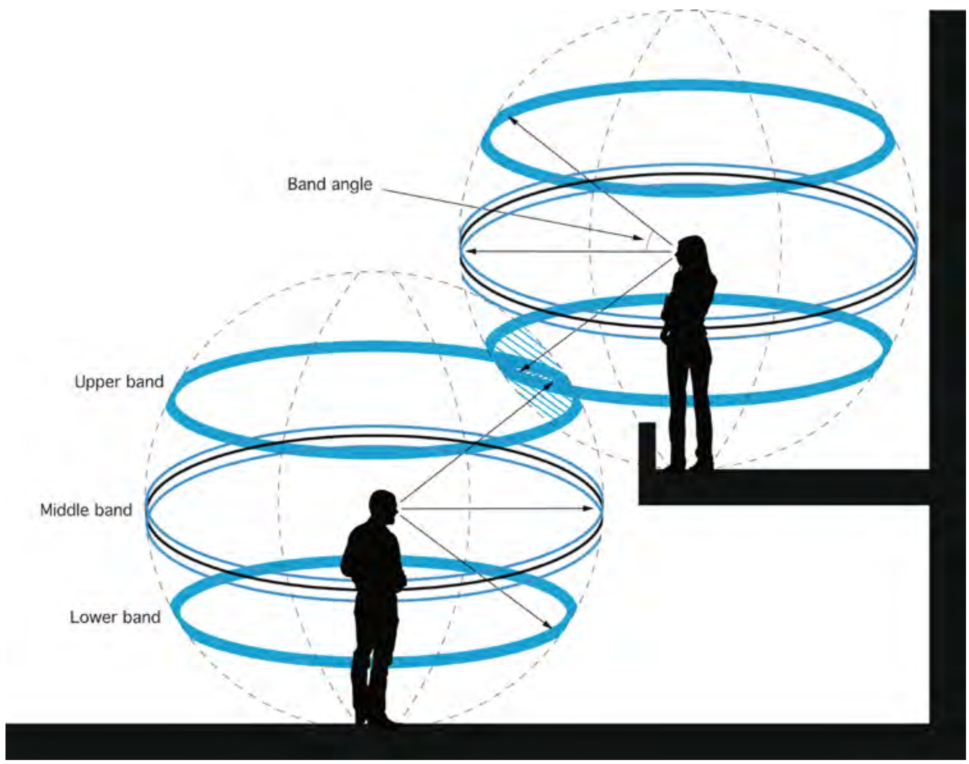


Fig. 3.6 The principle of the construction of a 3D isovist (original Dalton et al. 2015; image redrawn)

3.2 Visual Graph Analysis

Building upon the logic of an isovist analysis, visual graph analysis (VGA) integrates all of the isovist fields from all location points (roots) of a given space. In other words, VGA is a method for analysing the intervisibility connections of urban space. VGA is a raster-based method. For each cell in the grid an isovist is carried out, and its topological visibility in relation to all other cells is calculated. This is done for all cells, and the analysis takes into consideration a cell's centroid as the root. Every move from one cell to another cell in the grid is a topological step, and thus it is possible to calculate how integrated each cell is in relation to all other cells in the grid. Hence, the integration calculations explained in previous chapters can be applied. The VGA calculates how each cell relates to all other cells in the grid. Obstacles like walls, fences, trees, etc. contribute to the topological depth between various cells (Turner 2007).

Prior to the millennium, convex maps were drawn manually, but VGA has replaced convex space analysis. The rule of thumb is to subdivide a space into the least number of convex spaces. Hillier and Hanson (1984, p. 98) define a convex space as "one space where all points within this space are visible to one another". In Fig. 3.7 we illustrate this principle.

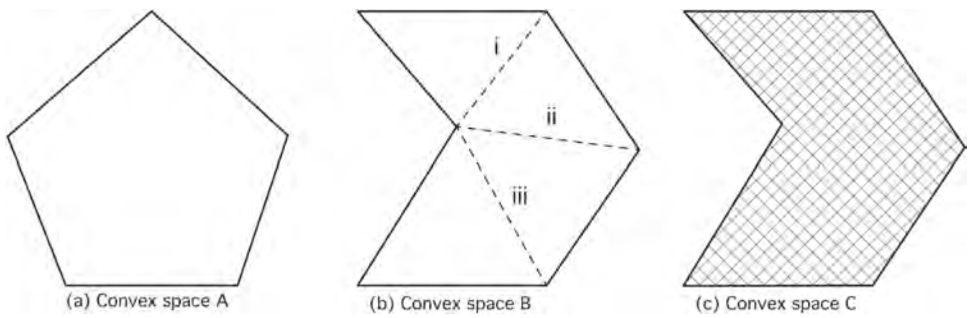


Fig. 3.7 Different types of basic spatial units for the 2D analysis: (**a**) an entire convex space with no subdivision, (**b**) a space with three options of subdivision for generating two convex spaces, and (**c**) a space with a superimposed grid

In Fig. 3.7, the scheme of space A is one convex space, whereas the scheme of space B is two convex spaces. Space B has three options for subdivision, represented by dashed lines (i, ii, and iii). All options are correct. When generating a convex map for a whole neighbourhood, the result is not free from the individual judgement of the modeller. The result can vary slightly when applying a spatial integration analysis to a manually generated convex map, and this particularly accounts for neighbourhoods with organic-shaped boundaries. Space C is superimposed with a raster, and for space C it is possible to calculate objectively how each cell in the raster relates to all other cells in the raster. This is the basis for the VGA.

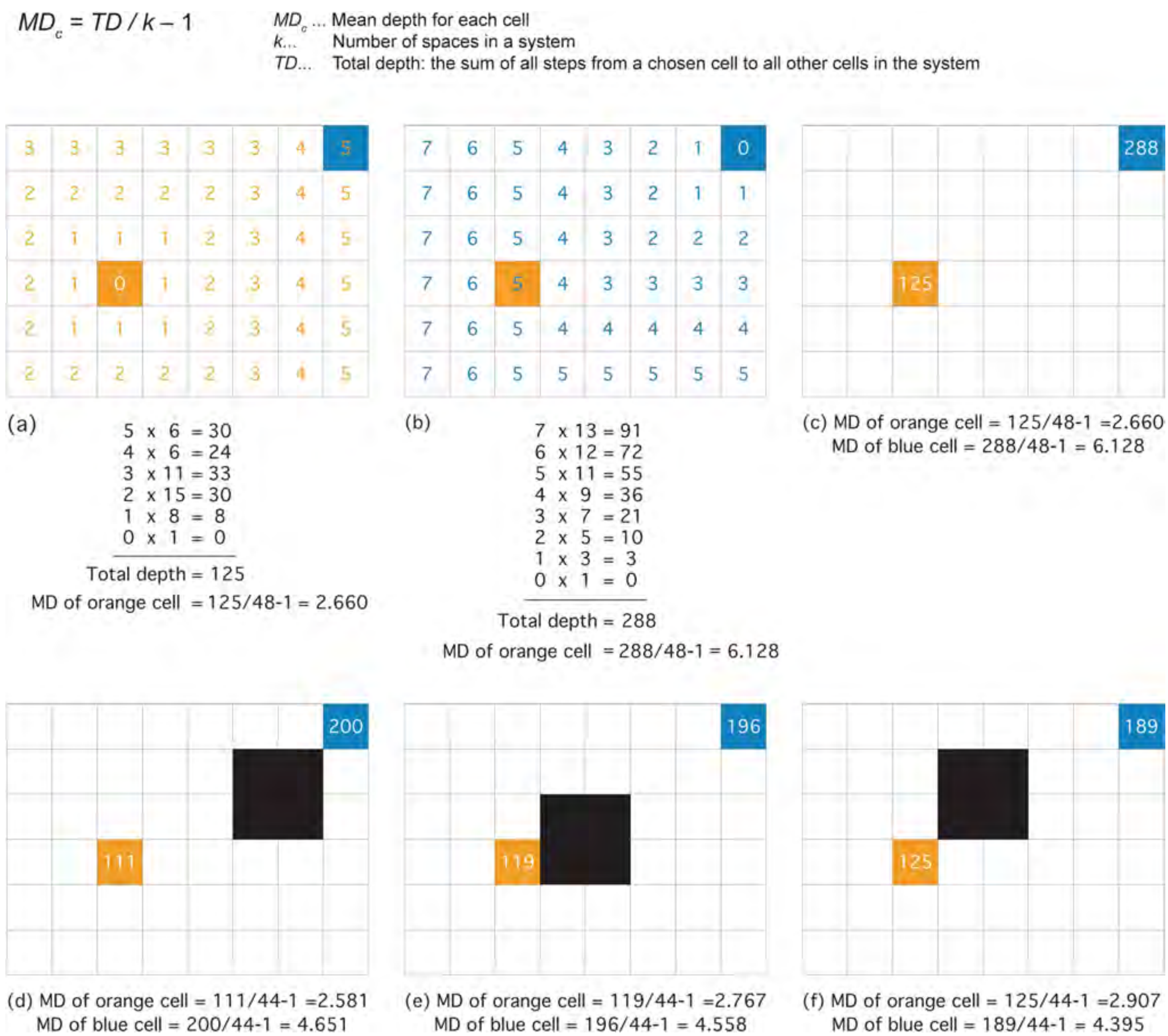


Fig. 3.8 Point-depth analysis: calculating the mean depth (MD) for two different roots excluding and including an obstacle with different positions in the grid

For drawing the digital base map for conducting all kinds of 2D spatial analyses, the following needs to be done. First, all obstacles such as buildings, fences, statues, and ponds need to be drawn as closed polygons on the map. Second, the chosen study area cannot be too big. A rule of thumb for the area's boundary is to include 2–4 blocks around the areas of interest. In most cases, the 2D spatial analyses tools are used for analysing all kinds of public squares. Finally, the study area needs to have a drawn boundary. This boundary is also a closed polygon, and it either follows the logic of the streets as a frame like in our example for Haarlem (Fig. 3.4) or it follows the street plinth of the study area. The more fine-grained the raster for the analysis, the more accurate the VGA results. Overall, VGA indicates how easy or difficult it is to orientate and navigate through neighbourhoods. Moreover, VGA indicates location potentials for stationary activities including social interaction in public squares and streets. Thus VGA is a static local measure.

The same logic for calculating the integration for axial maps also applies for VGA. The mean depth is calculated by the total depth divided by the number of cells minus one. For each step from one cell to another cell in all directions, a syntactic step is taken.

Figure 3.8 illustrates the principle on how to calculate the mean depth (MD) for a raster with two examples of different root cells (nodes). The same mathematical formula for calculating topological distance used in Chap. 2 is used. In example (a), the root indicated in yellow shows how this cell is connected to all others. Example (b) follows the same principle with a different root indicated in blue. The root in example (a) is located more centrally in the system than in example (b). Therefore, the system in example (a) appears shallower with a lower mean depth value than example (b).

The blue root in Fig. 3.8 is located at the upper edge of the system and therefore is not as well connected to all other cells in the system compared to the yellow root. Following this, for example (b) the mean depth value is higher and the system is deeper from this specific location than the yellow cell. The conclusion is that in example (a), all cells in the system are easier to reach compared to example (b) from the given root cell.

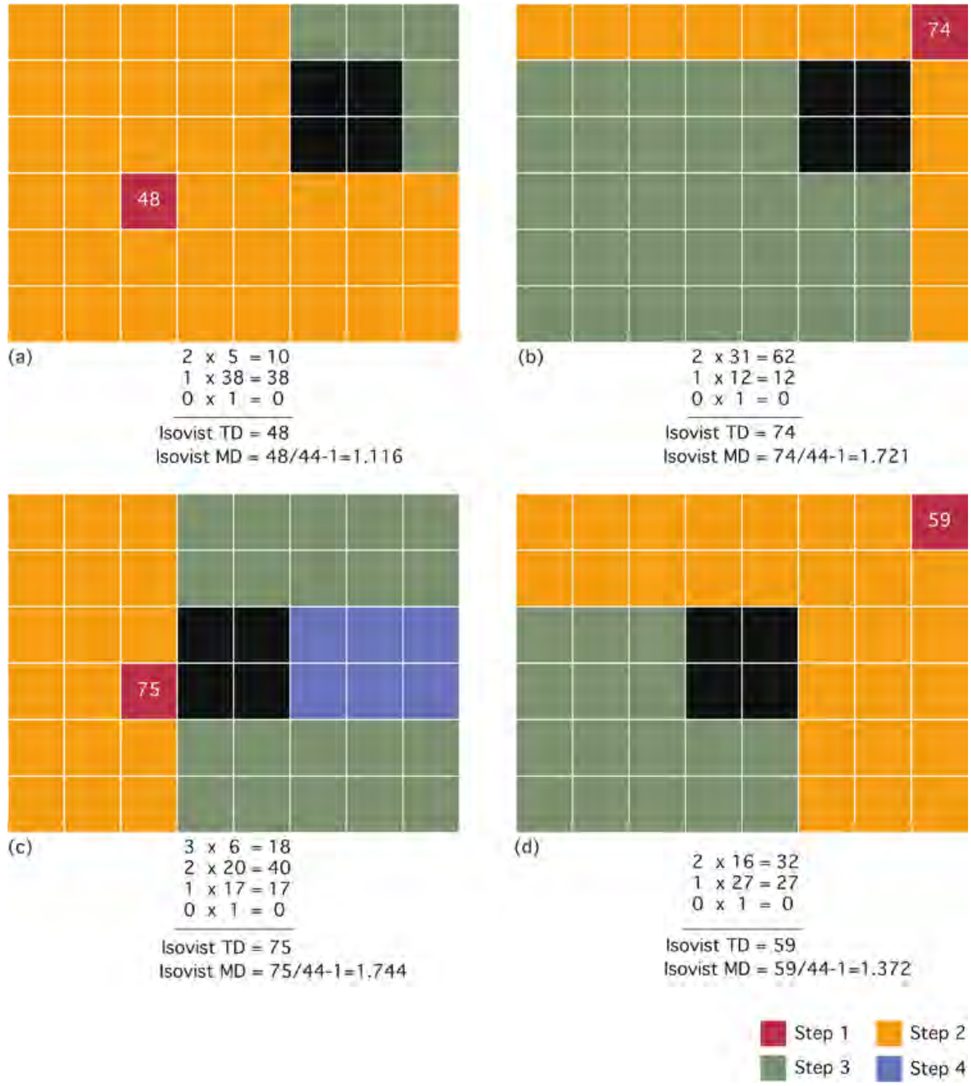
If we place an obstacle in the raster, the calculation takes it into consideration. In our examples (d, e, and f), our obstacle covers four cells in three different locations. Again, we apply to all examples both roots, marked in yellow and blue. All three examples highlight how the position of the obstacle influences the mean depth value.

Following a similar principle, the so-called 'through vision' can be calculated. Through vision analysis depicts the degree of through visions for a neighbourhood or public space. A through vision is the longest possible continuous view. All spaces or cells that can be seen from one point get the same value, like 1. This is the first step. When turning around a corner, all the spaces that can be seen get a new but same value. This is the second step.

Figure 3.9 shows how a through vision is calculated by applying the same setting for the raster, root cells, and obstacles as for calculating the mean depth for the VGA in Fig. 3.8. The red colour shows where the cell is located and is step 0. The yellow colour shows all the spaces that can be seen from the red root cell, thus step 1. The green cells show all the spaces that can be seen when 'turning around the corner' of the black obstacle. This is step 2. When turning yet another corner, the blue coloured cells are step 3.

The mean depth values of the through vision analysis vary according to the location of the obstacle in the grid. The closer the obstacle is to the root cell, the higher the through vision's mean depth value and vice versa. Seemingly, an object located in the middle of an urban space segregates the view field more than when it is placed on the edge. Therefore, through vision analysis from every point in a given urban space can show the degree of visibility for long distances. While the point-depth analysis shows the degree of adjacency, the through vision analysis shows the degree of through-visibility.

Fig. 3.9 Through vision analysis: calculating the mean depth (MD) for two different root cells excluding and including an obstacle with different positions in the grid



Often, important artefacts are placed at the end of the sightline of a through vision. Examples are The Spanish Steps in Rome at the Piazza di Spagna, the Siq in Petra in Jordan, and London Town Hall next to Tower Bridge in London, as shown in Fig. 3.10. Conversely, large open spaces in cities tend to have high values on both the VGA and through vision analysis. Figure 3.11 shows the Old Town Square in Prague and one of the main squares of the Forbidden City in Beijing.

Fig. 3.10 Examples of public spaces with a high degree of through vision: (left) The Spanish Steps in Rome, Italy, (middle) the Siq in Petra, Jordan, and (right) London Town Hall in London, UK

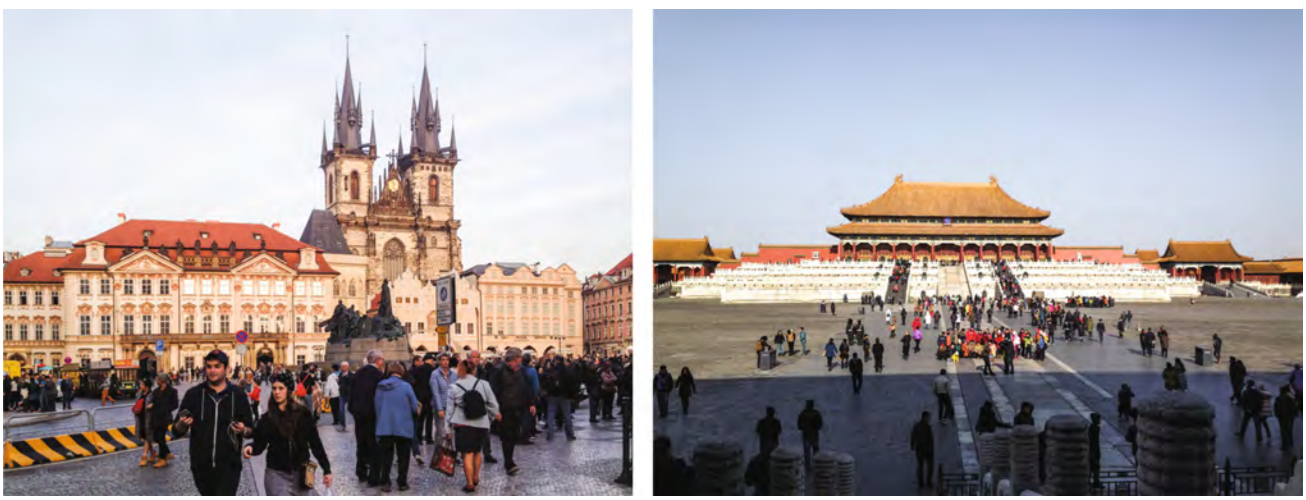


Fig. 3.11 Examples of public spaces with a high degree of visibility (VGA): (left) The Old Town Square in Prague and (right) the Forbidden City in Beijing

For park X, we conducted both a VGA and a through vision analysis (Fig. 3.12). For public spaces such as parks or squares, high intervisibility and a high degree of through vision often overlap. This indicates that those locations are the 'hot spots' for orientation and navigation. In the analysis, the red areas indicated locations in park X that both analyses found to be the most integrated spaces, whereas the areas in blue indicated the most segregated spaces located behind the trees, fences, and buildings. For the point-depth analysis, a syntactic step was taken from one cell to the next cell. For the through vision analysis, the large visible surfaces as a whole were taken as one syntactic step. This analysis further indicated movement routes to or from the park and between and behind trees, fences, and buildings.

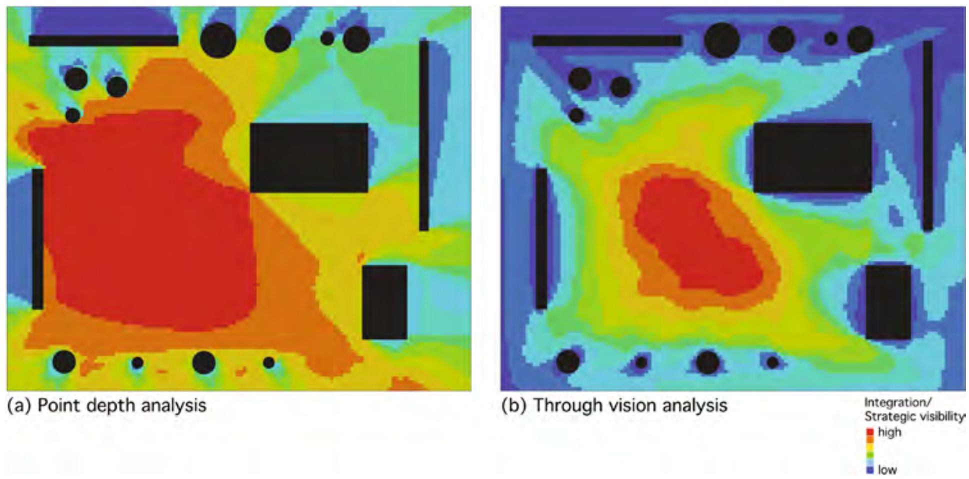


Fig. 3.12 Point-depth analysis (**a**) and through vision analysis (**b**) for park X

In Fig. 3.13, we applied the point-depth and through vision analyses to the areas around the Old Town Square of Prague. The point-depth analysis in image (a) shows that the square is the most visible space in the neighbourhood. In contrast, the through-vision analysis illustrates the longest total through vision, which is influenced by the morphology and shapes of the urban blocks. This has an effect on the integration calculation of the through vision. Often, the largest flow of people can be identified in the most integrated spaces when entering the square. Interesting enough, adjacent to the most integrated spot the statue of Johannes Hus is located. For the VGA (c) and through vision analysis (d), the statue of Johannes Hus was added to the model as an obstacle. For users of the square, it seems that the statue is located very centrally in the square. However, the statue's slightly off-centre position does not affect the high degree of through vision and visibility.

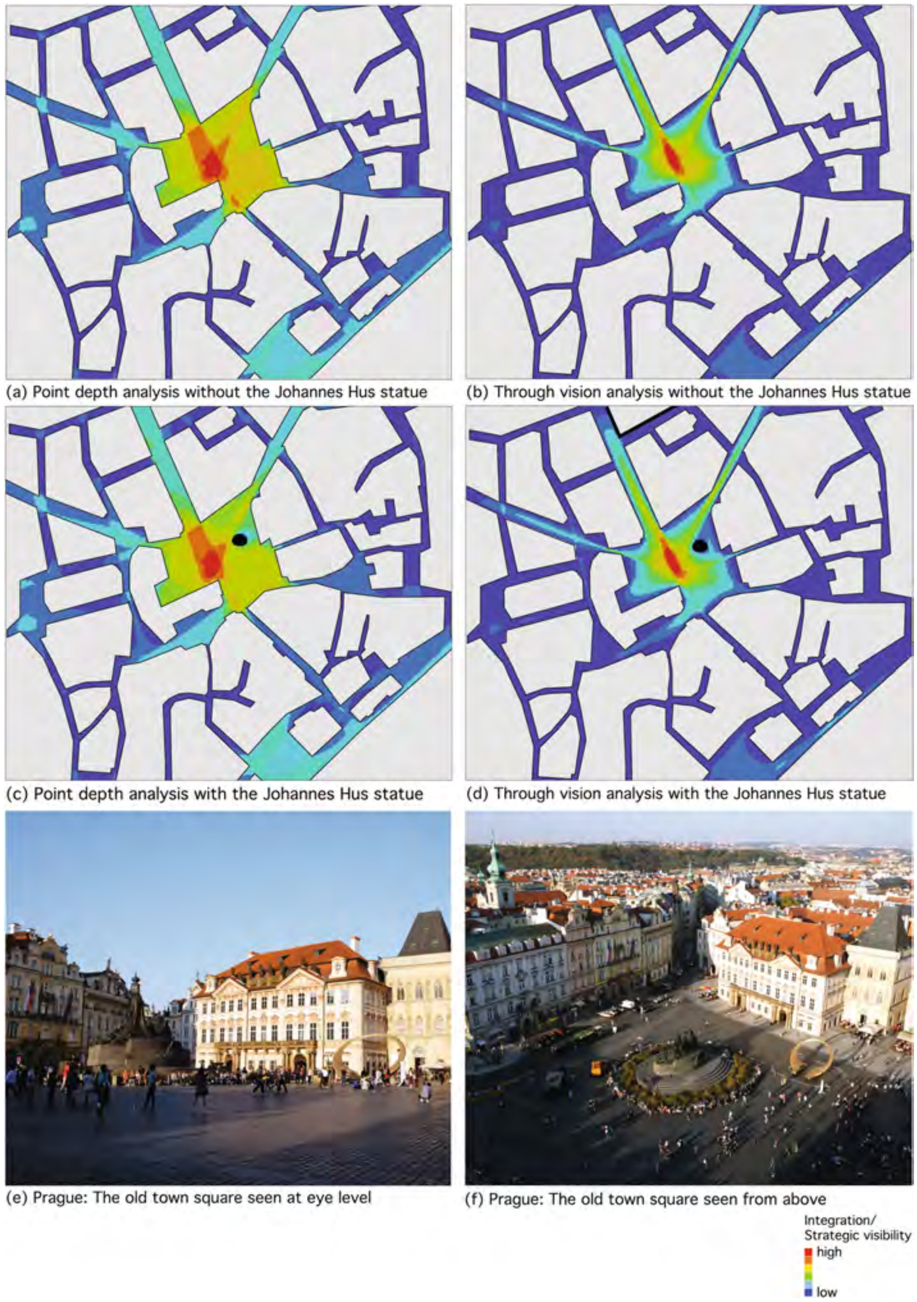


Fig. 3.13 Point-depth analysis (**a** and **c**) and through vision analysis (**b** and **d**) for the Old Town Square in Prague. Both photos (**e** and **f**) show the square with the Johannes Hus statue

VGA can be applied to demonstrate the visibility of strategic entry points into a public square and the optimal locations for monuments, fountains, or temporary structures in a public square (Yamu et al. 2021). At the architectural scale, VGA is useful for defining the locations of exits and fire staircases in public buildings or the anchor stores in shopping malls based on their visual façade exposure. VGA depicts how new urban interventions increase or decrease existing views. Moreover, VGA can be used in landscape architecture to evaluate the design of outdoor areas and parks and gardens. VGA allows one to identify 'hidden corners', which are places attractive for criminal activities. This analysis links to Bill Hillier and Simon Shu's concepts of natural surveillance (2000) and Jane Jacob's 'eyes on the streets' (1960) for generating safe urban areas.

When studying modernist neighbourhoods in the Zeitgeist of Mies van der Rohe or Le Corbusier, large portions of plots remain unbuilt. In historic urban areas, we find a clear distinction between the public and the private space. For modernist neighbourhoods, the semi-public or semi-private space between the public street and the private housing space softens these clear boundaries. Thus, in these areas streets are defined by ‘weak boundaries’ compared to historic neighbourhoods with their ‘hard boundaries’. The weak boundaries are defined by the border of the grass field, trees, planting, fences, pavements, and sidewalks (Trova et al. 1999). Due to the weak boundaries, the field of vision is enlarged, which dilutes and therefore minimises the wayfinding in the street. Modernistic neighbourhoods are often not very inviting and attract criminal activities due to their imbalance between high-rise buildings and open space. The geometry of the field of vision and intervisibility as well as through vision plays a role in orientation, wayfinding, and people’s behaviour (Fig. 3.14).

Fig. 3.14 Photo of the modernist neighbourhood Bijlmermeer in Amsterdam with its weak boundaries

For testing several locations for certain artefacts in order to identify their optimal locations, a *one-point isovist step depth* analysis can be carried out. This allows one to understand how the visibility changes within the vicinity using the different options. The degree of visibility can vary depending on the location of the isovist root. Our example illustrates the degree of visibility from points A, B, C, and D for park X (Fig. 3.15). The green colour shows the one-step isovists for all four locations, which show what can be directly seen from the isovist root. Location B has the lowest degree of visibility, whereas locations C and D have the highest degree of visibility. When placing, for example, a statue or a fountain, vantage points C and D have the largest isovist surface for park X.

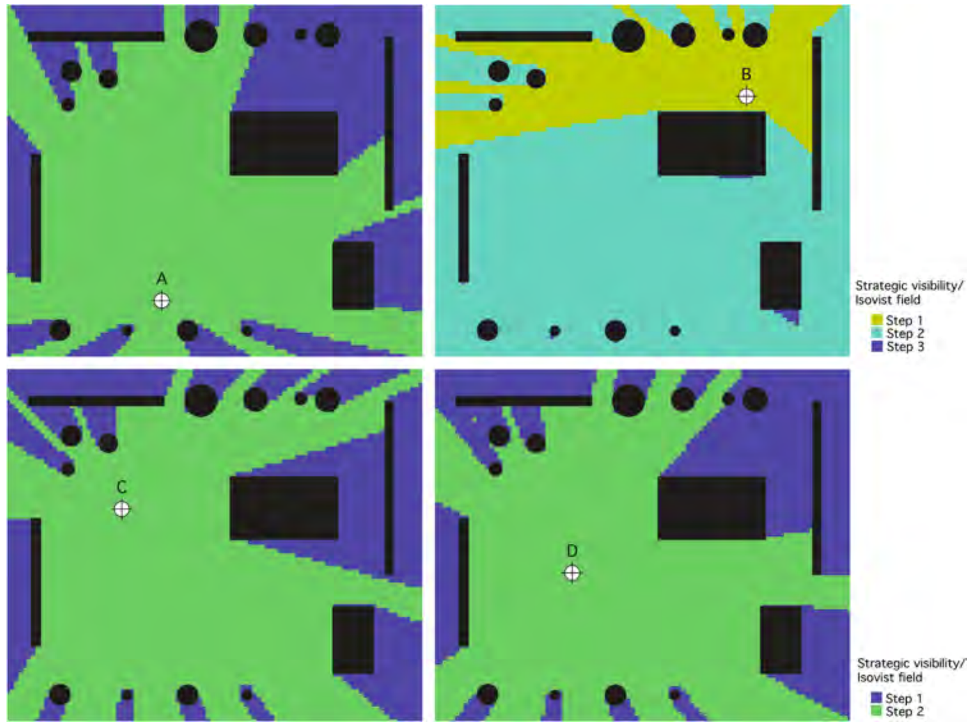


Fig. 3.15 A one-point isovist step depth analysis from four different locations in park X

Moreover, it is also possible to test one-point step depth analyses of isovists at several points at the same time. Figure 3.16 shows an example of the historic core of Sophia from the eighteenth century, which no longer exists. The base map was drawn using historic maps.

Fig. 3.16 Point-step depth analysis from one point (**a**) and two points (**b**) from an ancient area from 1300 in the centre of Sofia, Bulgaria

Culagovski et al. (2014) developed the first 3D VGA tool by changing from the 2D grid to a rectangular digital-elevation model where a 3D input model was represented as a grid of squares with associated elevations. For each square of the grid, a sightline analysis was performed with every other grid square. By treating each square as a node and each sightline as an edge between two nodes, a 3D visibility graph was constructed. For their study, the following four measures of configurational properties from graph theory were applied:

(1) closeness centrality or integration (Hillier and Hanson 1984),
(2) betweenness centrality as a measurement of control because the nodes with higher values are important communication routes within the graph,
(3) degree centrality representing the area that is visible from a given point as a local measure, and
(4) clustering coefficient (Watts and Strogatz 1998) representing the number of connections between the nodes of a given node's neighbourhood divided by the possible connections within the neighbourhood.

However, for this first approach, it is very time-consuming to build the 3D base map and process the model. Conversely, currently the 2D VGA is a robust analysis that has proven that the obtained results correlate with people's real-life social behaviour. Furthermore, the 2D VGA is a time-efficient analysis in comparison with the 3D VGA.

3.3 All-Line Axial Analysis

An all-line axial map represents all possible sightlines in all accessible spaces in a built environment. While VGA depicts how integrated a visibility point in a spatial system is in relation to all other visibility points of a spatial system, the all-line axial analysis shows how integrated each sightline is in relation to all other sightlines of a spatial system. Hillier (1996) and Turner (2005) define the all-line axial map as "a set of lines made up of all lines drawn tangent to vertices that can see each other".

The all-line axial map is generated from publicly accessible spaces represented as one spatial entity taking into consideration spatial obstacles. When weak boundaries between public and private spaces exist in a neighbourhood such as for modernist neighbourhoods, the all-line axial map can be advantageous for a local scale. For this situation, it is in general difficult to draw an axial map representing the fewest sightlines, but this allows one to grasp all of the open spaces between freestanding objects. The all-line map, including integration values for each sightline, can be generated using the space syntax computer application 'DepthmapX'. This is a simple and fast procedure. Reversely, it is also possible to generate an axial map from the all-line axial map. This is often favoured by archaeologists for the analysis of excavated towns.

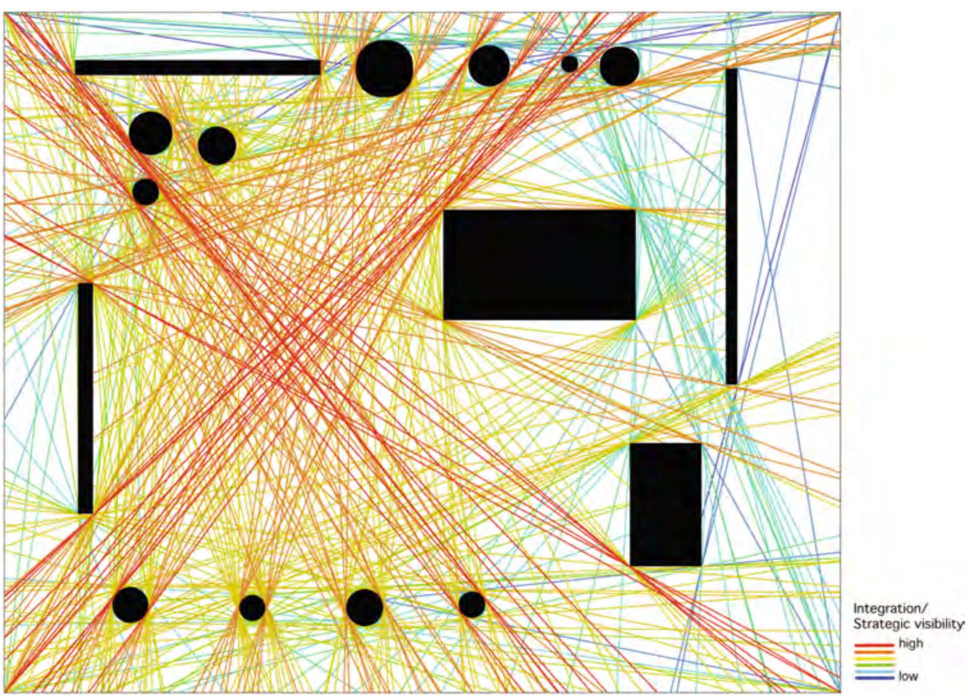


Fig. 3.17 All-line axial analysis for park X

The all-line axial analysis for park X shows that areas behind buildings and walls have low intervisibility values. The large open area in the park's centre is the most intervisible and integrated area of the park (Fig. 3.17). Red sightlines are the most integrated axial lines, and blue sightlines are the most segregated. The all-line axial analysis demonstrates the degree of integration of all possible sightlines in an urban area, and it is useful in areas with spaces and boundaries defined by a street network. The same mathematical formula for calculating axial integration is used in the all-line analysis.

Our example of the all-line axial analysis of the post-war Oosterwei neighbourhood in the Dutch town of Gouda shows that the shopping centre centrally located in the neighbourhood is poorly integrated in terms of visibility (Fig. 3.18 image (a)). At the shopping centre's front side, unemployed, low-skilled residents, and immigrants gather together. At the shop's backside, groups of adolescents with a migration background gather together. Along the sightlines with the highest

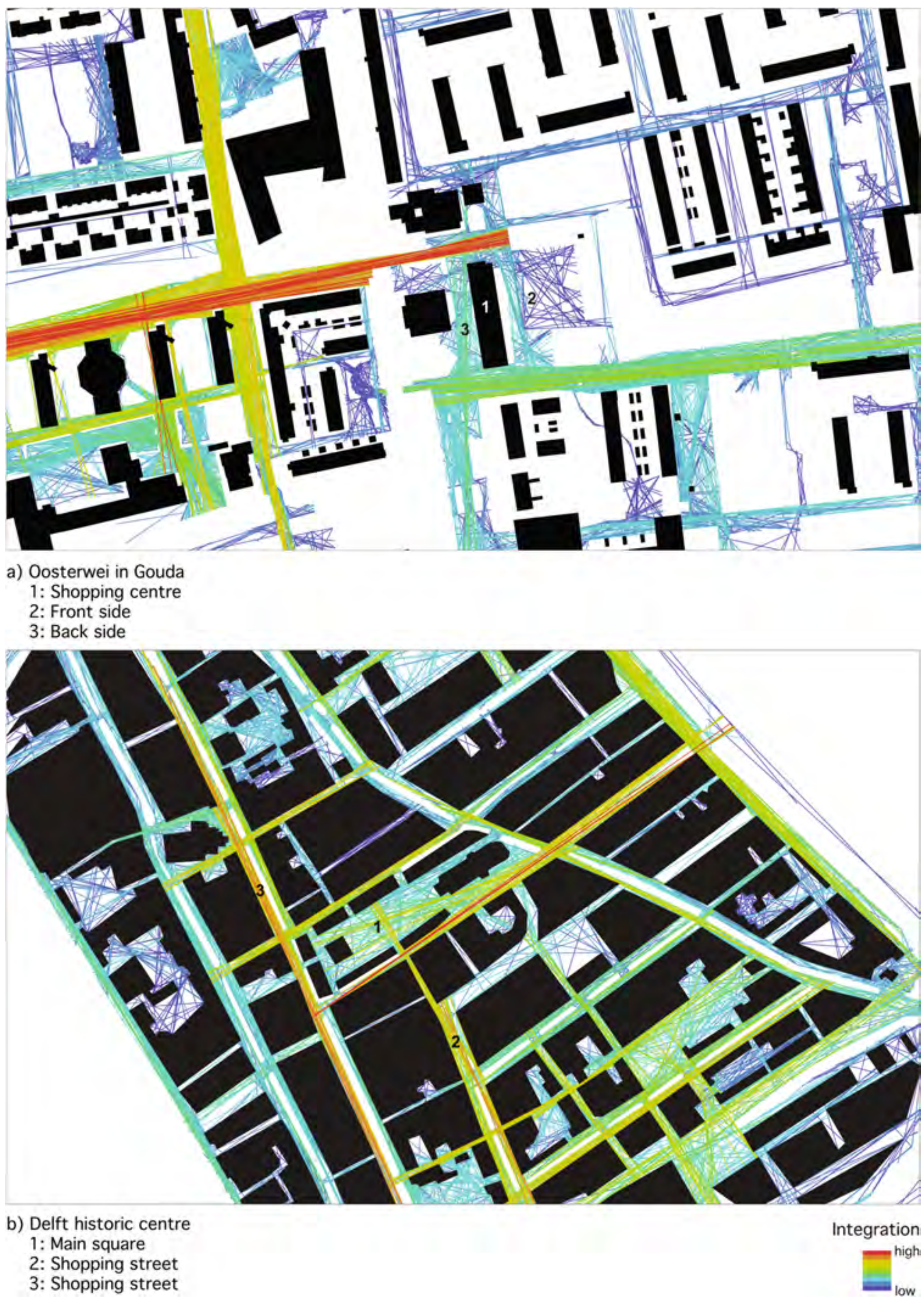


Fig. 3.18 All-line axial analysis for the neighbourhood of Oosterwei in Gouda (**a**), and the historic centre of Delft (**b**) in the Netherlands

integration (indicated in red), a social mix of men, women, and children of either a native Dutch or a migration background are clustering. For the remaining areas, there is a divide between native and non-native social groups. Only a few woman and girls move through or carry out stationary activities in the segregated spaces (Rueb and van Nes 2009).

In Fig. 3.18, we show an all-line analysis for the historic centre in Delft. In many ways, making and processing an axial map is much faster than drawing the base map for the all-line analyses for the Delft case due to the narrow streets. This is the case for most old urban areas. However, the all-line analysis of Delft shows the spatial potentials for the pedestrian movement flow in all of the open spaces or squares of Delft. The main shopping streets are highlighted along the highest integrated sightlines.

3.4 Agent-Based Modelling

The principles of agent-based modelling using visual fields and syntactic steps are rooted in the research of Ruth Conroy Dalton in 2001. According to Dalton (2001), people tend to choose the root with the fewest angular deviations towards their destination (see also Chap. 2). Agent-based modelling as applied in the arena of space syntax is built upon this research. Herein, for the agent-based model, as a raster-based analysis, a certain number of agents equally distributed in the space under scrutiny for a certain time frame aggregate their movement routes. An agent's sight field can vary. Space syntax agent-based modelling analysis can be carried out using space syntax software applications.

In our example in Fig. 3.19, we compare three different scenarios for park X.

(a) *The agent as an average person*. Five thousand agents walk three syntactic steps, or move three cells forward, before making a decision about their direction change based on their sight field. This sight field is set at 15°. Results with these parameter settings comply with the registration of people's real-life movement routes through a certain built environment.

(b) *The agent as a tourist*. When enlarging the sight field angle to 30° and reducing the syntactic steps to one, a different movement pattern occurs. All agents concentrate in the centre of park X. This is a typical movement pattern for tourists. Tourists are not familiar with the built environment they are in and want to explore it. Therefore, a strategic location with the longest views into the urban space is chosen.

(c) *The agent as a local*. When reducing the sight field angle to 7° and increasing the number of syntactic steps to five, another movement pattern occurs. This is the movement pattern of locals. Locals are familiar with their neighbourhood and the city in general, and they have knowledge about which route to take to reach their destination efficiently. Their movement lines are straightened out, and they do not cluster in the centre of the park or public space.

The number of agents released, the number of syntactic steps, and the visual field can be adapted to any urban situation.

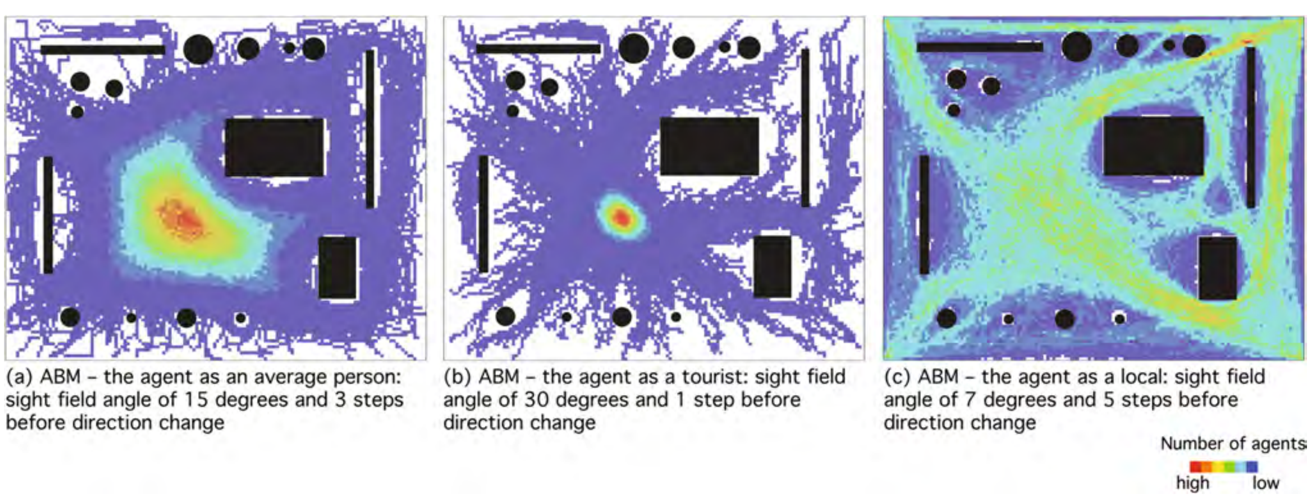


Fig. 3.19 Three different parameter settings for an agent-based model for park X: (**a**) the agent as an average person, (**b**) the agent as a tourist, and (**c**) the agent as a local

We applied this agent-based modelling logic to a neighbourhood of Siena's historic centre in Italy in Fig. 3.20. The parameter settings for the 'agent as an average person' depict both the movement routes of tourists and locals. Naturally, the result is a bit blurred because it covers both. The agent-based models for the agent as a tourist and a local illustrate the differences of their movement patterns. When comparing the results from the agent-based modelling with the results of the VGA and through vision analysis, the following can be stated: Tourists cluster in places where the largest integration of the through vision can be found, whereas locals move according to the results of an angular choice analysis. The reason for this is that tourists like to gather in places where they can get a large overview of the place they are visiting. In the case of Siena, this is the Piazza del Campo. The tourists like to gaze around and get an overview of the place and its buildings. Locals already know these artefacts. Therefore, the movement pattern of the locals has a clear origin and destination and can be classified mostly as necessary activities.

As an add-on, the space syntax software 'DepthmapX' enables one to trace the movement routes of agents individually. A perspective map with 3D agents can also be generated. We applied this to our example of Siena in Fig. 3.21. Our example depicts a group of agents released from the same location with a given time frame of 2 min. The release spot for the agents was located where one street is leading into the Piazza del Campo. This application in the DepthmapX software allows one to understand how the agents orientate and navigate through space departing from the same location in the neighbourhood, and this analysis is useful for understanding the degree of orientability of an urban area from a certain strategic location. This can be, for example, the city gate, a metro stop, a train station, harbour ports, the entrance of a park, etc.

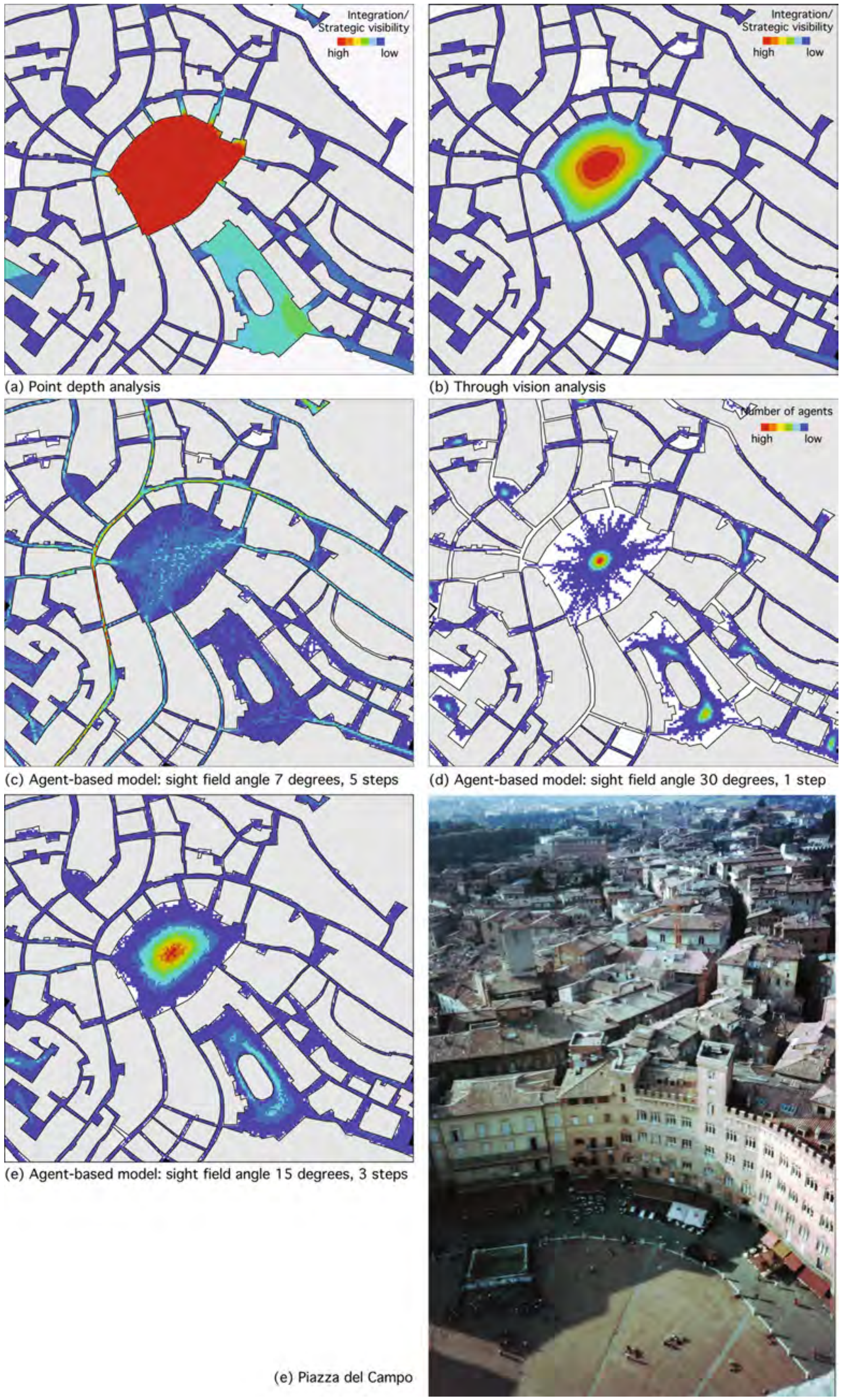


Fig. 3.20 Agent-based analysis and VGA for the central areas in Siena in Italy: (**a**) the point-depth analysis, (**b**) the through vision analysis, (**c**) the agent as a local, (**d**) the agent as a tourist, (**e**) the agent as an average person, and (**f**) an image of Siena's main square Piazza del Campo

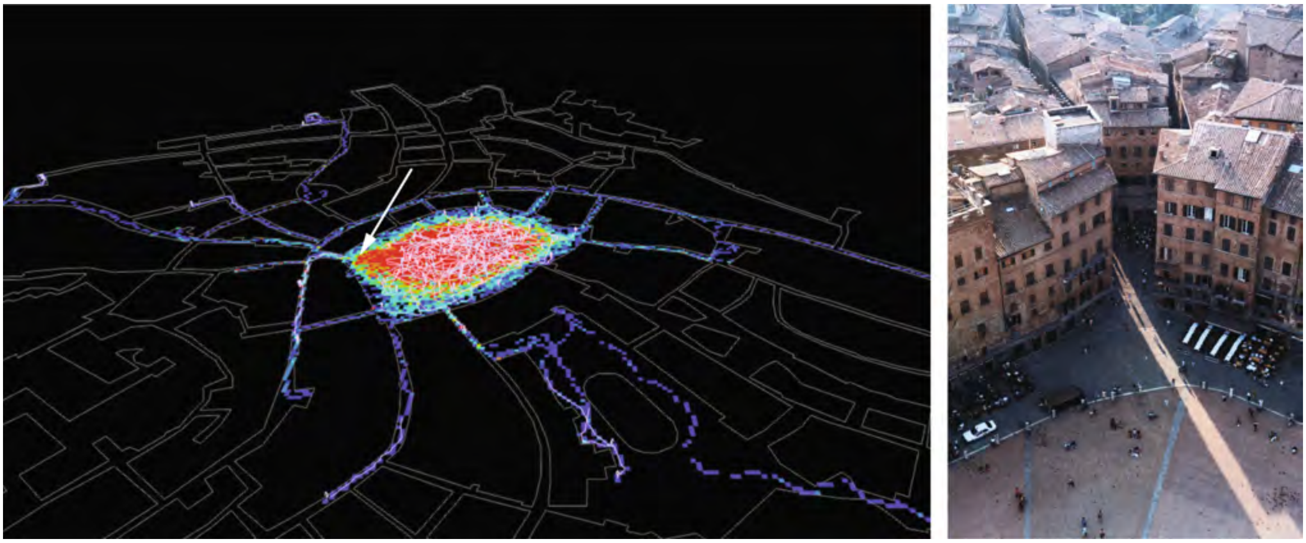


Fig. 3.21 Agent-based model from one point (left) and a picture of the location of the agent's starting point (right)

3.5 Conclusion: Some Common Errors to Be Aware Of

In its early stage, VGA was applied to buildings only. In particular for art galleries and museums, this analysis was useful for investigating the various degrees of orientation and wayfinding through the buildings and the accessibility and visibility for the most or least frequently visited collection items. Over the years, VGA has been applied for urban squares and neighbourhoods, which is possible due to on-going computer application development and increasing computation power.

There are some common errors and misuses to be aware of. When drawing or generating the base map for analysis in geographic information system software (GIS software) or AutoCAD, the novice modeller tends to forget to snap the ends of either the boundary line or the polygons representing urban blocks. Often the snapping tool is not activated. When generating the raster for the analysis, often a too coarse-grained raster contributes to the exclusion of narrow streets because their surfaces do not fully cover two-thirds of a cell's surface and are therefore dismissed. The VGA results will thus be inaccurate. Likewise, forgetting to add vegetation and fences to the base map will influence the analytical results of the visual graph, through vision, and all-line analyses.

VGA and all-line axial analysis calculate accessibility and visibility in parallel two-dimensionally, but how should one deal with soft spatial boundaries such as small ponds, grass fields, and flower beds? The rule is to represent these kinds of soft boundaries and include them in the model by outlining them in the base map. The reason for this is that we see them, but do not move across them—accessibility is more important than visibility.

The current challenge with the 2D VGA for urban areas is that it does not allow one to include several terrain levels like bridges and fly-overs at the same time. Many modern city centres like the Central Business District in Hong Kong are distributed among several levels. On-going development includes an efficient analytical tool for processing a 3D VGA (Bruyns et al. 2019).

3.6 Exercises

Exercise 1

Manually generate an isovist from two different locations of a familiar urban square. Describe the differences between the two isovist fields. Do they overlap?

For the exercises below, you need to use computer software.

Exercise 2

Draw a polygon base map consisting of the outlines of buildings, vegetation, fences, etc. of a familiar neighbourhood or public square. You can use any computer software that allows exporting your base map file as a .dxf or .mif file. Process an all-axial line analysis map using the space syntax software 'DepthmapX'. Explain and interpret the results and how they relate to your own experience of the chosen area.

Exercise 3

Run a VGA from your previously drawn base map. What are the differences in the results from the visual graph, through vision, and connectivity analyses? Process a one-point step depth and several-point step depth analysis from the map. Explain and interpret the results.

Exercise 4

Run an agent-based model from the same base map. Experiment with different visual field angles and syntactic steps. Describe, explain, and interpret the results. Explain the following: How do the results of your agent-based model correlate with the results from the VGA, all-line axial analysis, and real life?

Exercise 5

Figure 3.22 illustrates a figure ground map of a park with a couple of trees. A concert organiser wants to place a music stage in the park. Where do you suggest placing the stage for a maximum number of seats for the audience and in such a way that every concertgoer has a good view of the stage. If you could remove one tree, which one would it be to increase the visibility for all and why? Choose a suitable analysis to present your suggestion as a 'before and after' situation. You can test various options.

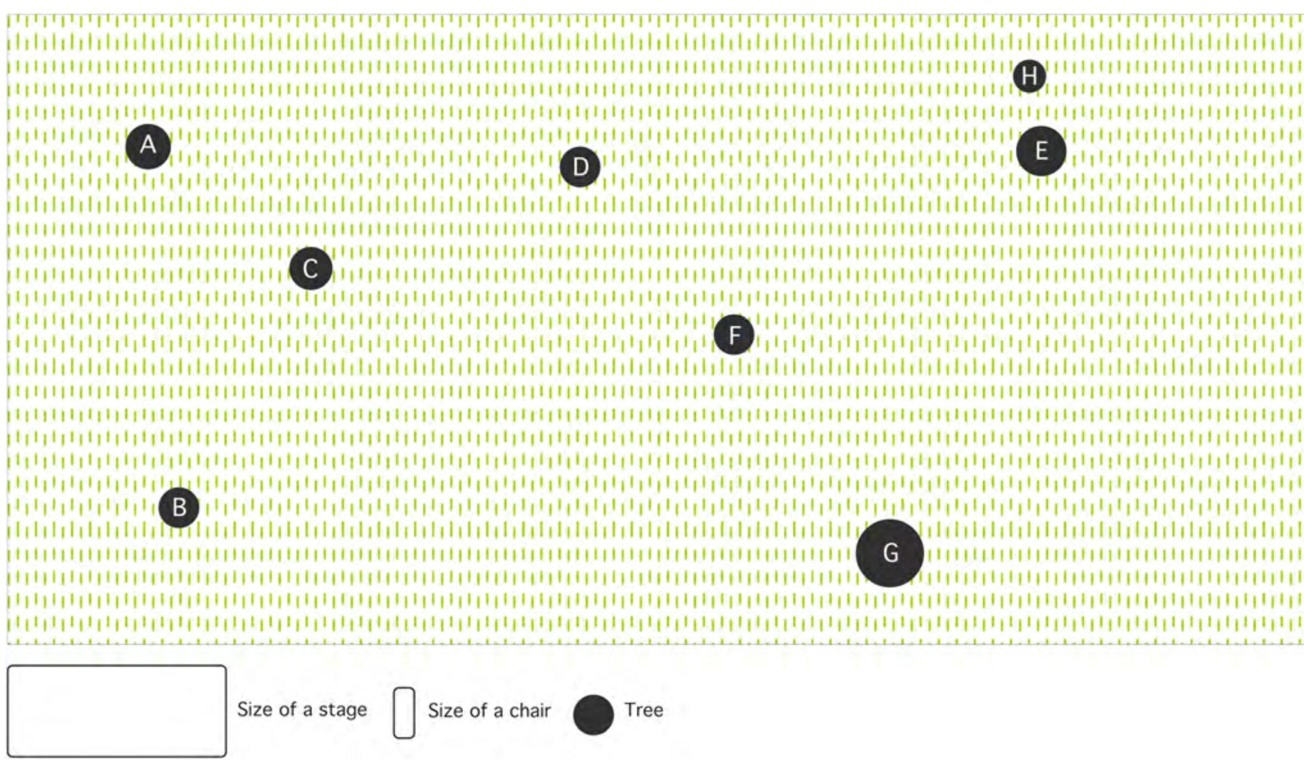


Fig. 3.22 A park with trees

3.7 Answers

Exercise 5

The maximum number of seats can be gained by placing the stage at the bottom of the figure and removing tree ‘f’.

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Further Readings

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4 Private and Public Space: Analysing Spatial Relationships Between Buildings and Streets

Contents

Abstract

In this chapter, we discuss and demonstrate how to analyse the urban micro-spatial relationships between private and public spaces. These methods allow one to analyse intervisibility between buildings and streets, entrance density from buildings towards streets, street constitutedness, and the topological depth between private and public spaces. These urban micro-scale analyses are a quantification of Jane Jacob's (1960) and Jan Gehl's (1996) presumptions about the interrelation between streets and building entrances and windows. Exercises are provided at the end of this chapter.

Keywords

Street life • Natural surveillance • Active frontages • Building–street interface • Public and private spaces • Intervisibility • Topological depth • Street constitutedness • Social control

Key concepts

Street–building permeability • Entrance intervisibility • Entrance density • Street constitutedness • Topological depth between public and private spaces

A. van Nes and C. Yamu, *Introduction to Space Syntax in Urban Studies*,
https://doi.org/10.1007/978-3-030-59140-3_4

Learning Objectives

After studying this chapter you will

- have knowledge about the concepts of social control, naturalsurveillance, and degree of street life;
- be able to conduct spatial analyses such as topological depth between private and public spaces; intervisibility, constitutedness, and entrance density; and
- be capable of critically reflecting on the analytical results connected to social control, natural surveillance, and degree of street life.

4.1 Introduction to Natural Surveillance and Urban Liveliness

Since the 1980s there has been an on-going debate about how streets can be made safe. Empirical research on crime and space is marked by the controversy between Jane Jacob's conception of lively, permeable urban environments and Newman's conception of closed, defensible spaces (Hillier and Shu 2000). In Jacob's view (1960), passers-by in streets, represented by, for example, strangers and inhabitants, function as a natural form of surveillance. In contrast, in Oscar Newman's opinion (1972), strangers are potential intruders, and the inhabitants' behaviours, their dwellings' spatial layouts, and the neighbourhood's spatial pattern are effective means of defence against them.

If we summarise the key elements of this debate, it is first about the spatial structure of the built environment's street network and second about the micro-scale spatial relationship between private and public spaces. In urban studies, the micro-scale spatial relationship is about the interrelation between buildings and adjacent street segments. More precisely, it is about how building openings are connected to the street network, in other words, the degree of topological depth from private space to public space and the intervisibility between doors and windows across streets. Thus, the challenge is how to quantify and calculate spatial parameters for the building–streetinterface and how to quantify degrees of so-called 'active' frontages.

The formula of Jacobs and Gehl for achieving urban liveliness is that many entrances and windows should face towards a street (Gehl 1996; Jacobs 1960). What both authors are missing in their writings on urban street life is a consistent spatial tool for measuring the spatial conditions needed for vital street life and for measuring the degree of urban safety. A first approach for measuring the building–street relationship was applied by Hillier and Hanson (1984) on a small scale for a neighbourhood in London, before and after modernisation in the 1950s. The purpose was to show how this modernisation affected the spatial relationship between private and public space. Their method was further developed by Shu (2000) in his Ph.D. thesis. This method is named 'street constitutedness'. Following this, van Nes and Lopéz (2010) added methods for analysing 'street intervisibility' and 'topological depth between private and public spaces'.

Figure 4.1 shows two examples of types of building–street interfaces that are not taken into account (left and middle) and one example of a building–street interface that is taken into account (right). The buildings in example (a) have doors but lack windows, whereas the buildings in example (b) have windows facing towards the street but lack doors. Both examples are considered to be cases where the buildings lack so-called 'active frontages' towards streets. Therefore, they are registered as 'disconnected' towards the street. Example (a) lacks visibility, whereas example (b) lacks accessibility. Therefore, the segment representation is coloured in blue, which means that the street segment is disconnected. Example (c) shows buildings that have both doors and windows facing towards the street. Here the street is both accessible and visible from the building and is considered as having an active frontage and is connected to the street, and thus the segment representation is coloured in red.

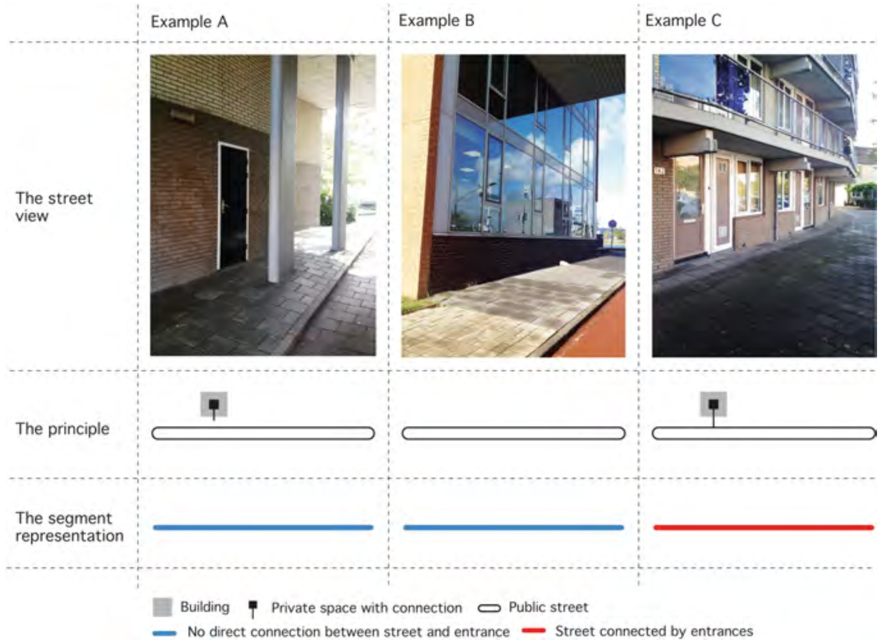

Fig. 4.1 The basic units for the micro-scale analyses

A method for visualising the degree of interface between buildings and streets is to register the number of building entrances with adjacent windows facing towards a public space. The image on the left in Fig. 4.2 illustrates how entrances from houses are connected to urban public spaces in the case of town X. Each entrance is represented as a black dot and the corresponding black line indicates to which street the entrance is facing, and therefore, connected to. Often the streets with the highest entrance density can easily be seen. However, this map does not clearly show the various degrees of entrance densities for each street segment. Therefore, the number of entrances per meter needs to be registered. One way to do this is to use colour codes. The map to the right in Fig. 4.2 shows entrance density added to the axial map. The main street has a very high entrance density, whereas the side streets have low entrance density.

There is an important rule for registering entrances when measuring and analysing the spatial properties of the building–street interface. Every entrance that is taken into account for the analysis must also have at least one window next to it. Entrances into parking garages and storage rooms are, therefore, not taken into account in the registrations because in most cases there are no windows adjacent to these types of entrances. A street with only entrances but with no windows along the facade facing a street on the ground floor level is not taken into account. The same accounts for streets with only windows facing the street on the ground floor level but with no entrances. Both visibility and accessibility properties from buildings towards streets need to be taken into account.

Measuring and visualising entrance density is easy. Figure 4.2 shows how entrance density can be visualised for town X. The degree of entrance density per meter can be quantified, and colour codes can be used to represent different degrees of entrance density. The purpose is to see in one glance the dispersal of entrance density in a neighbourhood.

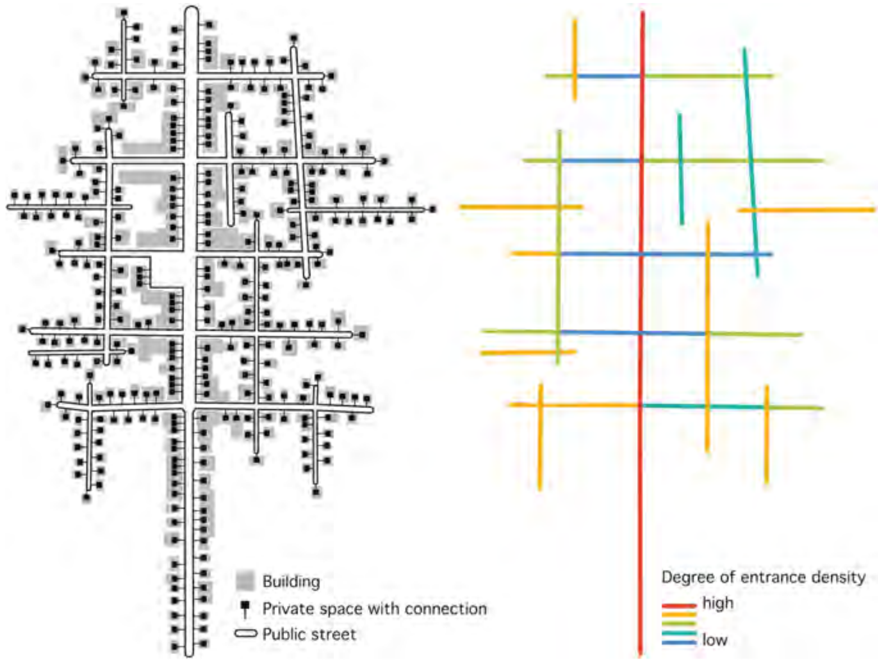

Fig. 4.2 Entrances with windows connected to the public realm (left) and the density of entrances with windows using an axial segment map of town X with colour coding (right)

In many ways, the density of entrances with windows next to them influences the degree of safety in urban areas. The higher the density of entrances with windows next to them per meter, the higher the probability that someone can leave or enter the house, as well as keep an eye on the street. However, a high density of entrances with windows next to them facing a street does not always imply high intervisibility. There is a distinction in the way entrances with windows next to them constitute streets and the way they are intervisible to each other. The way entrances and windows are positioned in façades and their relation to each other for both sides of a street influence the probabilities for social control, natural surveillance, perception of safety, and degrees of street life. In the next sections, we demonstrate some more refined spatial methods for analysing the public–private interface between buildings and streets.

4.2 Constitutedness and Unconstitutedness

Constitutedness is about the degree of adjacency and permeability from buildings to the public space (Hillier and Hanson 1984, p. 92). If and only if a building is directly accessible to a street does it constitute the street. Conversely, when all buildings are located adjacent to a street, but their entrances are not accessible directly from the street, the whole street is unconstituted. A street or street segment's degree of constitutedness or unconstitutedness depends on how buildings' entrances with adjacent windows establish their connection to the street, as well as the visibility to the street. Here again, buildings with only windows facing towards the street are registered as unconstituted. Likewise, buildings lacking windows and that have only doors connected to the street are also registered as unconstituted.

This spatial relationship between private and public space has an impact on the vitality of street life in urban areas (van Nes and López 2007). In unconstituted streets, the stationary activity of people is lower. Fewer people tend to sit and stand for a longer time in unconstituted streets, and rape and street robbery tend to take place more in unconstituted streets (Alford 1996).

Fig. 4.3 Urban examples of constituted (**a**, **b**) and unconstituted (**c**, **d**) streets in the Netherlands

If the entrances with adjacent windows are located on only one side of the street, the street is still constituted. The examples for constitutedness in Fig. 4.3 are streets dating from the seventeenth century (Fig. 4.3a) and streets dating from the 1970s (Fig. 4.3b). The unconstituted streets are examples of a high-rise flat area from the 1960s (Fig. 4.3c) and urban development from the 1990s (Fig. 4.3d). In the case of the modernistic high-rise building, no entrances are directly connecting the private space with the public space. People have to enter the building through a semi-public side street to further arrive at the building's front door. For the development from the 1990s, all apartments are located adjacent to the street. Even though the street is highly visible from all of the apartments' windows, all entrances are located at the buildings' backside and are accessible from underground parking garages.

Figure 4.4 illustrates schematically the difference between constituted and unconstituted streets. Thus, there is a difference between a building being located adjacent to a street and being permeable and visible from a street.

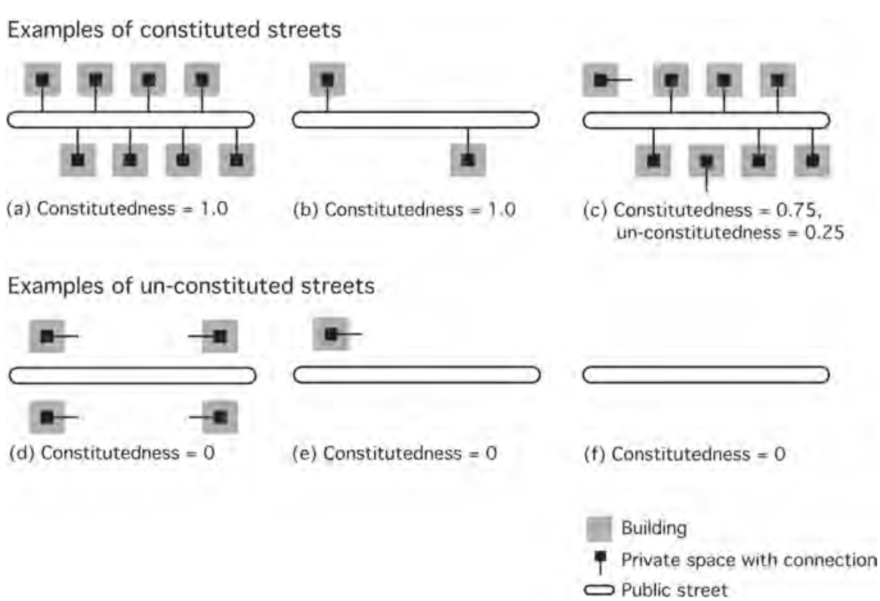

Fig. 4.4 Schemes of the spatial principle of constituted and unconstituted streets. Example (**a**) constitutedness = 1.0, (**b**) constitutedness = 1.0, (**c**) constitutedness = 0.75 and unconstitutedness = 0.25, (**d**–**f**) constitutedness = 0 and unconstitutedness = 1.0

In order to measure various degrees of constitutedness, the number of entrances directly facing a street in relation to the number of entrances not facing the street is registered and calculated. It is the percentage of the entrances that are connected to the street that determines the degree of street constitutedness (Fig. 4.4).

There are several ways of visualising the 'urban network–building permeability' relationship. Hillier and Hanson (1984, p. 104f) use the concept of an 'interface map' to illustrate the links between streets directly connected to adjacent buildings. All building entrances with adjacent windows that are both adjacent and directly connected to the street network are registered, and a colour code is applied to the street network to indicate constituted and unconstituted street segments. Also, a more differentiated map can be generated indicating for each street segment the topological depth between the street and building entrance (this will be explained below). In addition, Hillier and Hanson further applied a method generating a 'converse interface map' of the relationship between the street network and building permeability. The converse interface map highlights all street segments with no building entrances directly connected to a street segment. This kind of registration shows where there is a relation between adjacency and impermeability (Hillier and Hanson 1984, p. 105).

The analysis of constitutedness and unconstitutedness reveals the spatial conditions for the degree of street safety and social control between buildings and streets in urban areas. Some scholars define a street with a degree of constitutedness >0.75 as a 'completely' constituted street (Shu 2000, p. 119). This means that three out of four buildings have their entrances directly connected to a street segment. Buildings without entrances with adjacent windows connected to the street make the street unconstituted (Hillier and Hanson 1984, p. 92). Clear examples of unconstituted public spaces are highways and subways.

For the constitutedness analysis, the total number and density of entrances with adjacent windows is not of interest for revealing the spatial condition of constitutedness and unconstitutedness for a street. Instead, this analysis shows the ratio between the number of entrances with adjacent windows directly connected to the street and the number of entrances with adjacent windows not directly connected to a street (see Fig. 4.4).

The constitutedness analysis has been useful in studies dealing with crime and space because there is a correlation between the degree of constitutedness and the distribution of burglaries in neighbourhoods. Unconstituted streets are more affected by criminal activities than constituted ones. Moreover, entrances hidden behind high fences and hedges have little visibility from neighbours, and criminals seem to prefer to operate in spaces of this kind (Shu 2000, p. 445). In Fig. 4.5, using the example of the town of Gouda, the constituted versus unconstituted street network analysis is superimposed with data on burglary. Most intruded homes are entered from unconstituted streets.

Fig. 4.5 Street network–building permeability relationship analysis superimposed with data for intruded homes for the town of Gouda (van Nes and López 2010). Points of entry into dwellings are marked as a line from the street or back path at issue to the data point (burglary) in different shades of grey

A constitutedness analysis does not show to what extent entrances are located on only one side or on both sides of a street segment. A more refined analysis is the street intervisibility analysis allowing for constituted street segments to reveal the spatial potentials for the natural surveillance mechanism between buildings and streets, as well as between buildings across streets. This method was developed by van Nes and López (2006, 2007).

4.3 Intervisibility and Density of Entrances and Windows to Streets

Intervisibility is defined as a 'point-to-point' visibility. The way entrances and windows (on the ground floor level) are positioned to each other influences the probabilities for social control and street life and for control between buildings across street segments. Entrance and window density can, to some extent, indicate the degree of liveliness in a street. As mentioned earlier, the more entrances that are connected to a street, the higher the probability that someone can come out from a private space into a public space. Streets constituted by many entrances with windows are often perceived to be safe to walk through at night (Tan and Klaasen 2007, p. 717).

There is a distinction in the way entrances with adjacent windows constitute streets and the way they are intervisible to each other from the street. Entrances and windows located opposite each other on both sides of a street give a high probability of natural surveillance, because people can keep an eye on each other, as well as access the buildings from a street. The natural surveillance mechanism can prevent homes from being burgled. Figure 4.6 shows some diagrammatic principles for the intervisibility–density relationship of entrances in a street.

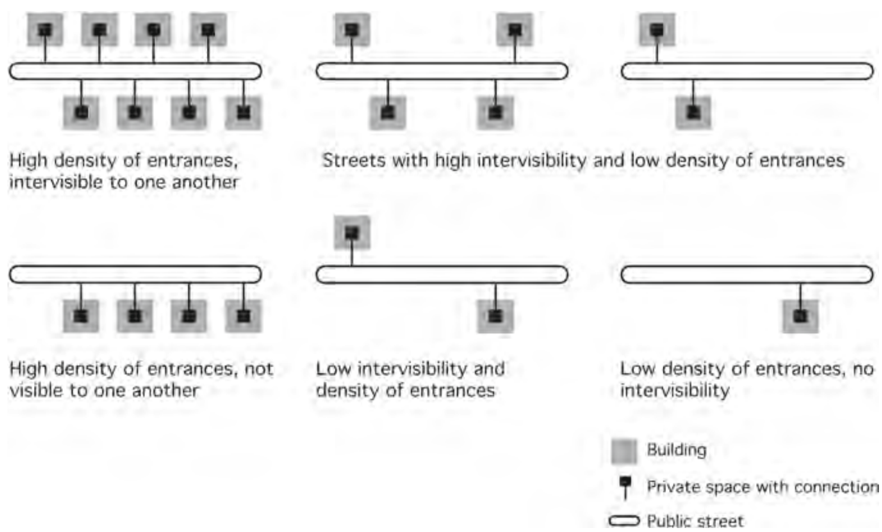

Fig. 4.6 Schemes of spatial conditions for the intervisibility–density relationship of entrances in streets

A convenient way to measure the intervisibility of, for example, entrances is to calculate the ratio between entrances that face each other across the streets to entrances that do not. Herein, Fig. 4.7 illustrates this simple calculation for four degrees of intervisibility related to entrance with adjacent windows density: (a) high = ≥ 0.75 (or 75%), (b) medium = ≤ 0.5–<0.75, (c) low = ≤ 0.25–<0.5, (d) very low = >0–<0.25, and (e) no intervisibility = 0. Entrances with adjacent windows hidden behind high hedges and fences are defined as non-visible.

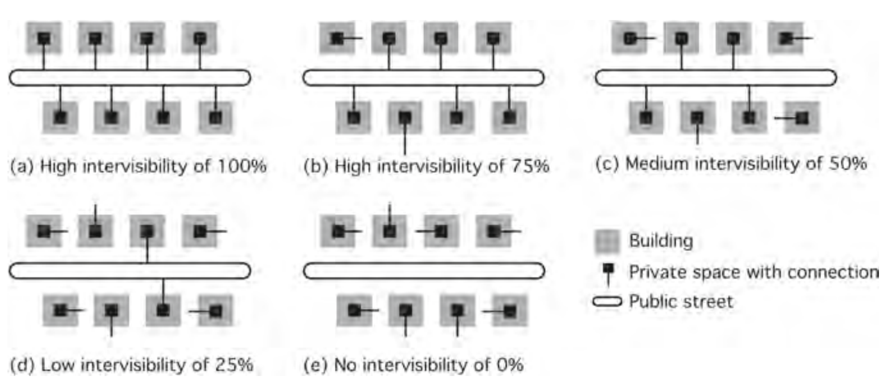

Fig. 4.7 Degrees of intervisibility of entrances with adjacent windows from high intervisibility to zero intervisibility

In traditional urban areas, the density of entrances with adjacent windows is in general quite high. This in contrast to suburban neighbourhoods with detached houses and modernistic post-war neighbourhoods with high-rise apartment buildings. For different cultures, we find different degrees of entrance densities. For example, Scandinavian cities have a low entrance density compared to continental European cities. In general, the degree of intervisibility is independent of the degree of entrance with adjacent windows density. However, enhancing window and entrance density on the ground floor level increases intervisibility and the potential for safe streets and neighbourhoods.

(a) (b)

Fig. 4.8 Examples of streets with high intervisibility (**a**) and low intervisibility (**b**) in a neighbourhood in the Dutch town of Haarlem

The example of high intervisibility (Fig. 4.8a) illustrates that all buildings have entrances and windows on the ground floor facing each other from *both* sides of the street. In contrast, the street with no intervisibility (Fig. 4.8b) has on the left side of the street entrances with no windows next to them. This is an example of a non-intervisible street because there are entrances with windows on only one side of the street. On the left side of this street, there are high fences leading to the back gardens of the buildings. Therefore, the intervisibility between the buildings in that street is lacking because there are buildings with doors and windows on the ground floor level on *only one* side of the street.

No windows on the ground floor imply no ‘eyes on the street’ from the ground floor level. Often buildings of this kind tend to have storage space on the ground floor level, and behind the entrances, there are corridors leading up to the dwellings starting from the first floor. One problem with these kinds of entrances is that a group of youngsters tend to gather together along the walls lacking windows, and the walls tend to be used for graffiti or other kinds of vandalism or anti-social behaviour (Rueb and van Nes 2009). Likewise, no doors on the ground floor level imply no direct accessibility to interfere with the street life. Even though there might be windows on the ground floor level, the lack of entrances creates a distance between the activities inside the buildings and the public street.

The street intervisibility analysis was applied to the Dutch town of Gouda and superimposed with burglary data (van Nes and López 2010; see Fig. 4.9). This study revealed that intervisible streets that have buildings with doors and windows connected to both sides of the street prevent homes from being burgled. To generate a relative range of visibility, the number of intervisible houses was divided by the total number of houses for each street segment and multiplied by one hundred. The intervisibility range was then grouped as follows: (a) high: 100–81%, (b) medium-high: 80–61%, (c) medium: 60–41%, (d) medium-low: 40–21%, (e) low: 20–1%, and (f) none: 0%.

The degree of density of houses and entrances with adjacent windows per street segment was not taken into account. As a reminder, a street with a high density of entrances with adjacent windows on only one side of the street segment has an intervisibility of zero. A high density of entrances with adjacent windows directly facing a street from only one side of a street segment can be an indicator of active street life, but not for the prevention of breaking and entering into buildings.

For Gouda, we can see that most burglaries from the front side occurred on streets with no intervisibility (Fig. 4.9). The homes intruded from the backside are located along streets with high intervisibility.

Fig. 4.9 Intervisibility analysis superimposed with burglary data for a neighbourhood in Gouda

The intervisibility analysis is also applicable in the field of archaeology. Our example of Pompeii depicts various degrees of intervisibility for the excavated parts of the town (Fig. 4.10). In addition, we also conducted an entrance density analysis (Fig. 4.11). Comparing both analyses, we can see that most shops, bakeries, and taverns are located along streets that are both intervisible and have a high density of entrances. The location of these functions was identified by archaeologists and recorded in detail by the German couple Liselotte and Hans Eschebach (Eschebach 1993).

Fig. 4.10 Analysis of various degrees of intervisibility for the town of Pompeii

Fig. 4.11 Analysis of entrance density for the town of Pompeii

4.4 The Topological Depth Between Private and Public Space

Often entrances to private spaces are not directly linked to the adjacent public street. In many cases, several semi-public or semi-private spaces are located between the private space inside a building and the public space represented by the street. Semi-public and semi-private spaces are hybrid spaces. They can be, for example, front gardens and front yards of houses or entrance halls and corridors in apartment buildings.

An easy way to reveal the relationship between private and public space is to register and map the topological depth between private and public space. This is done as follows: Count the number of semi-private and semi-public spaces between the private space and public space under scrutiny. If an entrance is directly connected to a public street, it has no hybrid spaces between the private and the public space. Its topological depth is one. If a small front garden is located between the house entrance and the public street, this front garden has a topological depth of two. The reasoning is that there is one space between the private space and the public space, and you take two steps from the public to the private space. Moreover, if the entrance is located at the side of the house adjacent to a front garden, the topological depth is three. Entrances accessible from back paths covered behind a shed have a value of four. For understanding the topological depth between private and public spaces, the topological steps between the public street and the private inside space are counted. Figure 4.12 illustrates various types of relationships between private and public spaces.

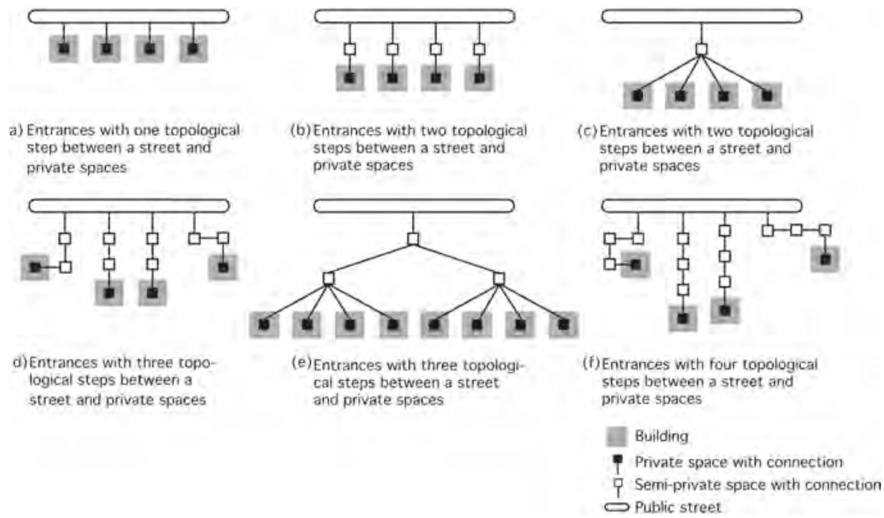

Fig. 4.12 Various topological depths between private and public spaces

Restrictions to the accessibility to entrances of flats can differ and depend on the degree of permeability between the private and the public space. Some multi-tenant buildings in the Netherlands have upper walkways that the entrance to an apartment is connected to (Fig. 4.13). Visitors can walk all the way to the intended apartment and ring the doorbell. This is different from what is seen, for example, in Manhattan, New York, where visitors have to use a calling system or are received by the concierge in the foyer who controls who enters the building.

The definition of semi-private and semi-public space depends on the accessibility of these spaces. For example, when carrying out a study and a multi-tenant apartment building's access is restricted by a calling system and the main entrance is permanently locked, the space is considered as a private space. When a visitor can walk all the way up to the flat's entrance door, the passed through spaces belonging to the apartment building are counted as semi-private or semi-public spaces.

In general, for collecting data it is important that the data for each side of a street segment are collected separately because the topological depth between public and private spaces often varies for each street segment for each side of the street. There can be individual houses with entrances connected directly to the street on one side, whereas an apartment complex with an upper walkway might be located on the other side of the street. Thus, one street segment can have different depth values for each side, and therefore, the average depth value is used for the street segment.

In most traditional urban areas, however, housing entrances are facing the street and therefore the topological depth is low. This is in comparison to most post-war urban areas where the topological depth between private and public spaces is often high. This means that people have to walk through several semi-private spaces before they can enter a private space.

Fig. 4.13 Streets A–E: Five examples with different topological depths between private and public spaces

For streets A–D in Fig. 4.13, the semi-private and semi-public spaces can be easily identified, and thus the topological depth can be calculated. The average topological depth between private and public space is the same for all entrances for each street segment on both sides. Street E represents a gated community with several semi-public and semi-private spaces. The rule is to count the number of syntactic steps for the streetsegment at issue. Because the depth values differ for each side of the street segment, we calculate the mean topological depth for the street segment at issue. For our example E, the mean topological depth is 7.5 (syntactic steps).

Figure 4.14 illustrates two different entrance situations: (a) from a traditional street in the Netherlands and (b) from an upper walkway of a modernist housing area from the 1960s in the Netherlands. In the traditional street, the entrance to the private space is directly connected to the sidewalk. The sidewalk is a public space for everyone because it is part of the street's public realm and its profile. Everyone has access up until a dwelling's front door, and strangers are not considered as a threat. Nobody will approach a stranger and ask about his or her intentions. For the example of the modernist housing, in order to reach a flat's front doors, strangers have to pass through the semi-private spaces. Thus, they are often considered as a potential threat because they do not belong to the multi-tenant building's community. The stranger will with high probability be asked by passing tenants what he or she is doing there. Often, these spaces are additionally controlled with video surveillance. Hence, micro-spatial parameters matter for how people perceive, behave, and interact in urban spaces.

Fig. 4.14 A traditional street (left) and a modernist building (right) in the Netherlands, both with different entrance situations

The same logic can be found in the difference between traditional shopping areas compared to modern shopping centres. Shopping centres have only a few entrances for accessing all the various indoor shops. A feature of the mall's façade is, except for the entrance, that the building has no 'active frontage' oriented towards the street. In many cases, the shopping centres have large walls with 'blind' windows, or sometimes the wall is covered by advertisements. Conversely, a feature of traditional shopping areas is a high density of shops' entrances directly connected to the street with transparent frontages. Figure 4.15 shows an image of a traditional shopping street in Utrecht centre (left) and a modern shopping centre in Haarlem (right) in the Netherlands.

In general, transparent and semi-transparent frontages enhance the perception of safety and increase the 'natural surveillance' of an area and enable people inside and outside a building to see each other (van Nes et.al 2017; Rønneberg Nordhov et al. 2019).

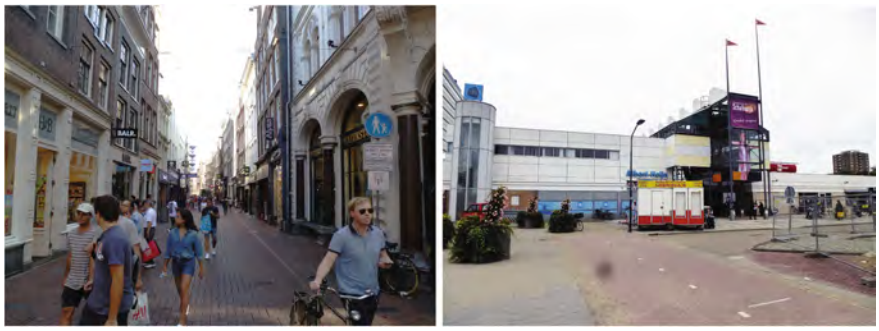

Fig. 4.15 A traditional shopping street in Amsterdam with shopping windows and entrances facing the street (left) and a modern shopping centre in Haarlem with only one main entrance facing the street (right)

The topological depth between private spaces to public spaces seems to increase in highly segregated urban areas and in areas topologically far away from the main routes, which can be urban streets as well as roads (van Nes and López 2010). The higher the number of direction changes a street is located away from the main route network, the more the street is frequented by only inhabitants. As expected, the dwellers in these areas prefer to protect their private lives from the eyes of their neighbours. Often the social control among neighbours is higher in segregated urban areas due to the lack of random visitors. Therefore, views into private space are protected by curtains and high hedges in segregated streets.

Along highly segregated street segments, entrances are often hidden away from the street and are poorly visible from neighbouring buildings. In many ways, inhabitants in such areas provide a stronger watch over each other's lives than in topologically shallow urban areas. In urban areas located close to or adjacent to main routes with high pedestrian traffic, entrances with windows on the ground floor level tend to open directly to public streets. The streets are frequented by visitors as well as by inhabitants. Often, inhabitants want to be part of the vital urban street life or keep an eye on it. Urban homes are revealed to passers-by and are often not hidden behind opaque curtains.

Fig. 4.16 Topological depth analysis between private and public spaces for the Laksevåg and Sandviken neighbourhoods of Bergen, Norway

Figure 4.16 shows the topological depths between private and public spaces in two different neighbourhoods in Bergen, Norway. Both neighbourhoods are located adjacent to Bergen city centre. The rental prices are high in Sandviken, whereas they are low in Laksevåg. Sandviken is a popular area to live in, whereas Laksevåg has a bad reputation. As can be seen from the figure, most streets in Laksevåg have 3 or more topological steps between the private and public spaces, whereas in Sandviken most streets have 1 topological steps between buildings and streets.

4.5 Combination of Micro and Macro-spatial Measurements

A combination of various micro-spatial measurements enables one to describe in a systematic and quantitative manner the local spatial features of neighbourhoods. These features are, however, not always present in studies focusing on macro or citywide spatial analyses. For example, a street with few street connections in its vicinity can still be full of social activities if a high density of entrances with adjacent windows constitute the street and if there is high intervisibility between public and private spaces. The reverse can be seen, for example, in highly integrated but distributed, unconstituted streets with a low number of entrances and low intervisibility.

Independent of cultures and architectural styles, micro-spatial measurements make it possible to describe the spatial set up of built environments at a local scale. Thus, an urban area's degree of liveliness depends on its spatial conditions on a macro as well as micro level. Therefore, analyses of both levels contribute to a thorough spatial configurative description of urban areas.

In this context, the study of crime in the towns of Alkmaar and Gouda by van Nes and López (2007) showed a set of statistical analyses between different spatial parameters that micro and macro-spatial variables are highly interdependent. In particular, the topological depth of a street segment in relationship to its nearest main route gives a detailed description of the spatial set-up of an area. In this way, most micro-spatial variables turn out to be related to the macro-scale variable of angular choice with a high metric radius. This variable identifies the main routes through cities and shows strong correlations with the micro-scale variables presented herein.

The study of Alkmaar and Gouda revealed that the farther a street segment is located away from the main routes, the lower the percentage of intervisibility of entrances and windows on the ground floor level. Seemingly, homes located on segregated streets tend to hide their entrances from the streets. Likewise, the farther a street segment is away from the main routes, the more the streets tend to be unconstituted. Homes located along unconstituted streets located in the heart of an urban area with low intervisibility from windows and entrances tend to have a high risk of being burglarised. The unconstituted back alleys tend to be the topologically deepest street segments.

4.6 Conclusion

Micro-scale analyses have been shown to be useful for an array of application themes in urban studies, for example, to understand the spatial logic of deprived neighbourhoods where van Nes and López (2013) and van Nes et al. (2017) showed that most of these neighbourhoods in the Netherlands have a high number of unconstituted streets with a low degree of intervisibility and a high number of topological steps between private and public spaces. Further applications include the relationship between behaviour patterns and ethnic groups (van Nes and Aghabeick 2015) or the safety perception of dwellers in their own neighbourhoods (de Rooij and van Nes 2015). For the latter, the results showed that people avoid staying in or passing through segregated and unconstituted streets with a low degree of intervisibility of entrances and windows because such streets are perceived as unsafe. Also, for the arena of gendered mobility, women tend to avoid frequenting unconstituted, segregated streets with low intervisibility of entrances (Nguyen and van Nes 2014).

For the protests during the Arab Spring in Egypt, in 2011, the degree of visibility of entrances in Tahir and Rabaa Al-Adawiya squares, in Cairo, played a role in the success of the protesters. Protesters seem to seek spaces with a high degree of accessibility on a local scale as well as on a citywide scale and with a high degree of symbolic value. The high visibility of entrances and windows helped the protesters to escape into buildings at Tahir Square when tanks and armed police forces tried to stop the demonstrations. At Rabaa Al-Adawiya Square, high fences with no entrances made it impossible for protesters to escape from the large military tanks (Mohammed et al. 2015a).

Furthermore, for understanding active land use, the application of the micro-scale method to the excavated town of Pompeii showed that shops were located in streets with a high density of entrances and a high degree of intervisibility (van Nes 2011). Likewise, the locations of shops in informal urban areas of the city of Cairo, in Egypt, are primarily along highly intervisible, locally integrated streets (Mohammed et al. 2015b).

In the case of the study of densification strategies in Bergen, Norway, it could be shown that the topological depth between private and public spaces influences the degree of walkability. The more entrances are directly connected to streets, the more people tend to choose to walk instead of using private vehicles (De Koning et al. 2017). In connection to this, the urban micro-scale analysis method has been used to study urban planning regulations and their impact on urban form in Recife, Brazil. The results showed that building types with parking garages on the ground level contribute to streets with no intervisibility and no natural surveillance (Carvalho Filho and van Nes 2017).

Işın Can (2012) showed in a study of three different neighbourhoods in the city of Izmir, in Turkey, that semi-private spaces that facilitate stationary activities such as sitting and standing are important for a neighbourhood's vital street life. Connecting the importance of micro and macro-spatial measurements, this study revealed that the street network must have high local integration values and the houses' entrances and windows must be oriented towards the street.

Micro-scale spatial relationships between buildings and streets play a significant role in the socio-economic life of people. The private–public interface influences the quantity and quality of street life, safety, and the risks of criminal victimisation. This is not only important for urban studies, but also for the design and planning of cities. However, 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 lack adjacency, permeability, and intervisibility between buildings and streets. This has negative effects both on the quality and quantity of the street life and on the safety of these urban areas.

Fig. 4.17 A new housing estate contributes to unconstituted streets with a low degree of intervisibility and many topological steps between private and public space

Instead, present urban project developers tend to build with high density or high floor-space-index and propose large variations of urban functions in these areas. The degree of interconnectivity and the topologically shallow public–private interface is often forgotten. All of these activities depend on the spatial configuration along the plinth of built-up street sides. Micro-scale spatial relationships add value to the analysis, design, and policymaking in urban areas.

Figure 4.17 shows some images of a new housing complex built in 2009, in the municipality of Rijswijk. As shown in image 1, the western-oriented homes have an active frontage towards the canal. Image 2 shows an unconstituted street. Image 3 shows the back-garden part for the eastern-oriented homes. This design solution contributes to an unconstituted street with no 'eyes on the street' from the buildings. When moving to image 4, the short ends of the homes have no doors and few windows oriented towards this street segment. This is the main entrance into the housing complex, and this street segment is also unconstituted and not intervisible. Image 5 shows the entrance to the parking garage with stairs up to a semi-private space, and image 6 shows the 'parking' street for the houses. The topological depth between the semi-public parking street and the homes is two. The entrances are not directly connected to the street level. On the other side of the street, a wall can be seen. This street segment is unconstituted because there are only garages on the ground floor level.

Another challenge is the day and night difference of streets. Some streets have a high degree of intervisibility, connectivity, and a shallow public–private space relationship during the daytime. During the night, the inverse can be observed. Curtains, walls, and a lack of natural surveillance from windows due to the absence of people contributes to an unsafe feeling in these streets. Thus, the registration of day and night situations is useful for an appropriate analysis of the real situation. For

Fig. 4.18 Day and night situation of the shopping street Kalverstraat in Amsterdam

example, Amsterdam's main shopping street Kalverstraat represents an example where the day-versus-night aspect plays a role. During daytime, the shopping street is very lively. At night, several shops have dropped their iron curtains, contributing to an unconstituted street with no intervisibility. Figure 4.18 illustrates a day and night situation from the same location for Kalverstraat in Amsterdam.

When applying micro-scale analyses, there are some common errors to be aware of. When registering entrances in street segments, the functions of buildings must be active, such as offices, residential apartments, or shops. Passive functions, such as storage and parking spaces, contribute to a lack of natural surveillance. Likewise, entrances need to have adjacent windows on the ground floor level. When a building has several windows on the first floor and up, and only storage spaces on the ground floor level with no windows, it will contribute to unconstituted streets with low intervisibility.

However, the urban micro-scale methods need further testing for various cultures. For example, in cultures with a clear gender separation, the private–public relationship where the domestic space is predominantly for women and the public streets are for men has not yet been studied.

4.7 Exercises

All exercises can be carried out manually.

Exercise 1
Choose a shopping street and a dwelling street in two different neighbourhoods you are familiar with. We suggest choosing a traditional and a modernist neighbourhood. Conduct a topological depth analysis of the private–public space relationship for all four streets. Describe and explain the differences.

Exercise 2
Conduct a constitutedness and intervisibility analysis of the same streets you used in Exercise 1. Describe and explain the differences.

Exercise 3
If you have already computed a space syntax analysis (Integration and Choice) for a particular neighbourhood, conduct intervisibility, constitutedness, density, and topological private–public space depth analyses of all the streets. Compare the results from the micro-scale analysis with the results from Integration and Choice analysis. If you have not already computed a space syntax analysis, proceed with Exercise 4.

Exercise 4
Conduct intervisibility, constitutedness, density, and topological private–public space depth analyses of two different neighbourhoods you know. Choose a traditional and modernist neighbourhood. Generate a map for each analysis. Describe the differences and similarities between the two neighbourhoods.

Exercise 5
If you have a processed axial map of the same neighbourhood (see also Exercise 3), describe and explain the relationship between choice with both high and low metric radii and the results of the analysis from Exercise 3.

Exercise 6
Below are some addresses you can look up at street view level via www.google.com or www.baidu.com. Describe and reflect upon the results.

For those of you who can use Google, perform micro-scale analyses of the street segments where the addresses below are located:

(a) 176 Telok Kurau Road, Singapore
(b) 230 Orchard Road, Singapore
(c) 13 Admore Park, Singapore
(d) 18 Cuff Road, Singapore
(e) 19 Veerasamy Road, Singapore
(f) 12 Cross Street, Singapore
(g) 131 High Street, Mansfield Victoria, Australia
For those of you who can use www.baidu.com, perform micro-scale analyses of the street segments where the addresses below are located:
(h) No. 106 Huangpu Da Dao Xi, Tian He, Guangzhou, China
(i) No. 54 Wende South Road, Yuexiu District, Guangzhou, China
(j) No. 19 Xin Nong Street, Xicheng, Beijing, China
(k) No. 34 Xintaicang Hutong, Dongzhimen, Beijing, China
(l) No. 1, South Zhongguancun Street, Hai Dian, Beijing China .

4.8 Answers

Exercise 6

(a) low density of entrances, no intervisibility, street is constituted, topological depth between private and public space is 2–3 steps
(b) low density of entrances, no intervisibility, street is constituted, topological depth between private and public space is 2–3 steps
(c) low density of entrances, no intervisibility, street is unconstituted, topological depth between private and public space is more than 3 steps

(d) high density of entrances, high intervisibility, street is constituted, topological depth between private and public space is 1 steps
(e) high density of entrances, high intervisibility, street is constituted, topological depth between private and public space is 1 steps
(f) low density of entrances, no intervisibility, street is constituted, topological depth between private and public space is 2–3 steps
(g) low density of entrances, no intervisibility, street is constituted, topological depth between private and public space is 2–3 steps
(h) low density of entrances on one side, high density of entrances on the other side, no intervisibility, street is constituted, topological depth between private and public space is 1 steps on one side, more than 3 steps on the other side.
(i) low density of entrances, no intervisibility, street is unconstituted, topological depth between private and public space is more than 3 steps
(j) low density of entrances, no intervisibility, street is unconstituted, topological depth between private and public space is more than 3 steps
(k) low density of entrances, no intervisibility, street is unconstituted, topological depth between private and public space is more than 3 steps
(l) low density of entrances, no intervisibility, street is unconstituted, topological depth between private and public space is more than 3 steps

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5 Empirical Data Collection and Analysis, and Connecting Data with Space Syntax

Contents

Abstract

In previous chapters, we demonstrated various analytic techniques focusing on the spatial aspects of the built environment. In this chapter, we discuss various methods and techniques for collecting qualitative and quantitative data dealing with human behaviour and how to connect such data to the results from various space syntax analyses. This chapter provides a brief introduction to these methods to stimulate ideas for connecting an array of spatial and socio-economic data to space syntax. At the end of this chapter, we provide an exercise, references, and further readings.

Keywords

Quantitative data • Qualitative data • Primary and secondary data • Observation techniques • Data collection • Combination and correlation of data

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Key Concepts

Data collection • Data analysis • Combination and correlation of data • Data aggregation • Primary and secondary data

Learning Objectives

After studying this chapter you will be able to:

- collect quantitative data for pedestrian movement and stationary activity;
- collect qualitative data in the form of interviews, existing documents, and reports;
- analyse the data, connect them to space syntax results, and interpret these results, and
- reflect on and critically discuss the space–society relationship based on a given data set and statistical testing.

5.1 Linking Space Syntax Analyses to Empirical Data on Human Activities

In previous chapters, we presented various methods for analysing the built environment's spatial properties. However, quantifying, calculating, and visualising spatial relationships becomes particularly useful when comparing these results with empirical data on socio-economic activities. Connecting the results from space syntax analyses with primary and secondary data of human activities provides new knowledge about the society–space relationship.

Until recently, urban designers have shown little interest in evidence-based analysis of the socio-economic impacts of their design proposals. They come up with very precise spatial solutions on vague presumptions of how these new urban areas should work after they are built. In the education of architects and urban designers, there has been so far a lack of focus on elementary research methodology skills with the purpose of understanding the space–society relationship. In general, most writings on urban design tend to take a normative approach (Hillier and Hanson 1984, p. x) to create liveable urban areas based on weak or controversial empirical support. Conversely, urban sociologists, urban planners and urban geographers generally apply a set of well-established qualitative and quantitative research methods. Their research focus is mainly on past and present conditions, however, and thus urban sociologists and urban geographers are not able to propose precise solutions on how to create well-functioning built environments.

Gaining knowledge on the space–society relationship relies on well-defined spatial concepts, having operational and objective spatial analysis tools, and the ability to link spatial analytical results with various socio-economic data (Hillier and Hanson 1984, p. 90). Data collection and statistical testing is a discipline in its own right and is often an independent, but integrated, research and teaching field in geography and urban planning. Thus, this chapter gives a glance at quantitative and qualitative data collection and how to correlate different data sets. We have chosen the most common methods connected to space syntax. However, a new tradition is being established, namely analytical design, which bridges urban planning and urban design.

In general, the research questions not only define the applied methods, but also what kinds of data are collected or are selected from other sources. In other cases, the available data and experiments with the data can lead to refined research questions for further data gathering.

In the field of quantitative research, the focus is on establishing facts, and the reality is objective and unchangeable. In the methodological approach, the data come from measurements. The data analyses are performed through numerical comparisons and statistical deductions, and the results are presented as statistical analyses. The data can be gathered from field work, online research, cross-sectional research, and experimental research.

In qualitative research, the focus is on answering the research questions on the basis of, among other things, interpretations, experiences, and meanings. Here the reality is interpretative and dynamic. Qualitative data are derived from documents, literature reviews, and observations and are analysed by means of inductive or deductive codes, and the results are represented by word descriptions. The data consist mostly of literature reviews, interviews, focus groups, field observations, analyses of written documents, discourse analyses, and policy analyses. In comparison with a quantitative approach, where the focus is on probability, predictability, replication, correlations, and control, a qualitative approach is complex, context-dependent, and subjective and deals with understandings and meanings.

In recent years, a mixed methods approach combining qualitative and quantitative data has gained prominence in urban planning. In social sciences , triangulation is the application and combination of several research methods used to study the same phenomenon. Triangulation is a way of validating the research by combining multiple observation methods, theories, and empirical materials. The purpose of triangulation is to overcome intrinsic biases and to make robust generalisations and theories. According to Kadushin et al. (2008), the difference between triangulation and mixed methods in research design is as follows. Triangulation describes statistical tests of correlation between alternative quantitative measurements and is employed to test the accuracy of those measurements, while the broader concept of mixed methods describes the integration of diverse qualitative and quantitative approaches and is employed to gain general understandings or to build theory. Both concepts are developed to study complex phenomena.

Both quantitative and qualitative data can be connected to the results of space syntax analyses. A quantitative approach includes the correlation of space syntax numerical values with place-bounded quantitative data. These can include pedestrian flow rates, numbers of people in the streets, numbers of criminal incidents, shopping and spending capacities, property prices, building density, or population density. In order to connect the qualitative data to space syntax results, various statistical tests can be applied. In particular, scatterplots as mathematical diagrams for displaying and correlating two variables for a set of data are useful.

A qualitative approach visualises human activity superimposed onto visual space syntax analysis results or links qualitative interpretations of impressions of particular places to the space syntax results. The same can be done with quotations from in-depth interviews. Other qualitative materials include written histories of places, people's shared memories, or the perceptions of people about a place. Furthermore, we are also dealing with the intangible qualities of the place itself, in other words, the sphere of the place, the place's character, and the senses of the place such as smells, sounds, and textures. Qualitative aspects of the built environment also include building functions, aesthetic aspects, building types, architectural styles, and urban art such as graffiti or sculptures. Qualitative data can be translated into quantitative data, for example, by counting the number of certain building types within a neighbourhood or recording the amount of graffiti along a wall.

In general, we operate with primary data represented by empirically collected data by the researchers themselves and secondary data from other sources. Examples of secondary data include traffic census data from the government, data collected from other researchers or organisations, registers, data from central bureaus of statistics, crime data from the police, etc. In the following, we explore empirical quantitative and qualitative data collection for the acquisition of a basic set of data of the type that is mostly applied in the arena of space syntax research and practice, and this is referred to as the 'space syntax observations method'. We complete this by presenting methods that have gained prominence in recent years. This is followed by a brief discussion about using secondary data. At the end, we shortly discuss how GIS can be used as a platform for aggregating the results from various space syntax analyses with each another and with results from Spacematrix and MXI analyses (discussed in Chap. 1).

5.2 Observation Techniques

On-site observations have several advantages. First of all, you get to know the study area very well from a spatial as well as from a social perspective. Secondly, both quantitative and qualitative data can be acquired through on-site observations. Finally, you get raw data (primary data) that is unfiltered where you as a researcher can select relevant data for further analyses.

5.2.1 Pedestrian, Car, and Bicycle Movement Flows: Gate Counts

Counting the flow of human movement gives quantitative data for comparison with various spatial integration values. This method has been applied to provide evidence that highly integrated streets consist of high flow rates of human movement, while highly segregated streets have low number of people frequenting them (Hillier et al. 1998, p. 59ff, 2007; Hillier and Iida 2005). Gate counts allow the recording of observations of pedestrian and vehicular movement flows in an urban area, and gate count data tend to correlate well with normalised angular choice analysis. If a low correlation is identified, this often indicates spatial conditions that need to be investigated. The collected data can be represented graphically and statistically in a variety of ways (Grajewski 2001), and the data collection must be conducted consistently and with a controlled procedure for all cases. The registration of pedestrian, bicycle, or car movement is as follows:

(1) The boundary of the area under scrutiny is defined on a map. This should cover a range of well-used to moderately to poorly used spaces in and around the area of study.
(2) Select a number of gate positions. It works well to indicate the gates on the map manually when walking through the area. You can also choose the gates in line with the results of space syntax analyses. Grajewski (2001) suggests a minimum of 25 gates per area, and the more the better. The denser the gate network, the more accurate the pattern of movement that is obtained. For each gate position, pedestrian or vehicle movement flows are registered. The number of gates one observer can cover in an hour should not exceed 10 gates. This allows the observer to register 5-min long periods of pedestrian or vehicular movement per gate. The remaining time is allocated to walking to the next gate. Thus, within an hour the movements are recorded for all 10 gates.

(3) The observer starts at a certain gate where they draw an imaginary line across the street including the sidewalk (see Fig. 5.1). Only people or cars that have crossed the street are counted and registered (see Fig. 5.2). Always note the starting and ending time of the observation recordings so that errors can be avoided when later converted to rates per hour. For lightly used streets, one observer can cover the whole street and register pedestrian movement on both sides of the sidewalk, and can record pedestrian and vehicular movement simultaneously. For busy streets, three strategies for registration of pedestrian and vehicular movement can be carried out—(1) The pedestrian and vehicular movement counts can be divided into, for example, 2.5 minutes registering pedestrian movement immediately followed by 2.5 min registering vehicular movement, (2) one observer can cover pedestrian movement for both sidewalks while the other observer covers vehicular movement, or (3) both sidewalks can be covered by separate observers for pedestrian movement while a third observer covers vehicular movement.

(4) After completing an observation sequence from gate 1 to 10, the observation route should be repeated from gate 10 to 1. A minimum of two observation rounds should be done for each time period. This means that for each gate at least two rounds of data collection per defined time period should be carried out.

This observation registration should be repeated for at least two weekdays and two weekend days. Furthermore, observations should include peak hours and off-peak hours. Several rounds of observations should be conducted over the course of a day, and at least five different time slots over a day should be chosen for observations, for example, 8–10 a.m., 10 a.m.–12 p.m., 12–2 p.m., 2–4 p.m., and 4–6 p.m. Ideally, the observations will also include early morning and late evening time slots. The more time slots the better. However, the time slots may vary in different cultures due to different daily routines. It is also important to note the date and weather conditions, including temperature, because these influence pedestrian and vehicular movement flows. The advice is to choose a day with an 'average weather' for each particular case, which means that you need to check the weather forecast before you start the registrations.

Fig. 5.1 A gate with its imaginary line (coloured in yellow)

For the observed categories, the type of area is important. Whereas in a business area ‘suits’ or ‘white collars’ are included, in a family-oriented neighbourhood the category of ‘children’ might be divided into ‘girls’ and ‘boys’ and furthermore include mothers with children, for example, when pushing a pram. The individualised list is usually built upon the following categories for pedestrians: moving adults, moving men, moving women, moving teenagers, moving children, and moving working people (or ‘suits’). For vehicles, the following categories can be feasible: cars, buses, trucks, motorbikes, and bicycles. In general, the list should be tailored to the nature of the study and to the knowledge gap that is to be filled. Each observed pedestrian or vehicle is registered with a tally count in a prepared Table (Fig. 5.2).

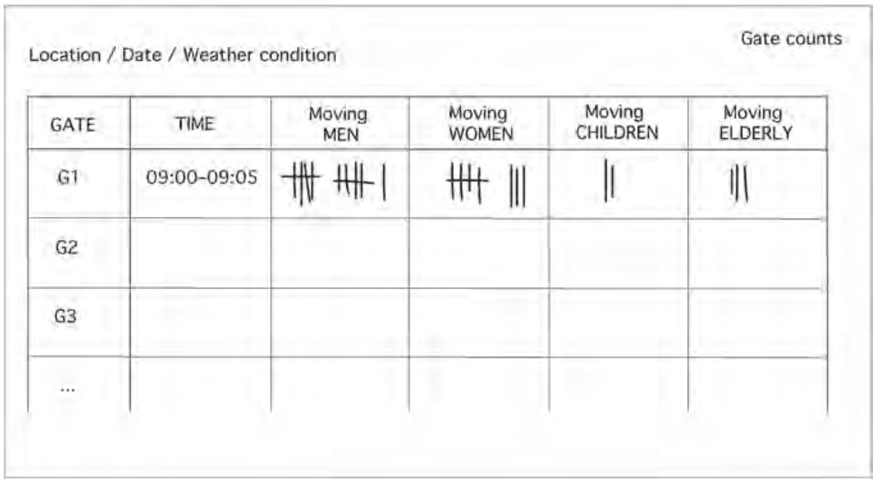


Fig. 5.2 Table for a tally count of pedestrian movement

In order to avoid errors in the data collection, it is best if several observers carry out the observation registrations. This will give greater accuracy because a single person might make repetitive errors. Working as a team is also more fun because different observers will have different gate rounds throughout the fieldwork. In addition, for more complex routes, it might be better that the same observer undertakes all gate rounds for one route (Grajewski 2001). In the following, we illustrate how the results from the gate method can be visualised using Geographic Information System (GIS). Figure 5.3 illustrates the results from the gate method for weekday pedestrian flows for Woolwich Squares in London (Space Syntax Ltd. London 2008). The pedestrian flow is represented in numbers as well as with colour codes. The colour codes give in one glance where the largest flows of pedestrians take place.

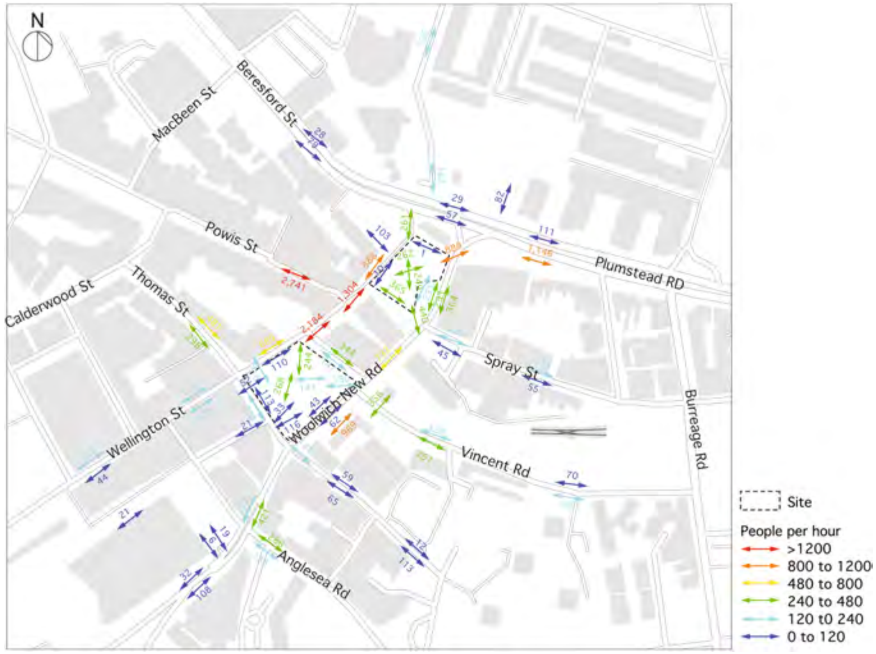


Fig. 5.3 Weekday pedestrian flows for Woolwich Squares in London visualised using GIS (Space Syntax Ltd. London 2008)

The results from the gate counting method correspond with the results from the various axial and segment line analyses discussed in Chap. 2. The empirical data results give indications as to the pattern of necessary activities—such as going to work, to school, or to do shopping—in a built environment.

5.2.2 Stationary Activities: Snapshots

The static snapshots method is an effective observation technique for the registration of various people's stationary activities, moving activities, and social interactions in public squares and parks. This method records the use pattern of a public space from specific moments throughout the day.

Fig. 5.4 Static snapshots from a certain moment of people interacting in a group (left) and individual people sitting and standing (right)

This method is carried out in the following way. The observer makes a mental snapshot of the public space and registers on a map where people sit, stand, walk, or socially interact like chatting with each other (Fig. 5.4) when walking through the study area. This registration is done in a given moment and repeated, for example, every two hours throughout the day from the same location the observer chose in the first place. If a number of public spaces are under scrutiny, the observer decides upfront on a route for the observations. Later, all collected data can be plotted on one map. This map gives an overview of which areas of a public square, park, or housing estate are most or least used. The software used for digital registrations for the snapshots are GIS, Vector Works, Auto Cad, Adobe Illustrator, or any kind of software that allows one to create vector images and use layers.

The results from static snapshots can be presented qualitatively and quantitatively. Figure 5.5 depicts a qualitative representation of observation data gained with the snapshots method for one moment (left) and throughout the whole day (right) for park X. Here a differentiation is made between men, women, and children and between moving and standing. In addition, registrations on whether people are moving alone or within a group can also be recorded. When adding all layers for each time slot on top of each other, a behaviour pattern of the public spaces can be seen. Here we see that in the middle of the park, there is a balance of the presence of gender, whereas behind obstacles, we see a concentration of only children. At the edges, the spaces are dominated by men, often standing in groups.

The registration of human behaviour can now be combined and correlated with results from the space syntax agent-based model, visual graph analysis (VGA), and all-line analysis. These registrations can be used qualitatively as well as quantitatively and give indications on social, necessary, and optional activities in urban space.

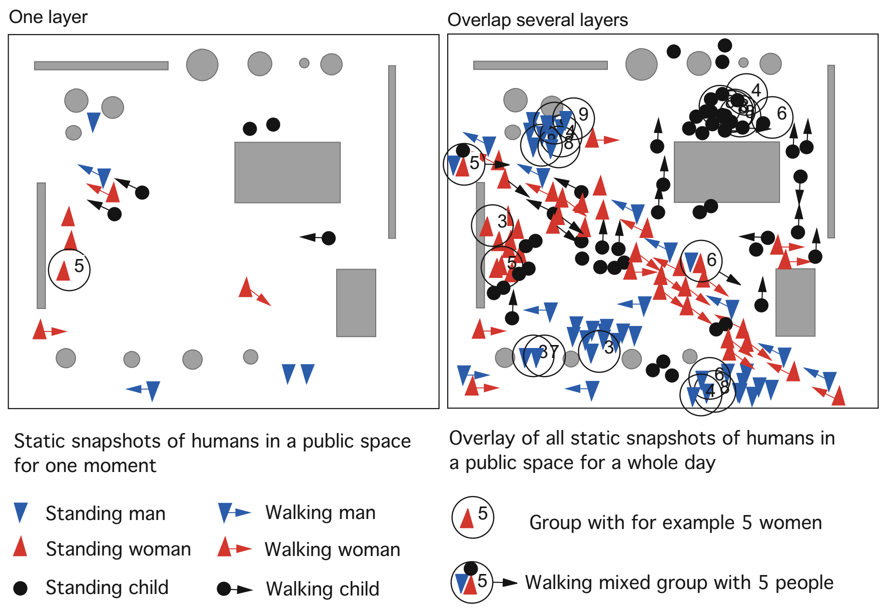


Fig. 5.5 Movement traces and static snapshots data for park X with one layer for one time slot (left) and all layers throughout a day (right)

Figure 5.6 shows a more advanced static snapshot registration map of Oosterwei in Gouda. This neighbourhood has a high number of low-income inhabitants consisting of Dutch and Moroccan inhabitants. The research question was to determine the social composition of the residents' behaviours and use of urban space in this spatially segregated neighbourhood. In the registration, a distinction was made between native Dutch and Moroccan, between men and women, and between teenage boys and girls. All registrations are compared with the results from the all-line analysis. In the most integrated areas, there is a balance between gender and ethnic background. In the segregated areas, the spaces are mostly dominated by men. For a detailed view, Fig. 5.7 shows a separation of the registrations based on gender. Here we can see that Dutch and Moroccan women are mostly close to their homes, whereas the Moroccan men and teenage boys dominate the segregated streets. Teenage Moroccan girls are hardly present in the registrations. These registrations were carried out on a weekday and a weekend day (Rueb and van Nes 2009).

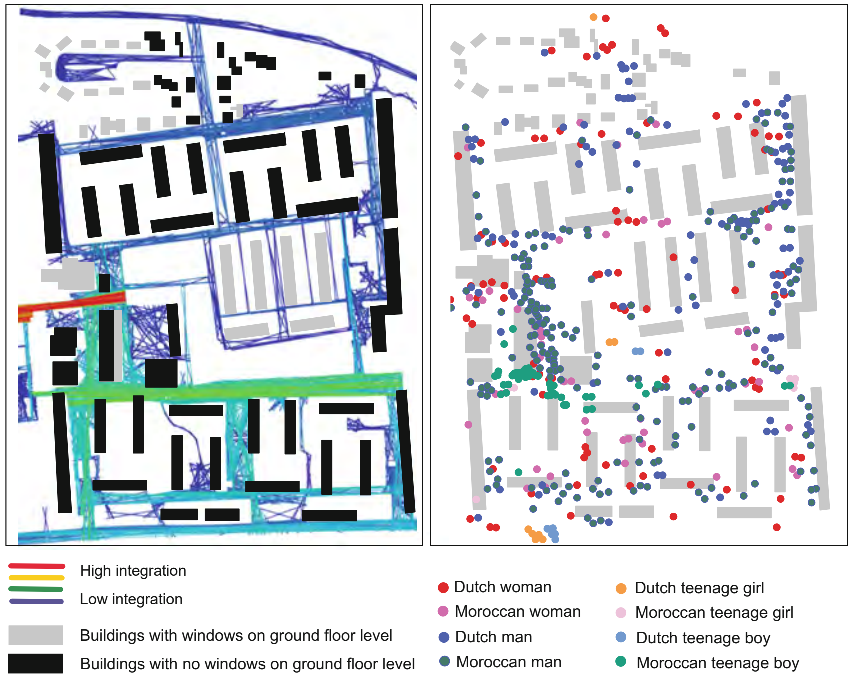


Fig. 5.6 Registrations of human behaviour over an entire day (right) and an all-line analysis (left) of the Oosterwei neighbourhood in Gouda, the Netherlands

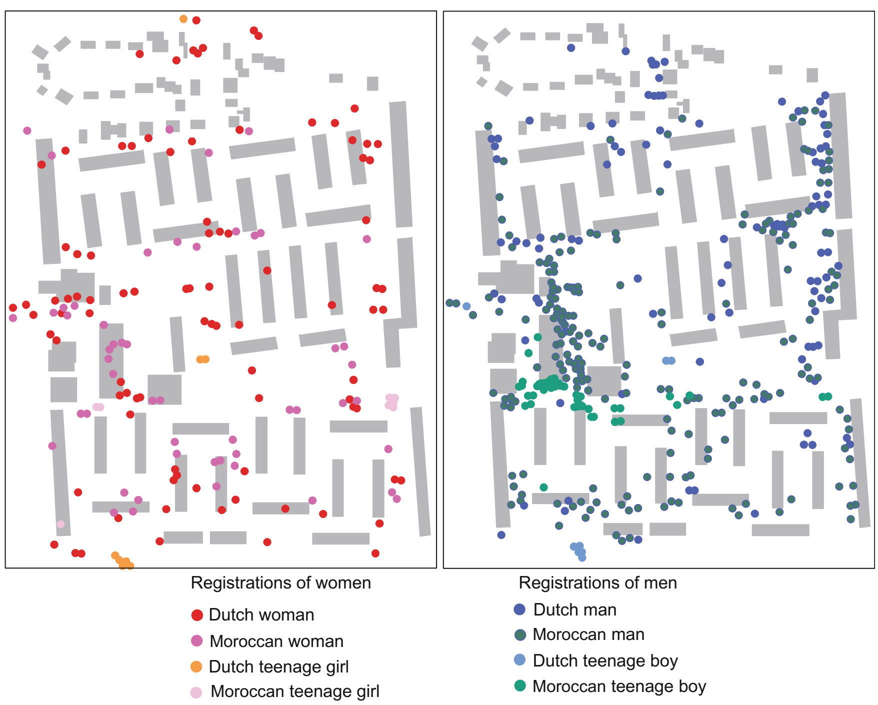


Fig. 5.7 Separation of the snapshot results of Gouda based on gender, with the registrations of all female behaviour (left) and male behaviour (right) of the Oosterwei neighbourhood in Gouda, the Netherlands

There are several possibilities for presenting the data from the static snapshots registrations quantitatively and qualitatively. You can use the results to show how children use public space differently from adults, where people tend to gather in groups, where people are standing or sitting, etc. The options are many. What categories you choose depends on the research question at issue. The same applies to the time slots used.

For example, in a research project on sexual harassment against women (Miranda and van Nes 2020), the static snapshots registration was useful for correlating the degree of sexual harassment risk with the number of women present in the streets in comparison with men. For every street segment, the numbers of women and men were counted separately and put into an Excel file for comparison with the spatial variables from the micro and macro-scale analyses and the recorded numbers of various types of criminal incidents.

5.2.3 Pedestrian Routes (Traces): Pedestrian Following

The pedestrian-following technique allows the collection of qualitative data by observing pedestrian movement that disperses from specific, strategic locations. Grajewski (2001, p.10) explains that this technique allows the investigation of three specific issues, namely the patterns of movement from a specific location, the relationship of a route to other routes in the area, and the average distance that people walk from the specific location, which can help determine the pedestrian catchment area of a retail facility or public square. This type of observation is useful for understanding how people use a specific public space. Overlaying all registrations on top of each other provides us with an image of pedestrian movement throughout an area under scrutiny. This observation technique can also be combined with space syntax normalised angular choice results to understand how the built environment works for people in the context of the natural movement theory and function-driven movement. In the following, we explain how to register pedestrian routes manually:

(1) For the fieldwork, a map of the area under scrutiny is prepared that indicates the survey area's boundary, the specific locations for starting the pedestrian following, so-called entry/exit points, and the site itself (Fig. 5.8). We suggest printing several copies of the maps for the observers in an A3 format. This paper format allows them to conduct fieldwork without being hindered by a huge plan, whereas an A4 map is too small for an urban area to register traces in detail.

(2) The observers record the movement routes on chosen dates. It is useful to note the weather condition for the fieldwork on the map. Each trace is indicated with a waterproof pencil on the map. Often the traces are registered during a whole day from 8 a.m. to 8 p.m. For recording traces, it is important to select individuals randomly from the chosen entry point into the area for a specific time period per entry point. Pedestrians' traces are registered until they leave the observation area or stop for any activity that lasts more than two minutes. Following people and recording their movements has to be done discreetly. This means keeping an appropriate distance from the person that is followed. However, cultural differences can appear. For example, in London, the observer can have less distance to people when following compared to Izmir, Turkey, where the distance has to be greater between people and observer. The 'good' distance will be found during the people following and recording process.

(3) After a pedestrian has been followed and their movement route registered, the observer returns to the same entry/exit point and randomly selects another individual who is followed. Grajewski (2001) suggests collecting 20–25 traces per entry point. In striving for objectivity, it is important to have a distribution between different types of people in terms of age and gender. Several observers starting from different entry points allows for different routes to be followed and different route sequences to be identified. In Fig. 5.8, Observer 1 has the route A to C; observer 2 has the route C to A; and observer 3 has the route B to A. Thus, the data reflecting movement patterns throughout the whole day will be more complete.

Figure 5.8 shows the movement routes from one starting point and the registrations of all movements recorded during one day from all gates. Already in our example of park X, it is possible to see a pattern of where the largest flow of movement takes place.

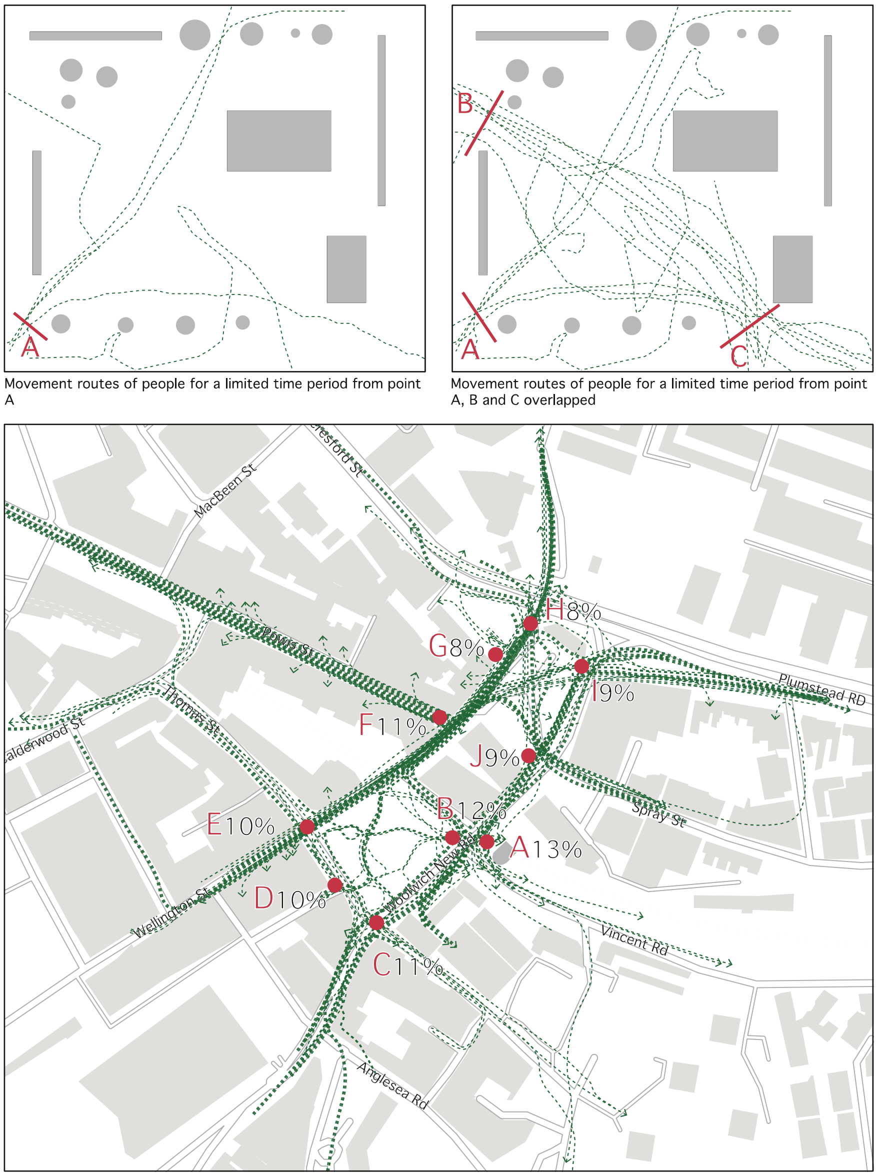


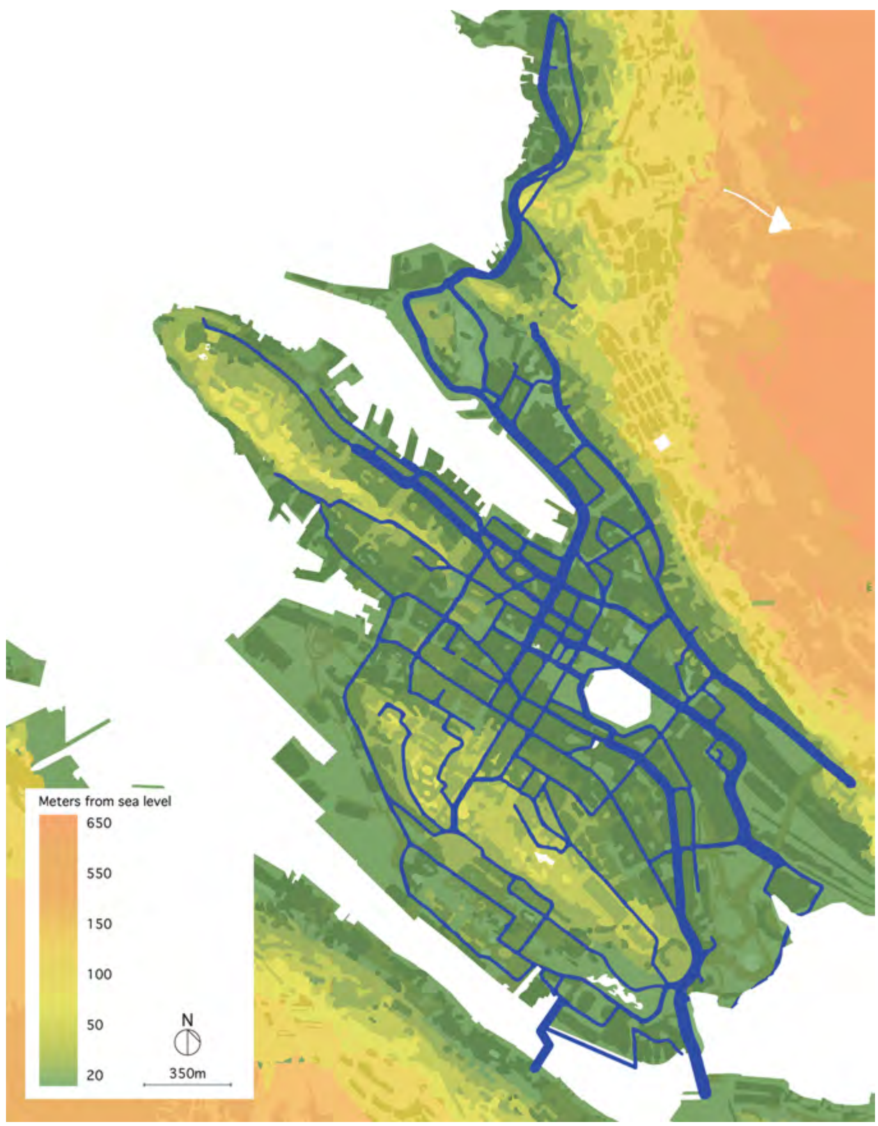
Fig. 5.8 Top: Pedestrian routes from starting point A (left) and the overlay of all registrations of starting points A, B, and C (right). Below: Overlay of all registrations of one day in Woolwich Squares in London visualised using GIS (image below – original: Space Syntax Ltd. London 2008; redrawn by authors)

After all traces are collected, it is useful to register them digitally in GIS, Excel, Auto Cad, or any kind of software that uses layers for further processing and spatial analysis. For pedestrian routes, Global Positioning System (GPS) tracking can be useful because the observer can use an application on a mobile phone or tablet or a GPS tracker when following people. This will also allow the observer to save and export all traces in a GIS file format. However, this will mean that the observer has to exactly imitate the movement route of the followed person.

During a research study in 2019 (Bolset and Kampenhøy 2019), bicycle routes in Bergen, Norway, were investigated. The motivation for the project was that until then no data on cyclists' route choices existed for Bergen. There are eight roads leading into Bergen centre, and this made it easy to define the entry points. The researchers followed randomly chosen cyclists heading towards the centre from eight different points. They used a GPS watch to record the movement trails for each cyclist. As soon as each cyclist had reached their destination or left the city centre, the recording was stopped. All registrations were saved, imported into GIS, and plotted on a map. Figure 5.9 shows the procedures the researchers followed, and Fig. 5.10 shows the results of all the registrations. These primary data on cyclists' route choice through the urban area contributed to the following information: mainly cyclists followed the most spatially integrated main routes through the city centre while at the same time avoiding steep hills and traffic lights (Fig. 5.10).

Fig. 5.9 GPS registration procedure of bicycle routes in Bergen, Norway (Bolset and Kampenhøy 2019)

Fig. 5.10 Cyclist trailing results for Bergen, Norway, superimposed onto a topographic map (Bolset and Kampenhøy 2019)



5.2.4 General Movement Traces

The people-following method records the precise movement routes of people when moving through a space and allows the registration of collective movement flows through a predefined area. The routes of people from all directions are registered. This distinguishes the movement traces method from the people-following method, where people are followed from predefined entry points into an area (see Fig. 5.8). This analysis correlates well with results from space syntax agent-based models.

For this method of registering general movement traces, the observer tracks and maps all movement traces in all directions from a chosen location with a maximised view of the area. From this fixed position, the observer records the movement traces for a time period of five minutes, repeating it several times throughout the day. A downside of this method is that it is restricted to a smaller area that one observer can cover and register pedestrian movement. Here, printed maps of the area under scrutiny allow manual recording of the traces.

Moreover, GPS tracking is a useful tool for an exact tracing of people's movement through a city (Hardner et al. 2012). A number of applications that track movement can be installed on a mobile device such as a smartphone. In this case, a chosen number of participants agree to take part in a project. Often, the collected data have to be anonymised because sometimes participants forget to turn off the device or app before entering their home. This technique allows the collection of data for a whole city. When involving locals, daily routines, shopping, and leisure activities in connection to movement routes are explored. When involving strangers and they are asked to randomly move around in the city, the focus is more on navigation and orientation linked to the visibility of different neighbourhoods in a city. Another method involves gaining knowledge of people's locations through their mobile phone activities. General mobile phone data can provide an understanding of where and when large amounts of people move or stay in various urban areas. These data are provided by telephone service providers. The disadvantage of this method is that the time when the mobile phone is used can be irregular.

In general, all empirical observation data can be further processed quantitatively and qualitatively. The quality of the data and the size of the data set decide the way in which these data are processed.

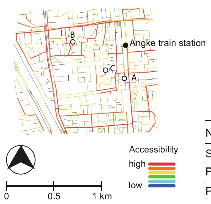
5.2.5 Ethnographic Observations: The Walking with Video Approach

The essential core of ethnography is concerned with the meaning of actions and events, and participant observation is the central data collection technique in ethnography (Punch 2014). Herein, the 'walking with video approach' (Pink 2007) allows the recording of sensory elements within the context of a certain built environment. Videos are taken while walking through a public space, and this method supports an understanding of the qualitative issues of the public realm.

There are two ways to conduct walking with the video approach. In the first method, the observer takes part in the life of a public space in a discreet way and becomes a participant observer, while in the second method, the observer walks with participants through a public space and also records their experiences and expresses emotions and comments. In addition, sketches about the place and notes about smells, sounds, and events can add to the richness of this approach. The observer collects as much detail about the public space as possible.

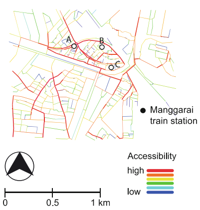
The walking with the participant through the public space approach provides the added value of recording mobility experiences compared to the conventional method of installing a video camera in a static place to record pedestrian and vehicular movement (Guo et al. 2012; Van der Horst et al. 2014; Hidayati et al. 2019, 2020). This observation technique is open-ended as it is guided by the observation itself. It might take 15 min, or it might take 2 hours or the whole day. Pink (2007) concludes that walking with video is a method that can produce an empathetic and sensory embodied and emplaced understanding of another's experiences. It is itself productive of place in any one moment in time. A number of computer software programmes are available that are tailored to analyse videos. These kinds of data are qualitative (which also can be quantified) and their results can be juxtaposed and discussed against the space syntax results for describing spatial properties on where and how certain types of human behaviour take place in the context of the built environment (Fig. 5.11).

Kampong Angke



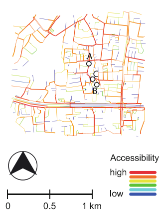
	street segment **A**	street segment **B**	street segment **C**
NACH local	1.31 (high)	0.97 (middle)	0.84 (low)
Sidewalk	No	No	No
Presence of pedestrian	Yes	Yes	Yes
Presence of shops	Yes, food hawkers	No	No
Street-facing buildings	100%	100%	50%
On-street survey	I feel relaxed, sometimes wary, but so far it is safe (female, 65)	I feel safe because I am familiar with the place (female, 54)	I feel safe because there is nothing bad ever happen before (male, 66)

Kampong Menteng



	street segment **A**	street segment **B**	street segment **C**
NACH local	1.35 (high)	1.11 (middle)	0.18 (low)
Sidewalk	No	No	No
Presence of pedestrian	Yes	Yes	Yes
Presence of shops	Yes	No	Yes
Street-facing buildings	100%	100%	70%
On-street survey	So far there is no problem (male, 27)	I feel very safe because I am used with the place (male, 42)	I feel cautious when walking (female, 45)

Kampong RW 06 Cilandak



	street segment **A**	street segment **B**	street segment **C**
NACH local	1.36 (high)	0.96 (middle)	0.74 (low)
Sidewalk	No	No	No
Presence of pedestrian	Yes	No	No
Presence of shops	No	No	Yes
Street-facing buildings	56%	40%	50%
On-street survey	It is easy to walk around (female, 51)	I feel unsafe (female, 46)	It is easy to move around as I drive carefully (male, 47)

Fig. 5.11 The walking with video approach juxtaposed with space syntax results and human perceptions about mobility safety (Hidayati et al. 2019)

5.2.6 Phenotypological Registration on Site

We can register everything that we immediately see on a site. A phenotypological registration refers to the appearance of the built environment, and a variety of data can be collected. For example, to understand the relationship between the spatial setup of a neighbourhood and vandalism or anti-social behaviour, the location of all graffiti, broken windows, or other broken items can be registered. Space syntax analysis describes the spatial properties of the locations where certain activities take place.

There are many types of place-bounded data that can be registered manually, such as the degree of building maintenance, types of vehicles parked in the streets, types of surnames on doorbells, types of advertisements, etc. All of these kinds of data can be correlated quantitatively and juxtaposed qualitatively with the results from the space syntax analyses. A quantitative approach is to count the numbers of each registration on the street segment level, whereas a qualitative approach describes the spatial features for certain socio-economic activities.

Figure 5.12 shows registrations of vandalism on buildings and street fixtures taken by walking through a neighbourhood at a given moment (Berge 2019). Here space syntax is useful for describing the spatial features on where such things take place.

Fig. 5.12 Registrations of vandalism on buildings and street fixtures in the town of Bergen, Norway (Berge 2019)

5.3 Map-Based Surveying

Surveying is the process of collecting data through a questionnaire that asks a range of individuals the same questions related to their characteristics, attributes, how they live, or their opinions (O'Leary 2014, p. 202). At present, face-to-face surveys or self-administered online surveys can be conducted using mobile devices such as smartphones and tablets that allow the collection of qualitative and quantitative data as well as geographic data. The respondent provides the surveyor with their answers, which are entered as data into a user-friendly GIS-based web platform (Fig. 5.13). A variety of computer and mobile applications exist online, for example, the online tool 'Maptionnaire' (https://maptionnaire.com).

The data are stored in a GIS format. These applications are mainly designed to collect quantitative and qualitative data on a personal computer or mobile device. Soares et al. (2019) suggest the use of online map-based questionnaires with user-friendly interfaces providing the users with multiple possibilities to report geographically referenced and map-based information. When entered into a geographical database, the data can be used for a variety of spatial analyses, spatial queries, and statistics.

In contrast to online surveys, face-to-face surveys have the advantage of a good response rate and allow rapport and trust to be established. This can motivate respondents and allows for immediate clarification and the reading of non-verbal cues.

However, a misfit is that, face-to-face survey's geographical range is limited and such a method does not allow anonymity or confidentiality. Further, face-to-face surveys require surveyor training. In contrast, self-administered online surveys offer confidentiality and anonymity, allow a wide geographic coverage, and give the respondents the opportunity to answer in their own time. A downside is that the response rate can be very low.

Fig. 5.13 Map-based survey using Maptionnaire to understand how locals perceive a neighbourhood in Paris

In general, a questionnaire is composed of closed and open questions. Open-ended questions provide qualitative information (McLafferty 2012), whereas closed or fixed-response questions provide quantitative information. O'Leary (2014, p. 206) provides a few basic rules for developing a questionnaire.

- Operationalization of concepts: This involves going from abstract concepts to variables that can be measured/assessed through the survey.
- Exploring existing possibilities: There is no need to reinvent the wheel. If an existing survey instrument has addressed variables that are interesting for the research/project, it can be helpful to adopt, adapt, and modify it.
- Drafting questions: New questions have to be drafted as clearly as possible; here McLafferty (2012) keeping the questions simple and clear, and the simplest possible wording should be used.
- Decision on response categories: One must consider both the effect of the response categories on the responses themselves and how various response categories translate into different data types that demand quite distinct statistical treatments.
- Review: Each question and response choice has to be read carefully and thought through to determine if the questions might be considered ambiguous, leading, confrontational, offensive, based on unwarranted assumptions, double-barrelled, or pretentious. This step has to be repeated as many times as necessary to get each question as right as possible.
- Ordering questions: For the survey, the questions have to be in an order that will be logical and easy for the respondents.
- Writing instructions: These have to be as clear and unambiguous as possible.
- Writing a cover letter/introductory statement: This generally includes information on the surveyor, the project's aims and objectives, assurances of confidentiality/anonymity, and whether results will be available to participants and asks for the consent of the participant.

If no internet or mobile device is available, questionnaire data can always be collected using printed papers. Sometimes questionnaires can be more feasible and efficient than in-depth interviews.

For a research project in Bergen on the relationship between urban micro-scale parameters, three researchers investigated how people perceive streets in their own neighbourhood. The researchers went in front of the local food shop in six different neighbourhoods. For each area, they had a large aerial photo of the neighbourhood on a poster and asked 200 respondents the following questions: “Are there any streets where you feel unsafe? If so, can you point them out on this map?” One researcher was asking the questions, and the other two were marking the results for each respondent on a separate map. This had the purpose that other respondents would not be influenced by already given answers from others. All of the results were put on a map and superimposed with the results from the various spatial analyses, and the combined analysis showed that segregated and un-constituted streets are perceived to be the least safe (Rønneberg Nordhov et al. 2019).

Street interviews were also conducted for identifying the locals’ perceptions of safety in the Pendrecht neighbourhood in Rotterdam. Figure 5.14 shows images of how this was conducted with a large aerial photo of the neighbourhood where the various people could point out and describe the perceived safe and unsafe areas.

Fig. 5.14 Images from the street interview where locals were asked to point out streets they perceive as safe and unsafe on an aerial photo of their neighbourhood (van Nes and Rooij 2015)

5.4 In-Depth Interviews

Often there are differences in what people do—their behaviours—and what they think and feel. The latter, what they think and feel, can be captured through in-depth interviews. These are ‘knowledge-producing’ conversations (Nagy Hesse-Biber 2006, p.128) often involving a one-to-one conversation between the interviewer and interviewee in which the interviewer is interested in gaining insight into a specific topic. Valentine (2005) highlights that the aim of in-depth interviews is to produce a deeper knowledge and that it also relies on words and meanings in its analytical approach rather than on statistics. Thus, the analysis of the transcriptions from the interviews requires a hermeneutic approach in which the purpose is to interpret human meanings and intentions.

An in-depth interview is conducted when it is of interest to understand how people make decisions, people’s own beliefs and perceptions, the motivation for certain behaviours, the meanings people attach to experiences, people’s feelings and emotions, the personal story or biography of a participant, in-depth information on sensitive issues, or the context surrounding people’s lives (Hutter et al. 2011, p. 110). Qualitative data are collected with this method, and the sample set is small. One of the criticisms of positivists is that the interviewers bias the interviewees. However, the counter argument is often that in social sciences there is no such thing as objectivism (Valentine 2005).

For conducting an in-depth interview, an interview guide has to be developed. The interview guide follows a certain format that eases the conduct of the interview. It is structured as follows (Hutter et al. 2011; O’Leary 2014):

(1) Introduction: The introduction explains briefly and in simple words the aims and objectives of the research project. It explains why the in-depth interview is being conducted and includes information about the interviewer, assurances of confidentiality/anonymity, and permission for audio-recording and consent from the interviewee.

(2) Background information: Herein the number of the interview, age of the interviewee, if they are an urban or rural residents, education, nationality, and other information is collected. This allows the collected information to be contextualised.
(3) Opening questions: These ease the interviewer's way into the main questions and themes. Opening questions should also build trust and rapport between the interviewer and the interviewee. Rapport allows the interviewee to freely share their thoughts, experiences, and opinions connected to the topic under scrutiny.
(4) Key questions: This is the central part of an interview, and with the key questions the core information is collected. The interviewer normally uses many probing questions during this phase so as to gain detailed information and to understand nuances with regard to what is being shared by the interviewee. It is necessary to allow sufficient time for these questions.
(5) Closing questions: By establishing rapport, the interviewer and the interviewee are connected, and the closing questions allow the interviewer and interviewee to re-establish a distance between them before the interview ends. This 'fade out' phase is generally conducted through more general questions where the interviewee can add additional thoughts or issues they might like to further briefly discuss. This phase is, especially important for sensitive emotional topics, where the interviewee might be in a vulnerable place.

It is important to offer something back to the interviewees. This can be done by letting the interviewee know how things are progressing or the interviewer can send a thank you note. Furthermore, results can be made available to the interviewee. Figure 5.15 is an impression from an in-depth interview in an informal settlement in Jakarta, Indonesia about research on mobility inequality.

Fig. 5.15 Impression from an in-depth interview conducted in an informal settlement in Jakarta, Indonesia, about mobility inequality (Hidayati et al. 2019)

Interviewing in different cultures can be challenging. In some cultures, conducting interviews requires more sensitivity to complex power relations between interviewer and interviewee and to local behavioural codes and local values (Valentine 2005). Furthermore, in some cultures, it can be challenging to talk to people about sensitive topics because they are considered taboo. Sometimes it is handy to bring a second person along who takes additional notes in case the recorder has technical problems during the interview. Transcription of the interview can be done using freely available software online.

In some countries, there are requirements to apply for permission to conduct interviews. Often one of the requirements is to submit the interview guide or the set of questions before permission is given. Therefore, these issues need to be clarified before approaching potential interview objects.

In summary, collecting primary data is connected to a present context. It is mostly used when other data are not available, not up to date, or secondary data are questionable with regard to their quality.

5.5 Secondary Data

The management, planning, and provisioning of complex societies gives rise to data needs, while in certain cases government agencies wish to gain insights into the lives of citizens for reasons of control. These exercises produce secondary data that once collected for one purpose may be used for another (White 2012, p. 62 ff). At present, a wide range of detailed secondary data are available for free online. White (2012) adds further that the secondary data can inform projects about what evidence has to be collected by other means or must be used in a primary form of information and then subjected to analysis of varying degrees of sophistication. For example, sources for secondary data can be governmental data, data from local archives, data from other research projects, or data from the Internet. It has to be noted that the quality of secondary data varies significantly.

In the following, we will give some examples of commonly used types of data that might be useful for space syntax research. It is meant as an inspiration for finding secondary data for connecting and correlating with the results from the various spatial analyses. We discuss examples of land use values, income, social media, and others.

In research on land use values, published lists, for example, the Globalisation and World Cities Study Group and Network (GaWc) from Loughborough University in the UK, can be used. Here you can identify the largest firms of each sector in advertising, accountancy, insurance, finance, law, and business management. Often, the location pattern of these firms tends to be along streets with the highest spatial integration values on a city or regional scale. Moreover, the various land values can be found at rental offices and property sales agents. The availability of the data varies from country to country. In some countries, the data are publicly available from the national bureau of statistics, whereas in other countries, the announced sales prices from estate agents can be used. Recently, most of these data are easily available on the Internet. The various rent and sales prices on available estates can function as a spot test for the prices in various areas in a built environment at any given moment. Herein, also various income or rent registrations can be used when studying the spatial setup regarding where different types of people prefer to live or are forced to live. In many cases, these data are available on the Internet as well as from the bureau of statistics (Rocco and van Nes 2005).

Recently, various countries have begun to offer free bicycle rentals through registration with mobile phones. The movement traces of the users are then GPS tracked. The degree of availability of these data depends on the degree of willingness of the private companies to share the data with you.

Social media tags and the locations of people's photos posted on Google Maps can also be useful sources for gathering place-bound data. In some countries, there are various mobile apps where people can report certain place-bound social activities. One example is the sexual harassment reporting app for women in Egypt (Mohammed and van Nes 2017).

In other cases, local archives or written documents can provide secondary data. Space syntax research dealing with past built environments relies on old sources that are often not digitally available. Examples of old place-bound data can be address books, old phone books, and old registrations on maps from events in the past. Likewise, membership lists from churches and other religious communities can be used to plot home addresses of various religious or ethnic groups in different time periods. Through registrations from various data sources, such as archives and research from other disciplines, useful and precise sociological and economic data about human life and where it took place can be gained for correlations with the spatial configurative analyses.

In research on space and the distribution of criminal activities, police registers are an important source of information. The degree of access to these crime registers depends on each police office's degree of willingness to share these data with you. If you are lucky, you might get registrations on street-resolution level with street names and house numbers, instead of just on the postcode or neighbourhood level. The most detailed registered criminal activity is burglaries of homes because an exact street address is given in the police registers due to requirements from the insurance companies. Some countries operate with georeferenced data or x and y coordinates. However, x and y coordinates are often not as precise as postal addresses.

Further, in many countries, burglaries of homes are registered in terms of point of entry and modus operandi. This information is useful for precise registrations from which street or back-path a home was intruded by a burglar. Theft from cars and vandalism are in some countries also registered in detail. The exact location of the car when it was broken into must be registered in detail because the degree of visibility from buildings to parking lots can vary between street addresses. In many cases, the registrations and aggregations need to be presented in such a way that the intruded homes cannot be identified due to privacy reasons.

Results from other research projects can be useful. In the Netherlands, regular investigations are carried out to measure the degree of liveability over the whole country. The inhabitants receive a questionnaire asking how they feel about and how they experience life in their neighbourhood. The project is named 'Leefbarometer' (liveability barometer) and is updated yearly. Issues such as perception of safety, occurrence of violence and harassment, experience of the quality of public spaces, provision of services and facilities, and the quality of recreation possibilities are taken up in the inquiry. The results are, however, not presented on street-resolution level, but on the postcode level. Figure 5.16 depicts a visualisation from the Leefbarometer results for Rotterdam. Herein, a quantitative approach is to take the average values from all the streets inside each postcode area from the space syntax analyses and to correlate them with the values from the liveability analyses. A qualitative approach is to use space syntax for describing the spatial features of each postcode area.

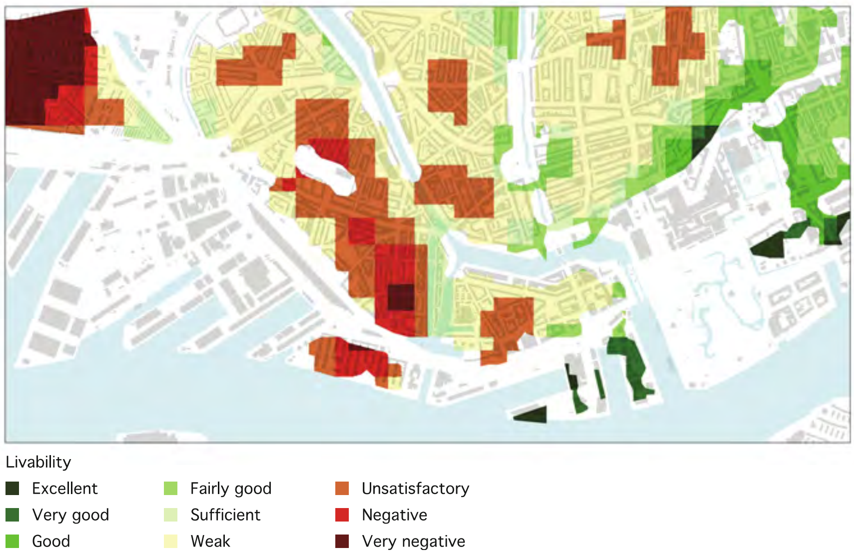


Fig. 5.16 Visualisation of the Leefbarometer results for Rotterdam (*data source* Ministry of Internal Affairs and Kingdom Relationships 2018; visualisation authors)

When applying space syntax in the field of archaeology for excavated towns, registrations of artefacts are useful. For Pompeii, Hans and Liselotte Eschebach carefully registered artefacts found inside buildings. They registered every excavated building and drew their walls and openings carefully on maps. Through the items found in buildings, their various functions could be identified and something could be said about the social status of the dwellers (Eschebach 1973). It is easy to recognise bakeries, public baths, temples, taverns, wool workshops, smiths, inns, drinking places, and brothels. Shops, however, are difficult to identify because items found inside buildings could be used for private use as well as for exchange. Here space syntax is useful for testing out these presumptions (van Nes 2011).

Further, empirical data from other research projects can be a useful source. In a research project on space and panic in Banda Aceh, Indonesia (Fakhrurrazi and van Nes 2012), empirical data from research reports from the 2004 tsunami disaster were used. Shortly after the 2004 tsunami, a group of researchers from Japan conducted a survey in Banda Aceh and its surrounding areas (Iemura et al. 2006). They collected data from people affected by the tsunami on what happened and what was expected by the people to be safe for future tsunamis. The survey is focused on these survivors' locations, how they managed to survive, and the location of the tsunami border in the city.

Connected to the space syntax research, Fig. 5.17 shows a map of Banda Aceh's street network's level of integration superimposed with mortality rates. The extent of the tsunami is indicated with a black dotted line. Mortality rates marked with a large circle represent the high mortality numbers, with the small circles representing the lowest death rate. Each circle presents the number of deaths for each local neighbourhood ('kampung'). The highest mortality rates occurred in the most segregated, fragmented parts of the street network . Five kampungs located close to the black dotted line were investigated in detail (such as conducting interviews with tsunami victims). This study revealed that a high number of segregated streets reduced the degree of people's orientability in a panic situation. This spatial condition resulted in the highest death rate.

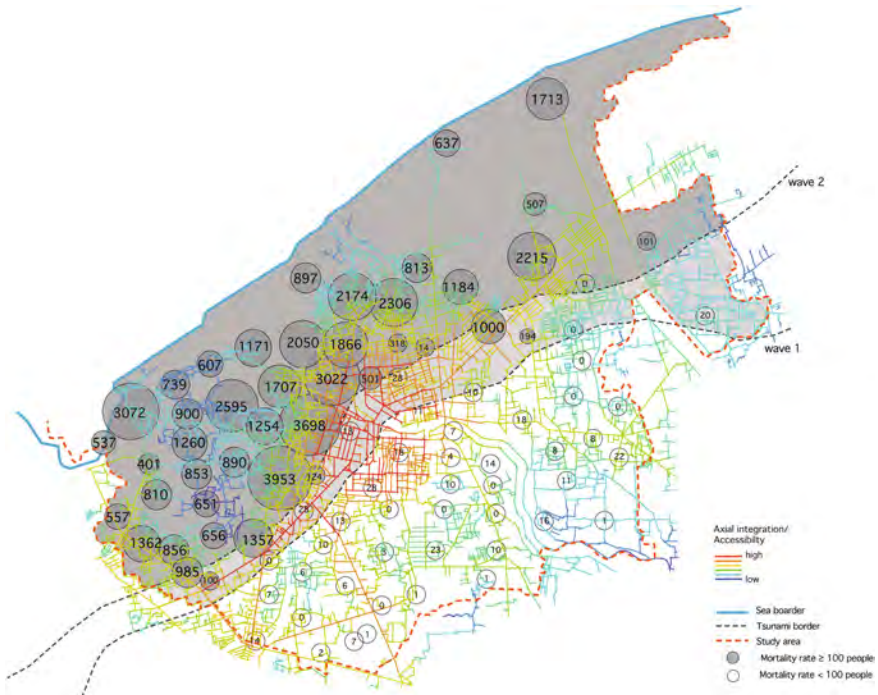


Fig. 5.17 Map showing mortality rates per kampung (neighbourhood) from the 2004 tsunami in Banda Aceh, juxtaposed with global integration data. The black dotted line shows the extent of the tsunami waves, and the size of the circles with numbers shows the mortality rates for each kampong (Fakhrurrazi and van Nes 2012)

For strengthening the understanding of space and panic, for this research project, in-depth interviews with 15 surviving families from the most affected neighbourhoods were carried out. As revealed in the interviews of tsunami survivors, people fled in the same direction of the tsunami and they followed the direction of the crowd. The survivors expressed that in the panic situation the visual orientation mattered and rational thinking in wayfinding was reduced (Fakhrurrazi and van Nes 2004). This research contributed to an understanding of how the spatial structure of the built environment matters for visual orientation in panic situations. The entire investigation had a qualitative approach.

5.6 Coding: Analysing Qualitative Data

Coding is central for analysing qualitative data. Punch (2014, p.173) explains that codes are tags, names, or labels, and coding is therefore the process of putting tags, names, or labels on pieces of the data. The pieces may be individual words or small or large chunks of the data. Coding not only allows one to index the data, but also in a more advanced way to cluster themes and to identify patterns.

Two main coding approaches are inductive coding and deductive coding. Thomas (2006) explains that inductive coding is an approach that primarily makes use of detailed readings of raw data to derive concepts, themes, or a model through interpretations made from the raw data. It allows the findings to emerge from the data without the restraints imposed by a structured methodology. In contrast, deductive coding tests whether the data are consistent with prior assumptions, theories, or hypotheses identified or constructed by an investigator. For analysing qualitative data, both approaches can be combined. Table 5.1 depicts a coding example of interviews conducted in Kuala Lumpur on transport policies and mobility inequality (Hidayati et al. 2021).

Table 5.1 Coding example of conducted in-depth interviews about transport policies in Malaysia

Interview ID	Excerpt interview	Code categories
expert #3, urban planning NGO	*"In 1980s, Malaysia was actually championing, they built the first* ***national car****. When the whole policy is about building the* ***national car, they somehow directly and indirectly influence the transport and land use policies****. Everything was about promoting the national car. So,* ***the use of the car has been glorified*** *and popularized ever since in Malaysia*	National car
	Now it is a bit less but, in the past ten years or twenty years, ***road expansion is everywhere****. Because* ***road expansion is to increase capacity, it has been institutionalized as our main solution to congestion.*** *We build roads to cater to the demand from the use of cars, but building more roads will invite more cars, right? So basically, the culture is being developed throughout the years, from twenty years ago*	Road expansion strategy
	I won't walk if I am not familiar with that place in KL, but if I am familiar with that place, I don't mind walking, even though I know it is not safe. Living in a vehicle-oriented city, ***is always unsafe when you are walking****."*	Walking stereotypes (negative) Safety (for walking)
expert #4, transport and urban planning lecturer	*"[using private motorized vehicle] is more convenient and also social status. If you already have a motorcycle, then you want to take a bus, or LRT. Ultimately, you own your own car. So, being a* ***pedestrian is the lowest social status****, whether it is discouraged or not, that is in our culture. Everyone strives to have their own car. Another related factor is institutional, and the people who make decision tend to provide access,* ***they strive to expand the roads, build new roads***	Walking stereotypes (negative) Road expansion strategy

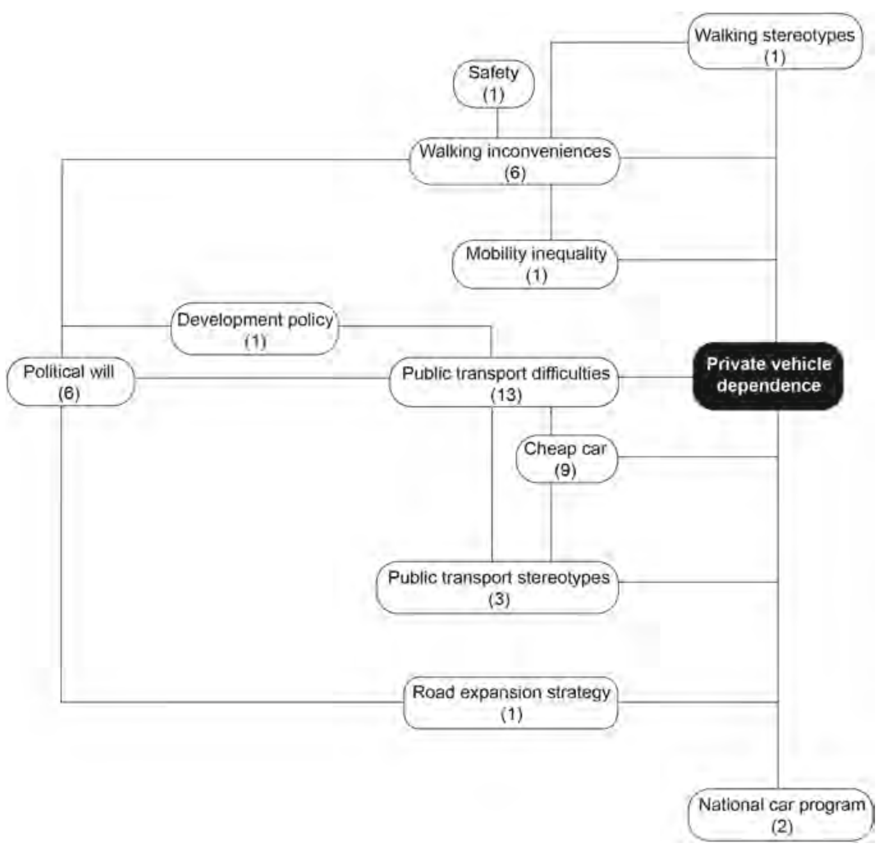


Fig. 5.18 Mapping and frequencies of codes (Hidayati et al. 2019)

Connected to space syntax research about mobility inequality in Jakarta, Indonesia and Kuala Lumpur, Malaysia (Hidayati et al. 2019, 2020, 2021), Table 5.1 shows an extraction of expert interviews and Fig. 5.18 the mapping and frequencies of codes of primary qualitative data. This provides an understanding of how often which kind of code—represented by a specific word—was used in the interviews. All codes are connected to the topic of private vehicle dependence. The results from this qualitative data analysis were connected to space syntax results for the city of Jakarta.

5.7 Statistics: Analysing Quantitative Data

This subchapter is written for those who do not have any knowledge about statistics. In most architectural and urban design education programmes, elementary statistics courses are not offered. Therefore, we provide some of the elementary statistical techniques that are commonly used in space syntax research.

Before undertaking a statistical analysis, it is important to have the ability to collect raw quantitative data and to manage these efficiently to build a full database. Further, variables have to be defined from the data in relation to both cause and effect and measurable scales (O'Leary 2014). O'Leary (2014, p. 280) explains that measurement scales refer to the nature of the differences you are trying to capture within a particular variable. There are four basic measurement scales: (1) nominal, (2) ordinal, (3) interval, and (4) ratio.

(1) A *nominal* level measurement assigns numbers arbitrarily to categories. Here we use an example from space and burglary research, for example, 1 = homes intruded through the front door, 2 = homes intruded through the back door, 3 = homes intruded through the side door, 4 = unknown point of entry, 5 = other points of entry. This allows one to tally responses with regard to different types of incidents or population distributions. A nominal measurement scale does not allow mathematical calculations; for example, average values cannot be calculated from nominal data.

(2) An *ordinal* level of measurement is more structured because it can be named, grouped, and ranked. This so-called scale-rank order provides an understanding of magnitudes and differences and allows a degree of opinion to be measured. The 'Likert-scale' (Likert 1932) is an ordinal measurement scale. For example, in a study, respondents were asked about their mobility experience with regard to safety in unplanned settlements in Jakarta, Indonesia (Hidayati et al. 2019). The respondents had the following possibility for feedback: 1 = very negative, 2 = negative, 3 = neutral, 4 = positive, and 5 = very positive. This is a linear measure that assumes a continuum from very negative to very positive or from strongly disagree to strongly agree.

Often in space syntax research, a challenge is to correlate various spatial characteristics with one another that have different numbering systems and with both qualitative and quantitative properties. In the social sciences there exist several techniques for quantifying qualitative aspects. For example, in questionnaires, people are frequently asked to rank on a scale from 1 to 5 or 1 to 10 the quality of their experience of a particular topic.

For a study on "liveability" in Rotterdam, inhabitants were asked to rank their impressions on topics like safety issues, provision of services, the degree of possibilities for social contact, etc. in their own neighbourhood. In the research project on the spatial properties of all 43 neighbourhoods, a grading system was used ranging from 1 to 5. A precise description was used for each grade and for each spatial property. One of the spatial parameters concerned a description of the position of the neighbourhood in relation to the position of the main routes in the city, and the grading system for that specific case was as follows:

Grade 1: Very low, which means that the main routes are segregated and are not connected at all to the neighbourhood.
Grade 2: Low, which means that the main routes are integrated and go around the neighbourhood.
Grade 3: Average, which means that the main routes have average values and partly go through the neighbourhood.
Grade 4: High, which means that the main routes are slightly integrated and go through the neighbourhood.
Grade 5: Very high, which means that the main routes are highly integrated and go through the neighbourhood.

(3) An *interval* level measurement scale can quantify the differences between values. It allows the assignment of a numerical value to any arbitrary assessment. O'Leary (2014, p. 281) explains the interval measurement as a scale that uses equidistant units to measure differences. For interval scales, the order and the exact differences are known between values. These can be measured by mode, median, or mean.

A standard deviation from the interval level can also be calculated. For example, an interval measurement might be the measurement of quality of life in a neighbourhood between the score 20 and 21 or 40 and 41. Both intervals are the same. Another popular example is temperature. The distance between 24 and 26 °C is the same as for 30 and 32 °C. However, this does not indicate that the temperature feels the same. The interval scale allows the calculation of the means and medians of variables. This scale does not have an absolute zero.

(4) A *ratio* or *scale* level of measurement is similar to an interval scale with the difference that it includes a zero. Each point on the ratio scale is equidistant. For example, height, age, income are ratio data. Because ratio data are real numbers or numerical values, all mathematical operations can be conducted. In space syntax research, property and rental prices are one example of ratio data.

For the ratio or scale-level data, various *mean*, *median*, and *mode* values can be calculated. Consider a group of 8 shopping streets with the following number of shops: 10, 11, 11, 11, 11, 13, 14, and 20. Thus, the number of cases is $N = 8$.

Calculating *mean* or average values is the most commonly used method in statistics for describing central tendencies. The method is to add up all the values and divide by the number of values. Thus, the mean number of shops of these 8 shopping streets is (10 + 11 + 11 + 11 + 11 + 13 + 14 + 20)/8 = 12.625 shops per street. Following this, the *median* is the score that is exactly in the middle of the set of values. Score numbers 4 and 5 are in the middle of the range of values, thus 11 is the median. If the two middle scores are different, you would have to interpolate them to determine the median. The *mode* is the most frequently occurring value in the set of scores. In our above-mentioned example, 11 is the most frequently reported score.

Dispersion refers to the spread of values around the central tendency. The most common measures are the range and standard deviation. The range is to take the highest value minus the lowest value, here in our case 20–10 = 10. The standard deviation is more accurate than the range because an outlier can make the range large. Therefore, the standard deviation shows how the scores deviate from the average value. Here in our case, we have to calculate the distance between each value and the mean. Hence, the difference from the mean is calculated as follows:

10–12.625 = −2.625.

11–12.625 = −1.625.

11–12.625 = −1.625.

11–12.625 = −1.625.

11–12.625 = −1.625.

13–12.625 = 0.375.

14–12.625 = 1.375.

20–12.625 = 7.375.

Then we square each discrepancy:

$-2.625 \times -2.625 = 6.890625.$

$-1.625 \times -1.625 = 2.640625.$

$-1.625 \times -1.625 = 2.640625.$

$-1.625 \times -1.625 = 2.640625.$

$-1.625 \times -1.625 = 2.640625.$

$0.375 \times 0.375 = 0.140625.$

$1.375 \times 1.375 = 1.890625.$

$7.375 \times 7.375 = 54.390625.$

The next step is to sum up all the square values, which is 83.40625. Then we divide this sum by the number of streets minus 1. Here the result is 83.40625/7 = 11.9151786. This number is known as the variance. The standard deviation is calculated by taking the square root of the variance, which in this case yields a standard deviation of 3.45183699. In summary, the standard deviation is the sum of the squared deviations from the mean divided by the number of scores minus one.

However, there exist several software programmes where these values can easily be calculated. In particular, when analysing built environments with a high number of streets, the formulas are programmed into various software such as Excel, R, and SPSS.

5.7.1 Descriptive and Inferential Statistics

Descriptive statistics describe what is or what the data show. Such methods summarize data and allow the presentation of data in a simple, understandable form. Often, descriptive statistics provide measures of central tendencies using mean values or measures of dispersion in the form of ranges, or they describe the shape of data by, for example, their normal distribution, such as a 'bell-shaped' curve.

In inferential statistics, the aim is to reach conclusions beyond just the immediate data. Whereas in descriptive statistics, we describe the data, in inferential statistics we aggregate and make interferences with the data for gaining more general conclusions about a phenomenon. Simply speaking, we use the information of a representative sample set to make a generalization about a certain phenomenon. In particular, correlating the various numerical values from the space syntax analyses with various socio-economic data can contribute to new knowledge on the space–society relationship. Figure 5.19 shows the change of syntactic values for Izmir in Turkey from 1700 to 2010 (Can et al. 2015).

Fig. 5.19 Syntactic space syntax measures for the city of Izmir, Turkey, from the 1700s to 2010 (Can et al. 2015). For each year the mean values of the various space syntax variables are presented in the table

Years/ Maps	NAIN citywide	NAIN local	NACH citywide	NACH local	Mean Depth
1700s	1.94	1.27	2.44	1.15	6.76
1836	2.53	1.75	3.62	2.40	14.32
1856	2.82	2.07	3.85	2.86	15.12
1876	2.97	2.06	3.88	2.73	15.20
1885	2.75	1.90	3.99	2.63	11.14
1905	2.75	1.75	3.92	2.33	11.39
1922	2.51	1.78	3.80	2.49	12.22
1941	2.96	2.32	4.25	3.28	18.99
2010	3.67	3.72	4.99	3.93	30.41

5.7.2 Pie Graph, Bar Graph, and Line Graph

A pie graph is a circular graph that shows nominal data in relative sizes such as percentages. It is drawn as a circle with 100% for 360° for a whole population. Figure 5.20 shows a pie graph for the percentage of gender (top) and gender combined with ethnic background (bottom) of the people registered in the public space of the Oosterwei neighbourhood in Gouda. As can be seen from the top figure, 62% of the registered people are men. When taking the ethnic background into account, most of the streets are dominated by Moroccan men (44%), followed by Dutch men (18%). Dutch teenage boys, Moroccan and Dutch teenage girls are hardly visible in public space (1%).

A bar graph shows the number of counts, thus depicting discrete values. Figure 5.21 shows a multiple variable bar graph that categorises the variables of energy use for transport (y-axis) and aggregated angular choice values with both a high and a low metric radius (x-axis). Herein, a clustered bar graph allows the juxtaposition of differences for nominal data.

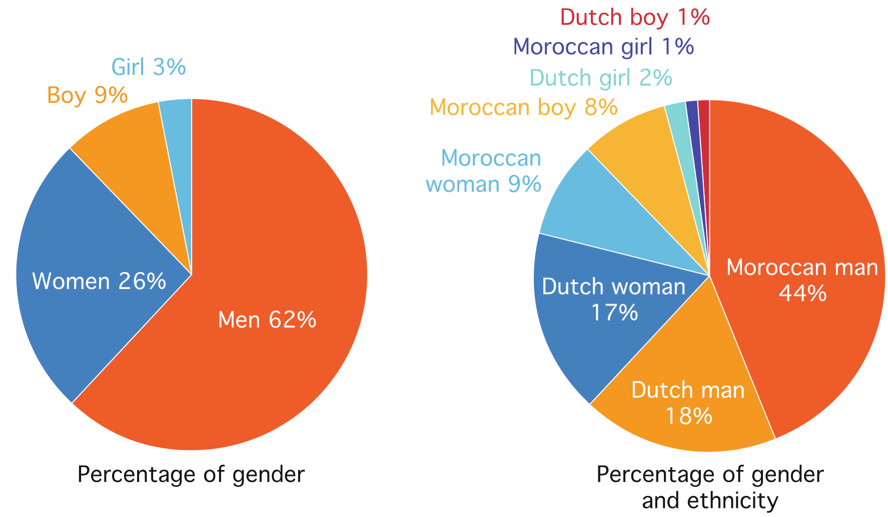


Fig. 5.20 Two pie graphs of the percentages of gender (left) and the percentages of gender and ethnicity (right) using the public spaces in Oosterwei in Gouda

Fig. 5.21 The juxtaposing between aggregated angular choice (combination of choice with a high and low metric radius) and energy use for transport for Zürich (de Koning et al. 2019)

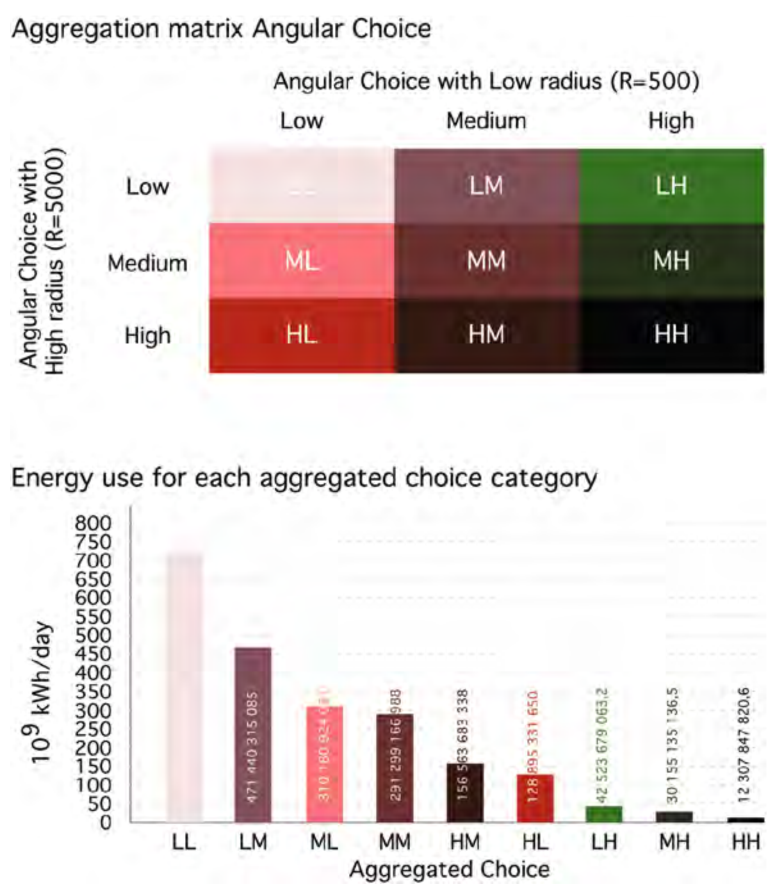


Figure 5.21 shows the juxtaposing between aggregated angular choice data (combination of choice with a high and low metric radius) and energy use data for transport in Zürich, Switzerland. Here the purpose is to show what kinds of spatial features of the street and road network generate low or high energy use for vehicle transport (de Koning and van Nes 2019). The aggregated angular choice values are ordinal data because these original scale-based data are clustered into high, medium, and low values. As can be seen from the bar graph, streets with the highest value on the angular choice with both a high and low metric radius generate low energy use for transport. Urban areas with these kinds of spatial arrangements seem to enhance a high degree of walkability. Conversely, streets with the lowest values on the angular choice with both a high and low metric radius generate private car dependency. In contrast to a bar graph, a line graph is more suitable for depicting changes over time. Figure 5.22 shows a line graph with the changes of mean NAIN and mean NACH over time in Izmir from 1700 to 2010 (Can et al. 2015).

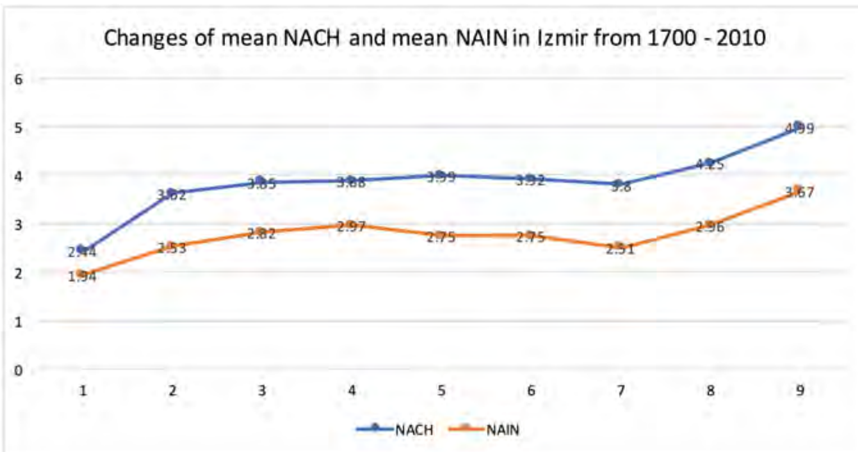


Fig. 5.22 Line graph with the change of the NAIN and NACH values over time in Izmir, Turkey

5.7.3 Scatterplot and Correlation Coefficient

A scatterplot explores the relationship between two quantitative variables, thus providing evidence of association. Each individual piece of information appears as a data point on the graph. For the scatterplot, the overall pattern is important. This overall pattern can be described through the direction, form, and strength of the relationship. So-called ‘outliers’ might appear, which are individual data points that fall outside the overall graph pattern. For the direction of the pattern, a positive association is indicated when above-average values of one variable cluster with above-average values of the other variable. A negative association is indicated when above-average values of one variable cluster with below-average values of the other variable. In terms of form, linear and curvilinear relationships exist (Moore et al. 2013a, b). The strength of an association is often measured by the correlation coefficient r *(also written as R)*. The range for r is as follows (Moore et al. 2013a, b): $r < 0.3$ no or very weak, $0.3 < r < 0.5$ weak, $0.5 < r < 0.7$ moderate, $r > 0.7$ strong. Outliers strongly impact the correlation coefficient.

Values from the spatial calculations can be correlated with one another. From the axial analyses in space syntax, the most commonly used are the correlation between connectivity and global integration, the correlation between local and global integration (Fig. 5.23), and the correlation between local and global choice. These kinds of measurements show a built environment’s degree of *intelligibility*. This cannot be shown on a map, but only on a scatterplot. Where there is a strong correlation between local and global integration, the area is known to have a high degree of intelligibility. This means that the area is easy to orientate through and is vital. When there is a weak correlation between local and global integration, the area is segregated in comparison with the rest of the city. In most cases, the main routes are at the edge of the area and the area itself has a broken-up street network. It thus has a low degree of intelligibility.

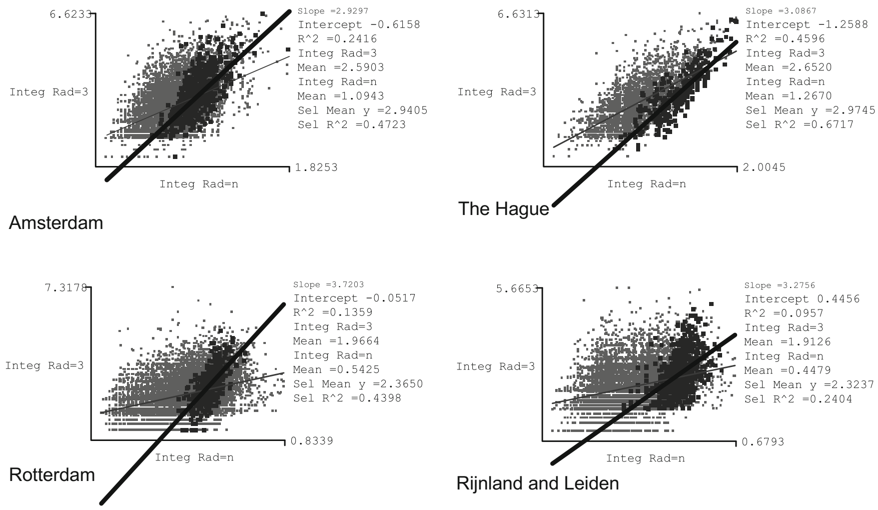


Fig. 5.23 Scatterplots showing correlations between global and local integration in Amsterdam, The Hague, Rotterdam, and Rijnland

For space syntax, scatterplots with a linear relationship are the most commonly used statistical tests. Recently, correlations have also been made between NACH with a high metric radius and NACH with a low metric radius. Where there are strong correlations between these two variables, the main routes are going through the neighbourhood and are well connected to the local streets. Conversely, where there are weak correlations between these two variables, the main routes are placed outside the neighbourhood and are poorly connected to the local streets.

A risk band analysis consists of comparing street segments with the same number of dwellings with one another together with integration variables. The data are aggregated by focusing on the number of targets per street segment. Segments with only one dwelling can be compared with one another, those with two dwellings with one another, those with three dwellings with one another, etc. In order to ensure that the number of analysed parts is not too small, the various units are unified into risk bands. These risk bands need to be comparable. In the analyses of Alkmaar and Gouda, nine categories were made, which included street segments with 1 and 2 dwellings, 3 and 4 dwellings, 5 and 6 dwellings, 7 and 8 dwellings, 9 and 10 dwellings, 11–15 dwellings, 16–20 dwellings, 21–40 dwellings, and more than 40 dwellings (López and van Nes 2007).

In order to illustrate this kind of data aggregation, the following experiment with three different street segments is presented. One segment has one dwelling, one has two dwellings and one has three dwellings. A burglary risk of 10% for all three street segments is used. By a normal dispersal of risk, the street segment with one dwelling will have a risk of 10% to be visited by burglars. Thus, it has a burglary risk of 100%, and in 90% of the cases, it will show a burglary risk of 0%. In the street segment with two dwellings with a burglary risk of 10%, the chance will be 81% that the dwellings will be safe from burglaries, 18% that only one dwelling will be burgled, and 1% that both dwellings will be burgled. In a street segment with three dwellings with a burglary risk of 10%, the chance will be that 73% that the dwellings will be safe from burglaries, and 0.1% that all three dwellings will be burgled. If we have a constant burglary risk for a whole area, the burglary risk for each segment decreases logarithmically as the number of targets increases. This implies the need to divide the number of incidents by the number of targets before correlating the results with the spatial properties of each segment (van Nes and López 2010).

There is a difference between *crime rates* and *crime risk*. When registering only burglary *rates* in a scatterplot, the burglary rates will increase steadily with the number of dwellings or targets in a street segment. In this way, cul-de-sacs and post-war housing areas tend to be the safest streets against burglaries. Conversely, when dividing the number of incidents by the number of dwellings, the burglary risk decreases the greater the number of targets there are in a street. The scatterplot in Fig. 5.24 shows a logarithmic correlation between the crime risk and the number of households for the Dutch towns of Alkmaar and Gouda. The higher the number of dwellings in streets, the lower the burglary risk. Figure 5.25 shows some statistical correlations between various space syntax results and burglary risk in the Dutch towns Alkmaar and Gouda.

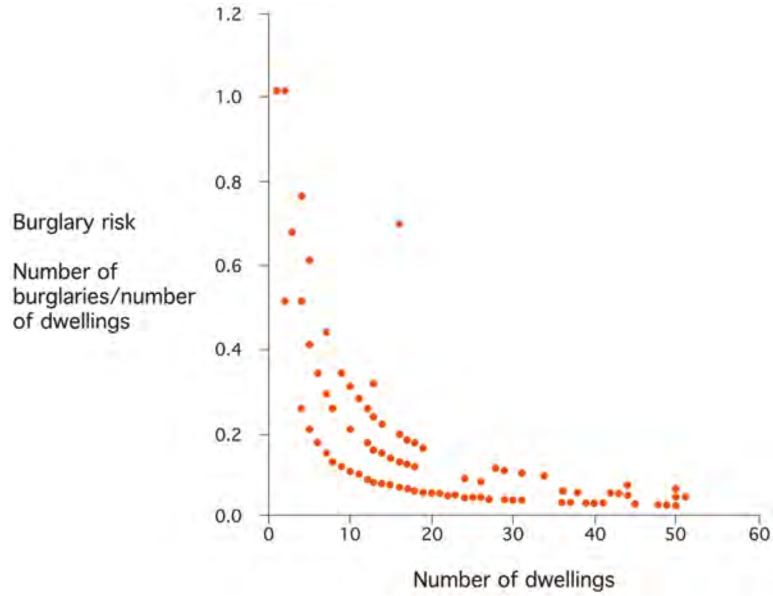


Fig. 5.24 Scatterplot showing how the burglary risk decreases with the increase in the number of dwellings per street segment in Alkmaar and Gouda (López and van Nes 2007)

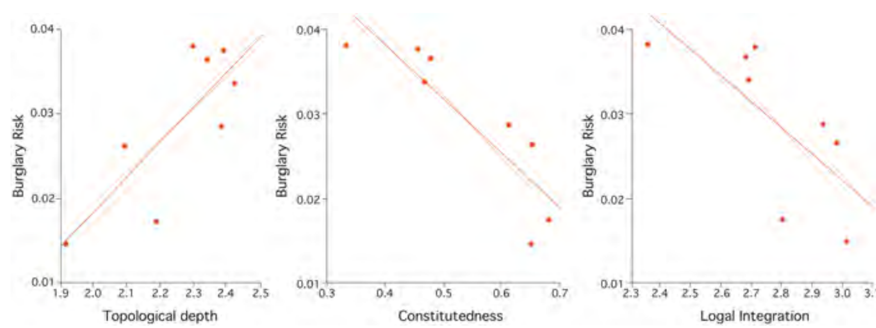


Fig. 5.25 Scatterplots correlating various spatial measurements with the dispersal of burglaries in dwellings in Alkmaar and Gouda. Left: The higher the topological depth from the main routes, the higher the burglary risk. Middle: The more a street is constituted, the lower the burglary risk. Right: The higher the local integration of the street network, the lower the burglary risk (López and van Nes 2007)

Statistics are useful means for correlating flows of human movement through urban streets using spatial analyses and provide precise data for theory building on how built environments function. Vehicle traffic and pedestrian movement can be studied separately to determine how they correlate with various integration values on a global as well as a local scale. As research has shown, correlations are found between global integration and car traffic flow rates and between local integration and pedestrian flow rates (Hillier et al. 1998, 1993, p. 31 and 61).

What the spatial analyses do not show, for example, in studies on crime in built environments, is the number of targets located along the axial and segment lines. Some streets have no homes, while others have several. In this respect, statistical means are helpful for demonstrating precise correlations between the various spatial measurements, the distribution of crime, and number of targets.

Statistical means are beneficial because exact numerical evidence can be used for hypothesis testing. However, there are some crucial traps to be aware of. One of them is not to correlate the number of incidents with the number of targets before correlating the social data with the results from the spatial analyses in studies on space and crime. Often such a trap can give an inverse picture of reality. Therefore, it is important to be aware of what to correlate and to think critically. Often it is recommended to take some elementary statistics courses because, in most architectural and urbanism studies, statistics is lacking in the education curriculum.

5.8 Aggregations and Additive Weighted Combinations of Space Syntax Results with Other Methods Through GIS

Aggregating the results from space syntax analyses with other spatial methods contributes to comprehensive knowledge on how cities are physically built up and on the interrelationship between the various physical objects and spaces between them. During the last decade, software development and computer capacities have allowed the aggregation of large amounts of place-bound socio-economic data and spatial data with one another. GIS has so far been a good platform to connect and aggregate the results from space syntax analyses with various quantitative morphological data from other methods such as MXI and Spacematrix (discussed in Chap. 1).

We show some principles on how data can be aggregated with the help of GIS. For conducting these analyses, you need some basic GIS skills. This chapter is meant for inspiration on how you can use GIS to aggregate various georeferenced data with the results from the space syntax analyses. The condition is that your axial or segment map is drawn in GIS and is georeferenced. It is possible to export a *.mif file (map info file) from the DepthmapX software and import it into GIS. The *.mif file contains a property table with all space syntax results connected to the individual street segment. Because GIS is able to aggregate, correlate, and visualise socio-economic data, maps can be made for correlating, for example, population density with spatial parameters, degree of accessibility by public transport, travel time with spatial parameters, etc.

In GIS, space syntax data can be transformed using the following three methods and spatial operations: (1) the raster method, (2) the polygon method, and (3) the buffer-line method. Each of them has various challenges to overcome, and the applicability of these three methods depends on the type of research question being asked. Figure 5.26 shows the three different methods for transforming the space syntax results from each axial line or street segment into planar georeferenced data.

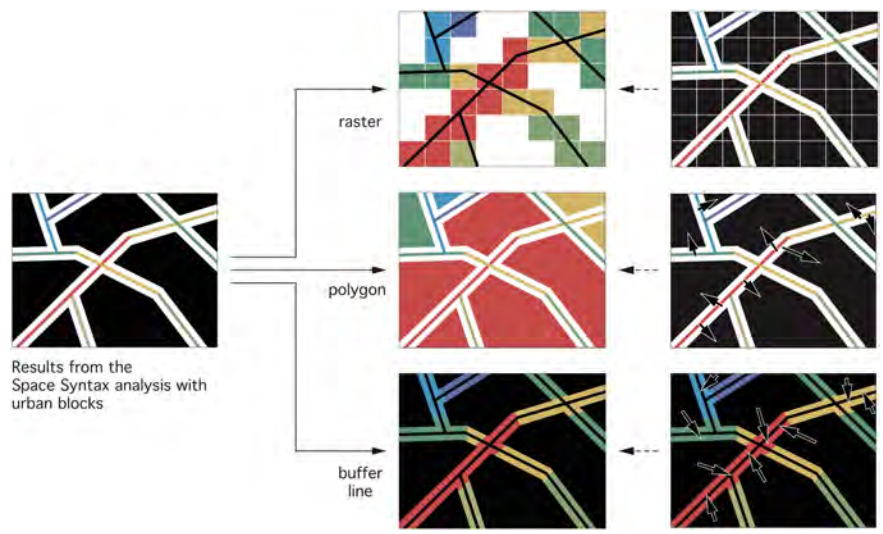


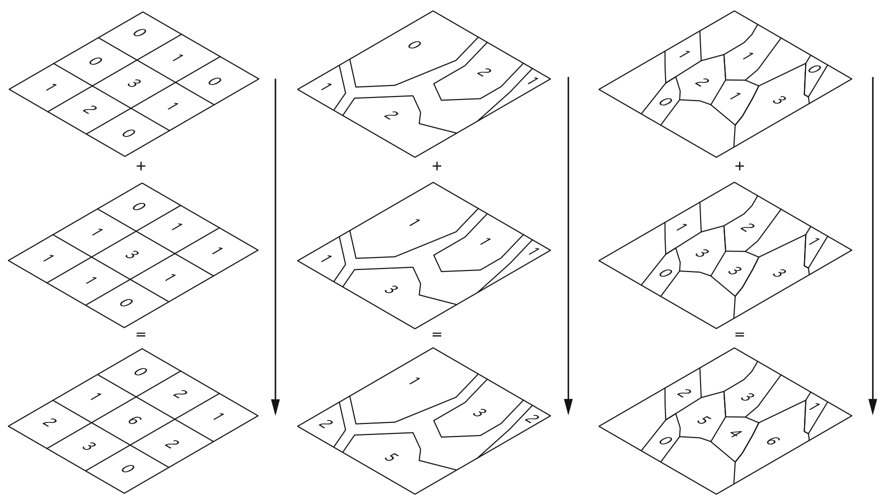
Fig. 5.26 Methods for combining street network data with urban block data

(1) The raster method seeks to find the most optimal resolution to catch the street and the adjacent block within one cell. The more fine-grained the raster, the more accurate the results. But a too fine-grained raster means that many cells cannot cover both the vector data and the polygon data. Some researchers have used a raster of 150 m × 150 m and others a raster based on 200 m × 200 m. The degree of fineness of the raster depends on the type of built environment at issue. Old cities have a more fine-grained street network with shorter urban blocks than modern cities. When analysing built environments with a variation of old and new urban areas, then the 200 m × 200 m grid is appropriate. The rule for each cell is that the line with the highest integration value decides the value of the cell.

(2) The polygon method consists of converting the results from the vector data into the adjacent blocks. For those blocks that are surrounded by several lines, the rule is that the line with the highest value determines the value for the block. From there on, the various space syntax data can be correlated with block data, such as floor space index (FSI), ground space index (GSI), MXI (discussed in Chap. 1), and property and rental prices. The advantage of this model is that the accessibility potentials of the various urban plots can be visualised. The disadvantage is that large urban blocks of large plots can distort the results.

(3) The buffer-line method consists of making a 35 m buffer from all road centre lines. The aim is to "catch" the buildings adjacent to the roads. Often there are several buildings on a plot, and the contents of the buildings adjacent to the street or road can be affected by the spatial integration values from the space syntax analyses. The values from the various plots can then be assigned to the buffer line. The advantage of the buffer-line model is that it shows the potentials of the adjacent plots next to the street and road network. For transport planners, the buffer-line models show that a street is more than just a street, and the degree of integration of the street affects the potentials of the land use next to it. Moreover, the buffer-line method is also useful for connecting the results from the urban micro-scale analyses into the model and correlating the results with the macro-scale analyses.

For combining results from different spatial analyses, an additive operation can be carried out. For each layer, each cell, polygon, or buffer-line has to have a numerical value. The next step is to make a new layer where the sum of all layers is added for each cell, polygon, or buffer-line. Figure 5.27 shows some principles for how to sum up the values from different layers.



(a) The raster model (b) The plot model (c) The buffer line model

Fig. 5.27 Adding values from different layers for the raster model (**a**), the polygon or plot model (**b**), and the buffer-line model (**c**)

The values of the attributes for each layer are determined by the natural break method, where all the values are grouped into low, middle, and high values. Thus, here the scale data from the various space syntax, Spacematrix, and MXI analyses are transformed into ordinal data.

When aggregating various spatial data with one another, the type of method needs to be chosen first. Afterwards, a decision needs to be taken on what to aggregate with what. In some cases, various space syntax variables can be aggregated with one another, and in other cases results from different spatial analyses methods can be correlated with one another.

These aggregations of the numeric data from various methods have contributed to new classifications of different types of urban areas based on the spatial, functional, and physical properties of built environments. Moreover, this aggregation approach can contribute to various spatial diagnoses of urban areas for developing suitable urban design or planning strategies.

For illustrating how the aggregation of various spatial data can be used, Fig. 5.28 shows a diagram of what kinds of implications to expect from the results when correlating the results from the space syntax analyses with MXI and Spacematrix. Where all the values are high, the area is highly urban with high building density, a high degree of multi-functionality, and a highly integrated street network. Conversely, where all the values are low the area is mono-functional, has low building density, and has a segregated street network.

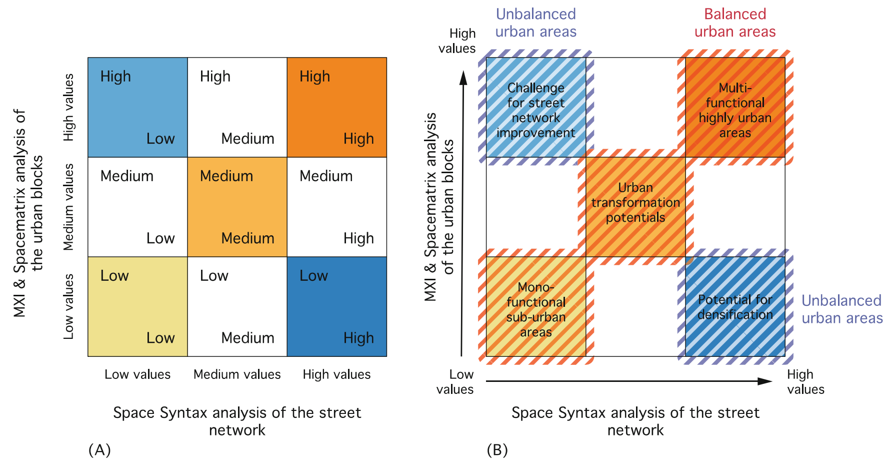


Fig. 5.28 Diagram on how to aggregate the results from the Spacematrix and MXI methods through the natural break method with the results from the space syntax method (image A). The diagram gives a rough initial classification of various types of urban areas (image B)

The most interesting cases are the unbalanced areas. Where the street network integration is high and building density is low, there are densification potentials. Conversely, where the building density is high and the street network integration is low, the accessibility of the street network needs improvement. Often several diagrams need to be made. First, you need to make one to correlate the local and global values from the various space syntax analyses. Then you need to make one diagram to correlate the MXI data with the Spacematrix data. Then you correlate all the space syntax data with the combination of the MXI and Spacematrix data.

In Rotterdam, an application and aggregation of space syntax, Spacematrix, and the Function Mix model data was done through GIS with the purpose of identifying the potentials for improvements in Rotterdam. Rotterdam municipality made strategic plans in 2011, for improving the southern part of the city. The area has a high number of problem neighbourhoods populated with low-income inhabitants. The core of this research project was to bridge the gap between space syntax, Spacematrix, and the Function Mix model and to make a tool in GIS to provide evidence-based operational tools for strategic planning. The location of public transport stations and the social index could also be used in the analyses through the use of GIS. A complete GIS file with socio-economic data (such as density, income, functions, distances, etc.) connected to all attributes was provided. The challenge in such work is to aggregate these various place-bound data with the results from the spatial analyses.

Figure 5.29 shows how the results from the angular segment analyses with a high metric radius can be represented in a raster. The line with the highest value determines the colour or value of each cell. Figure 5.30 shows a correlation of the results from the space syntax analyses with the FSI data. The dark blue cells show where there are potentials to densify, whereas the light blue cells show the areas where the street network integration is low and the build mass is high. The areas inside the dark blue cells have high values on the angular choice analyses with both high and low metric radius, but the areas have a low density of buildings.

Fig. 5.29 The angular choice analyses with both low and high metric radius (through movement potentials) of Rotterdam represented in a raster model (van Nes et al. 2012)

As observed in the Rotterdam case, where there is a balance between the FSI and GSI, the various local integration values are high. These streets tend to be vital. Moreover, the mix of dwellings, workplaces, and leisure/shopping activities tend to also be high in these areas. In most cases, these spatial features can be found in traditional urban areas with closed urban blocks with quiet back gardens, and the buildings have on average 4 floors. Conversely, areas with a poor balance between FSI and GSI tend to be mono-functional and to have low local integration values for their street networks (van Nes et al. 2012).

Therefore, the combination of the various spatial analyses tools can show where there are potentials for densification with chances for lively urban areas and areas where it is not worth putting in resources for improvements because they will not have any significant effects. In some places, the focus is on improving the physical structure, while in others the improvements must be on the social level. Moreover, the tools in this example were used to test the possible effects of new metro stations and a new bridge (van Nes et al. 2012). The next challenge is to make these tools applicable in the testing of various other proposals in strategic urban planning.

The aggregation and correlation of space syntax, Spacematrix, and MXI was further developed through a comparison of new and old towns in China and the Netherlands. In the first instance, the raster method was applied in three Dutch new towns and one Chinese new town and in one Dutch old town and one Chinese old town (Ye and van Nes 2014). Later on, the block method was applied (Ye and van Nes 2016). From both methods, a spatial description of various types of urban areas was made based on the correlation of space syntax, Spacematrix, and MXI. These ranged from 'highly urban' areas to 'highly suburban' areas, and the unbalanced areas were classified as 'transformation potential' areas (Ye and van Nes 2016).

Table 5.2 shows how the aggregation and weighting of the spatial parameters from the space syntax, spacematrix, and MXI analyses. This weighting is carried out with the average mean of each 'layer' of low, medium, and high values which are a defined range. In the next step, all 'layers' are added to arrive at a syntactical and aggregated value. This model was applied to six Dutch and two Chinese towns using the values from the raster and polygon models. This modelling approach allows for the classification of the following types of urban areas: highly urban areas, to urban, suburban, and highly suburban. This approach further indicates the potential for densification and the need to transform the street pattern.

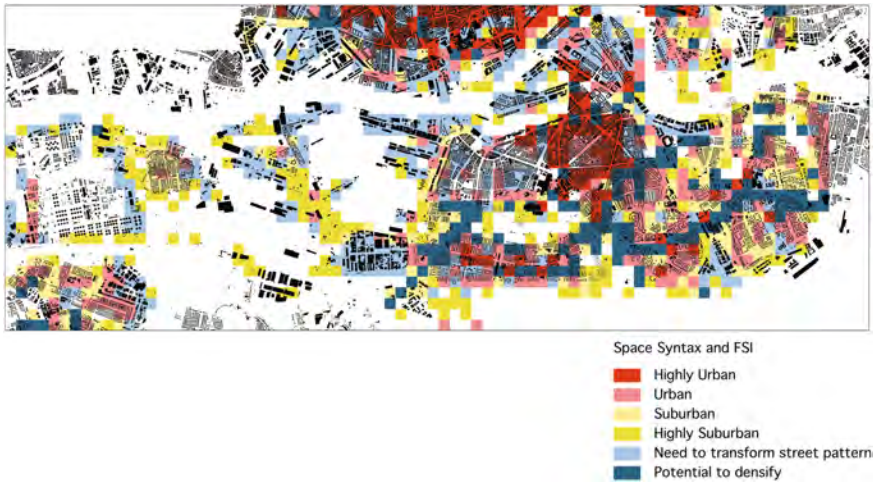


Fig. 5.30 The overlapped results from the space syntax analyses and the FSI of Rotterdam (van Nes et al. 2012)

Table 5.2 Table showing how the weighting of the various spatial parameters is done. All numbers from the space syntax, spacematrix, and MXI analyses are divided into high, medium, and low values (Ye and van Nes 2016)

Street-network configuration (sDNA)	High	B_b belongs to the highest one third according to the natural break method
	Medium	B_b belongs to the highest one third according to the natural break method
	Low	B_b belongs to the lowest one third according to the natural break method
	$B_b = \sum_{i=1}^{n} BtAR_{(x)i} \frac{L_i/D_i^{\alpha}}{\sum_{i=1}^{n} L_i/D_i^{\alpha}}$; *$B_b$ = the configuration values of each block, $BtAR_{(x)i}$ = the configuration values of surrounding streets, L_i = the length of street central lines affecting the blocks, D_i = the shortest Euclidian distance from the street central lines to the block's edge, α = distance decay value*	
Building density and types (Spacematrix)	High	$\text{Types E, F, I} = \begin{cases} E: mid-rise, stripe\ type\ is\ 3 < L_{average} < 7\ and\ 0.2 < GSI < 0.3 \\ F: mid-rise,\ block\ type\ is\ 3 < L_{average} < 7\ and\ GSI \gg 0.3 \\ I: high-rise,\ block\ type\ is\ L_{average} \gg 7\ and\ GSI \gg 0.3 \end{cases}$
	Medium	$\text{Types D, G, H} = \begin{cases} D: mid-rise,\ point\ type\ is\ 3 < L_{average} < 7\ and\ 0 < GSI \ll 0.2 \\ G: high-rise,\ point\ type\ is\ L_{average} \gg 7\ and\ 0 < GSI \ll 0.2 \\ H: high-rise, stripe\ type\ is\ L_{average} \gg 7\ and\ 0.2 < GSI < 0.3 \end{cases}$
	Low	$\text{Types A, B, C} = \begin{cases} A: low-rise,\ point\ type\ is\ L_{average} \ll 3\ and\ 0 < GSI \ll 0.2 \\ B: low-rise,\ stripe\ type\ is\ L_{average} \ll 3\ and\ 0.2 < GSI < 0.3 \\ C: low-rise,\ block\ type\ is\ L_{average} \ll 3\ and\ GSI \gg 0.3 \end{cases}$
	$FSI_x = F_x/A_x$; *Fx = gross floor area of (m^2) in the street block x; A_x = gross area of block x (m^2);* $GSI_X = B_x/A_x$; *B_x = gross building footprint of (m^2) in the street block x;* $L_{average} = FSI_x/GSI_x$;	
Functional mixture (MXI)	High	$\text{Mixed (triplefunctional)} = \begin{cases} 5\% < \frac{A_{housing}}{A_{gross}}\% < 20\% \text{ and } \frac{A_{amenities}}{A_{gross}}\% > 5\% \text{ and } \frac{A_{working}}{A_{gross}}\% > 5\% \\ 5\% < \frac{A_{amenities}}{A_{gross}}\% < 20\% \text{ and } \frac{A_{housing}}{A_{gross}}\% > 5\% \text{ and } \frac{A_{working}}{A_{gross}}\% > 5\% \\ 5\% < \frac{A_{working}}{A_{gross}}\% < 20\% \text{ and } \frac{A_{amenities}}{A_{gross}}\% > 5\% \text{ and } \frac{A_{housing}}{A_{gross}}\% > 5\% \end{cases}$ $\text{Highly} - \text{mxied} = \frac{A_{housing}}{A_{gross}}\% \gg 20\% \text{ and } \frac{A_{working}}{A_{gross}}\% \gg 20\% \text{ and } \frac{A_{amenities}}{A_{gross}}\% \gg 20\%$
	Medium	Bifunctional $\begin{cases} \text{Housing} + \text{Amenities: } \frac{A_{housing}}{A_{gross}}\% > 5\% \text{ and } \frac{A_{amenities}}{A_{gross}}\% > 5\% \text{ and } \frac{A_{working}}{A_{gross}}\% \ll 5\% \\ \text{Housing} + \text{Working: } \frac{A_{housing}}{A_{gross}}\% > 5\% \text{ and } \frac{A_{working}}{A_{gross}}\% > 5\% \text{ and } \frac{A_{amenities}}{A_{gross}}\% < 5\% \\ \text{Amenities} + \text{Working: } \frac{A_{amenities}}{A_{gross}}\% > 5\% \text{ and } \frac{A_{working}}{A_{gross}}\% > 5\% \text{ and } \frac{A_{housing}}{A_{gross}}\% < 5\% \end{cases}$
	Low	$\text{Monofuncional} = \frac{A_{housing}}{A_{gross}}\% \gg 95\% \text{ or } \frac{A_{working}}{A_{gross}}\% \gg 95\% \text{or} \frac{A_{amenities}}{A_{gross}}\% \gg 95\%$
	$A_{housing}$ = *the gross floor spaces of housing function* (m^2); $A_{working}$ = *the gross floor spaces of working function* (m^2); $A_{amenities}$ = *the gross floor spaces of all kinds of commercial and public facilities* (m^2). *Agross = the gross floor spaces in the analysed area*	

The polygon and the buffer-line model were applied in a research project in Bergen in Norway. The polygon model is useful for indicating the type of approach for various densification strategies, whereas the buffer-line model is useful for correlating spatial data with energy use for transport data. Figure 5.31 shows two different examples where all the space syntax measurements are aggregated and superimposed (de Koning et al. 2017).

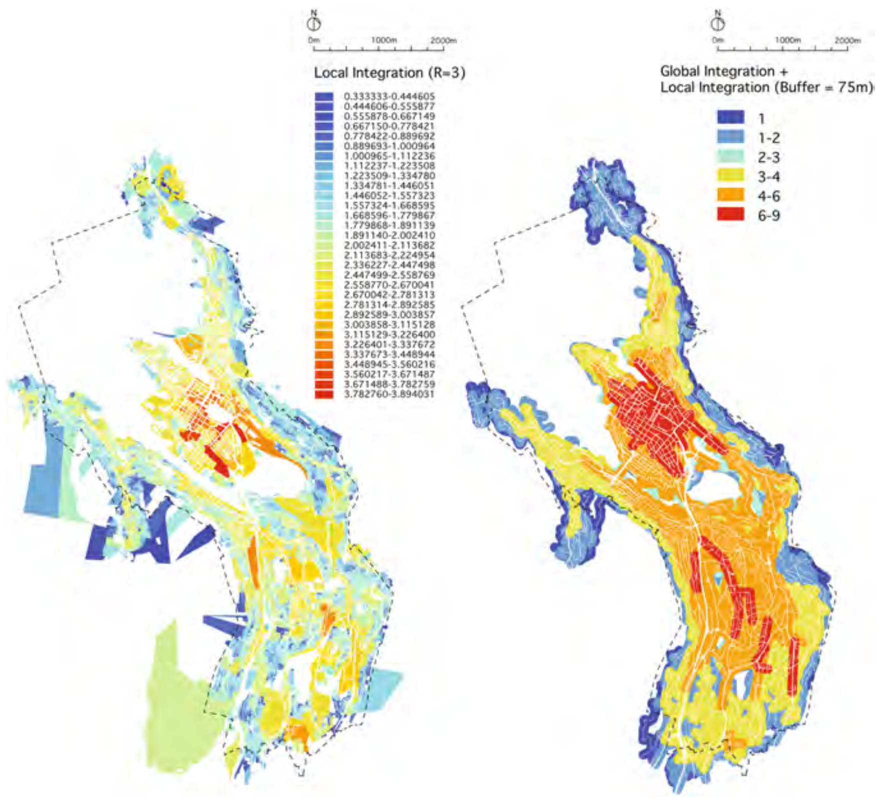


Fig. 5.31 Example of a polygon (left) and a buffer-line (right) representation of all space syntax analyses for the same area in Bergen (de Koning et al. 2017)

GIS is both a useful source, as well as a tool for aggregating, superimposing, and correlating big data sets and results from various spatial analyses. Some countries or cities can give access to useful files containing various place-bound socio-economic data such as income, social index of residents, location of functions, building density, average travel speed for cars on streets, building years of various artefacts, etc. At present, the possibilities of using GIS in space syntax research are growing. Current examples of computer applications, plug-ins, and toolboxes are the Place Syntax tool (Ståhle et al. 2005), the MIT Urban Network Analysis toolbox for ArcGIS (Svetsuk 2010), DepthmapX for QGIS (Gil et al. 2015), and Form Syntax (Ye and van Nes 2016).

5.9 Conclusions

For data collection and the presentation of the results of the various analyses with socio-economic registrations, there are some ethical issues to be aware of. In particular, it is important to anonymise and aggregate quantitative data so that individual persons or home addresses cannot be traced. In particular, for sensitive data such as crime data the victims and the intruded homes' addresses shall be presented in such a way that they cannot be recognisable and traceable. The same applies to qualitative data gathered from interviews. Herein, the interviewer has to explain to the interviewee how anonymity and ethical standards are applied and how the collected data will be used. Always ask permission for the usage of the data, whether it is gathered through interviews, from secondary sources, or from registrations conducted by other researchers. Remember to credit the persons from whom you use data or materials.

Convincing people to participate in an in-depth interview can be challenging, especially when the interview is related to sensitive, personal, or taboo topics. Therefore, reserve enough time for finding participants. Further, it is important to be aware that applying statistical methods to quantitative data and applying coding to qualitative data also has its pitfalls, and the results can differ from reality. You have to critically reflect upon the applied methods and the obtained results.

In general, the type of data being collecting depends on the research questions and the research approach. Some of the quantitative data are connected to causal explanation models where a *positivistic* approach is needed. This scientific approach is rooted in the natural sciences. Here, the focus is to explain the relation between cause and effect on the physical aspects of the built environment. Human intentions and meanings are mostly not considered. To some extent, where human intentions are unambiguous, it is possible to apply a causal explanatory model. Examples of unambiguous intentions are market rationality and travel time efficiency, where the purpose is profit maximising and cost savings.

Research and projects focusing on human intentions instead require a hermeneutic approach connected to qualitative data. Here the focus is on intentional explanatory models. The hermeneutic approach is rooted in human and social sciences, and the focus is to understand the intentions behind an action within a certain context. In addition, it is important to be aware that cause-effect explanations cannot be derived from these kinds of data, only understandings. These aspects are demonstrated in Chap. 6.

Finally, conducting data collection and data management and making statistic correlations, the following ethical standards must apply: honesty, accuracy, mutual respect, efficiency, objectivity, legality, and integrity. For further readings on ethical issues related to our discipline, we suggest Wachs (1989) and Resnik (1998).

5.10 Exercises

For the first 4 exercises, you need to reserve at least one whole day.

Exercise 1
Choose an urban square you know well. You can use the area you analysed in Chap. 3. Randomly choose 30 people with the largest variation of age and gender and track their movement routes. Choose to follow each person for 5 min. Trace their movement routes on a map. Correlate the results with an all-line and VGA analysis. Describe what you see.

Exercise 2
Make a gate counting of all the streets or roads leading into the square. Compare the results with the all-line and VGA analyses. Walk at least six times to all gates.

Exercise 3
Make static snapshots for every 15 min of the square. Make at least six different maps. Overlay the data and describe what you see. Correlate the data with the results from your space syntax analyses.

Exercise 4
Conduct a quantitative interview with 30 people to find out where the most and least preferred place to stay is on the square. Register the findings on the map and correlate the results with your space syntax analyses.

Exercise 5
Make a pie and a bar graph from the data you used in the registrations from the static snapshots. What are the percentages of the different types of people using the public space?

Exercise 6
Make a scatterplot where you correlate the data from the gate counting with the integration values from the space syntax analyses. What is the correlation coefficient between the flow of people and the integration values of your square?

Exercise 7
Conduct quantitative interviews with four persons about the perceived quality of the town or city centre you have analysed in Chaps. 2, 3, Chaps. 2, 3, or 4. Compare the results from the interviews with the space syntax analyses and make a qualitative description of the results.

Exercise 8

If possible, search for some new and old photographs of the main streets from the city you analysed in Chap. 2. Describe qualitatively the degree of street vitality from the present as well as the past situation.

Exercise 9

Imagine you have access to the following data for a whole region for each metro and railway station:

– Frequency of trains/metro lines
– Number of public transport modes (train, bus, tram, metro)
– Data for land use (dwellings, workplaces, shops, and amenities) for the whole region
– Data on FSI and GSI of the urban blocks
– A georeferenced and processed space syntax map.

Make a couple of correlation schemes based on the model in Fig. 5.32. Describe what you might expect in the 'balanced' fields and in the 'unbalanced' fields.

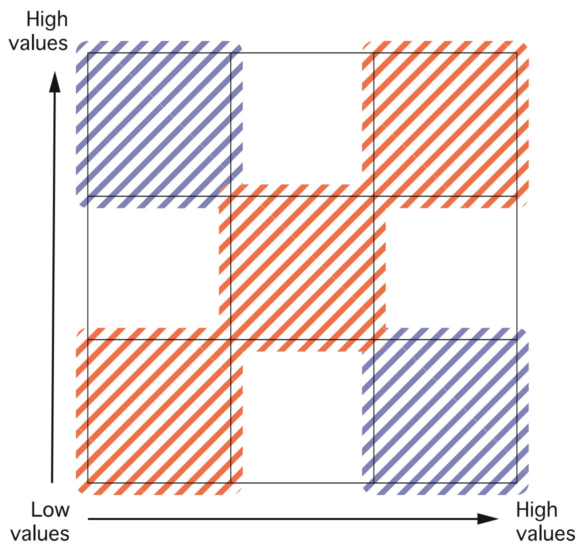


Fig. 5.32 Correlation scheme

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Theoretical Representations of the Built Environment

6

Contents

Abstract

In this chapter, we show what and how space syntax has contributed to theories and general knowledge of the built environment. First, we provide an introduction to two established research traditions, positivism and hermeneutics. The aim is to demonstrate through modal logic what the possibilities and limitations are for gaining general understandings and making theoretical explanations from space syntax research. Modal logic uses expressions to test the explanatory power of statements. Second, we show what space syntax adds to the debate about spatial integration and spatial segregation as seen in relation to market and social rationality. We will focus on the spatial aspects and discuss these in relation to declining versus vital neighbourhoods, crime, anti-social behaviour, cultures, political ideologies, gender, and

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the use of space. Third, we give some reflections on what space syntax has contributed in regards to a comprehensive architecture theory. Finally, at the end, we add as an epilogue a thought experiment on how space syntax theories can be applied within the compact city debate. Exercises are provided at the end of this chapter.

Keywords

Positivism • Hermeneutics • Explanations • Understandings • Theory building • Generalisation • Urban sustainability • Positivism • Hermeneutics • Modal logic • Explanation • Understanding • Urban theory

Key Concepts

Positivism • Hermeneutics • Modal logic • Explanation • Understanding • Urban theory

Learning Objectives

After studying this chapter you will

- distinguish between understandings and explanations, and distinguish which of them belong under the hermeneutic and positivistic research tradition;
- discuss how the three different theories created by space syntax research are able to predict the impacts of spatial interventions;
- test to what extent your research is able to provide explanations or understandings regarding some phenomenon; and
- explain models with the use of necessary and sufficient conditions based on research on built environments with regards to spatial segregation & integration, various types of urban centralities, space & society, and spatial cultures.

6.1 Generalisations on Urban Space and Society

Space syntax and its variants are constantly developing, and developments in computer science allow for improvements in the formal applications that the space syntax tools rely on. In particular, the increasing number of context-dependent case studies calls for a refined application and adequate interpretation of space syntax methods. Continuous research and its lasting results depend on methodological reliability and on a systematic accounting of the conditions under which the claims might turn out to be true or false. This is what theory development on built environments is dependent on, and thus how space syntax methods have been improved and developed over the last three decades.

While the social science disciplines have been well established, for urban sciences in general theory development and understandings of the role of the spatial component are still in an early phase. In urban sciences, theory development only started in the twentieth century, and much still needs to be done in terms of refining the definition of spatial components, performing empirical tests, and making generalisations and theories applicable in urban design and planning. Therefore, we introduce in Sect. 6.2 two established research traditions relevant to the urbanism disciplines. In Sect. 6.3, we show which parts of the space syntax research belong under the positivistic research tradition. The various theories and explanations developed with space syntax research are discussed here. In Sect. 6.4, we show which parts of space syntax research belong under the hermeneutic research tradition. Here the various understandings of human intentions, of causes, and of various cultures are discussed. In Sect. 6.5, we provide some complex explanatory models for both the hermeneutic and positivistic traditions.

The use of space syntax has contributed to an understanding of the spatial structure of the city as an *object* (Hillier 2001) shaped by a society, as well as to knowledge on how the physical layout of the built environment can generate or affect certain socio-economic *processes* in a society. To some extent, space syntax is able to predict some types of economic processes as an effect of urban interventions. Likewise, space syntax provides understandings of 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 condition *sial* integration and segregation. These issues will be discussed in Sects. 6.6 and 6.7. In Sect. 6.8, we reflect on what space syntax's contribution is towards a comprehensive theory on the built environment. Finally, in an epilogue section, we reflect on how space syntax can be used in the compact city debate.

6.2 Two Established Research Traditions—Positivism and Hermeneutics

Theory building on the built environment is still at a beginning phase in comparison with the theories of the sciences. The development of scientific theories started around 4,000 years ago, whereas descriptive research on the built environments started only in the 1920s, with the work of the urban sociologists at the Chicago school. Therefore, methods from elementary theories of science are useful for developing theories and for explaining how the built environment works.

There exist two established, but different, research traditions—*positivism* and *hermeneutics*. These two research traditions influence how we can gain explanations and understandings about the relation between the built environment and society. Space syntax research is interdisciplinary, and when dealing with research on urban artefacts, urban form, and urban space, these aspects lie at the overlap between the human, social, and natural sciences. We are dealing with research on the relationship between society, its members' cognitive aspects, and the physical 'framework' within which all of these activities take place. Therefore, general understandings and theory building on the built environment require a *hermeneutic* (dealing with intentional explanations) as well as a *positivistic* (dealing with causal explanations) approach.

The positivistic research tradition is rooted in the natural sciences. The focus is mostly on objects free from intentions and the meanings attached to them. Through experiments, observations, systematic testing, and technical interventions, operational theories are developed. These theories give insights into nature and technical applications. Most of their explanatory models, for example, the hypothetico-deductive method, are related to cause and effect (Føllesdal et al. 1996, p. 94). The hypothetico-deductive method allows for the formulation of a falsifiable hypothesis that can be tested on observable data where the outcome is not yet known. In other words, the hypothetico-deductive method consists of formulating a hypothesis and deducting the conclusion based on the premises. Consider the example below:

Hypothesis: If *A*, then *B*.

Premise 1: Not *B*.

Conclusion 1: not *A*.

Premise 2: *B*

Conclusion 2: *A*

Premise 1 and 2 can be verified through observations, and from there the conclusion can be derived. Research belonging under the positivism tradition deals with objects that are free from human intentions and meanings. Research of this kind has a high degree of predictability and is able to explain the phenomena around us in the field of the natural sciences. Therefore, the model above can easily be applied in Hillier's theories on spatial combinatorics (see Sect. 6.3).

Hypothesis: If an object is placed in a middle of a square, then the topological depth is increased.

Premise 1: The topological depth is not increased.

Conclusion 1: The object is not placed in the middle of the square.

Premise 2: The topological depth is increased.

Conclusion 2: The object is placed in the middle of the square.

Another example of the hypothetico-deductive method is the example below:

Hypothesis: All *A* are *B*.

Premise: *c* is *A*.

Conclusion: *c* is *B*.

Again, we can apply this example to Hillier's theory on spatial combinatorics for the case of the Victory Column in Berlin (Fig. 6.1).

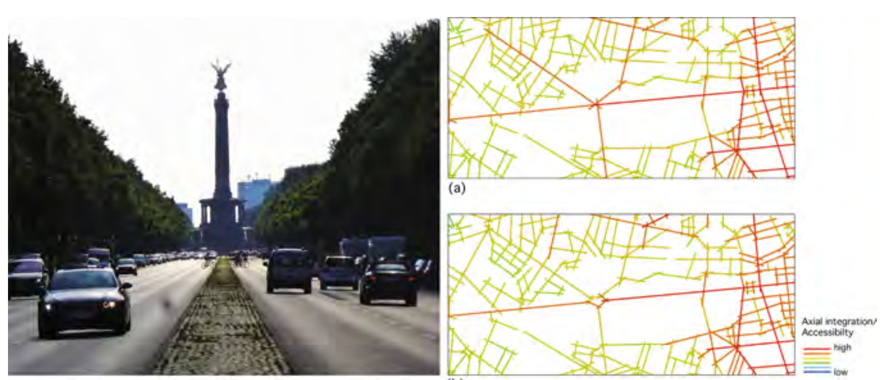

Fig. 6.1 The Victory Column in Berlin: a space syntax analysis of the street network without the column (**a**) and with the column (**b**)

Hypothesis: All objects placed in an open urban space increase the topological depth.

Premise: The Victory Column in Berlin is an object placed in the middle of the street Bundestraße 2.

Conclusion: The Victory Column in Berlin increases the topological depth of Bundestraße 2.

The success of the natural sciences contributed to several attempts to imitate its positivistic approaches in the human and social sciences, but without success. In the 1850s, German researcher Johann Gustav Droysen (1808–1884) noted that the aim of the natural sciences is to *explain* a phenomenon, whereas in the human and social sciences the aim is to *understand* a phenomenon. Here, the aim is to understand the motives and intentions behind the actions of the persons involved, to understand the action itself, and to investigate the results of these actions (Føllesdal et al. 1996, p. 95). Most research in the field of urban morphology and place phenomenology has focused on gaining an understanding of the built form as a product and an understanding of the meanings or memories attached to it.

The concept of 'hermeneutics' was introduced in the early seventeenth century, but its development as a research tradition took place in the nineteenth century through the work of German scholars Friedrich Schleiermacher (1768–1834) and Wilhelm Dilthey (1833–1911). In hermeneutics, the hypothetico-deductive method is applied to writings or objects that have meanings attached to them. The aim is to understand or to derive the original meanings and human intentions behind the material. Thus, hermeneutics is an interpretational approach. From the 1960s onwards, a new hermeneutic direction was developed by Hans-Georg Gadamer and Jürgen Habermas. Herein, Gadamer's concept 'fusion of horizons' (German: *Horizontverschmelzung*) was developed. It is defined as the sum of the impressions and attitudes we have at a certain moment, including those that are conscious, as well as those that are unconscious and thus not a target of our focus (Føllesdal et al. 1996, p. 101).

The difference between the 'traditional' hermeneutics and the 'new' hermeneutics is that scholars in the new hermeneutics acknowledge that the researcher can never free themself from their own understanding horizon. This is referred to by Gadamer as "the universal challenge in hermeneutics" (Føllesdal et al. 1996, p. 107). In general, the hermeneutic method consists of interpretation cycles, where the researcher has to interpret the available materials in terms of the meanings and intentions of past and present society. The fusion of horizons increases through reflections (Føllesdal et al. 1996, p. 105).

The challenge is to strive for objective knowledge. Popper claims that objective knowledge depends to a high degree on the falsifiability of hypotheses and on the methods that are used (Popper 1963, p. 39). Perception practice operates with two types of information that are relevant for falsification, namely subjective and objective knowledge. Subjective knowledge depends on cultural and personal values and how a built environment is perceived. The objective information in this context concerns geometrical and topological descriptions of the built environment's spaces and available socio-economic data. Quantitative socio-economic data can be correlated and tested against the spatial parameters resulting from the space syntax method.

In urban research, interpretation of the meaning and memory of urban artefacts and urban patterns and the understanding of society over time both belong under the hermeneutic research tradition. This is all connected to the researchers' own attitudes. We can also identify hermeneutic approaches within space syntax research, especially those approaches linked to research topics concerning socio-environmental disorder, history, archaeology, anthropology, and cultural tradition with an impact on urban space as well as religious activities in relation to space (Van Nes 2017; Aleksandrowicz et al. 2017, 2018). Within these fields, predictability is not embedded and therefore no theories or explanatory models with predictable power have been outlined.

Research on the built environment deals with the physical aspects of the environment, as well as with the meanings, intentions, and actions of human beings within the environment. Therefore, both research traditions are appropriate in the space syntax field. The reasons are as follows. First, the space syntax method separates definitions of spatial elements from human intentions and the memories attached to them. Second, the calculation methods deal solely with spatial objects. Therefore, space syntax is able to generate positivistic explanatory models for space and spatial relationships. The correlation of space syntax results with socio-economic data requires an understanding of human intentions and actions, and therefore, involves a hermeneutic approach.

Both research traditions need different explanatory models and are applicable for space syntax research. Interestingly enough, human intentions related to time and economic efficiency make it possible to derive causal explanatory models in line with the positivistic tradition. Following this, we explore the explanatory power of both research traditions using the philosopher Georg Henrik von Wright's modal logics with examples from space syntax research. Modal logics are a type of formal logic that extends the classic logic to include modality. Modality concerns a system's lingual options for expressing the general intentions of a society.

Von Wright has clarified how the notions of causal and intentional explanations depend on the positivist and the hermeneutic traditions. Both of these epistemological traditions impose different structures and conditions on their explanatory models. Epistemology is the study of the nature of knowledge justification and the rationality of belief. Von

Wright states that the way his modal logic models are built up depends on the types of conditions, and how they can be used to explain or understand a particular phenomenon (von Wright 1971, pp. 1–3). The positivist tradition emphasises the identification of the causes of a certain phenomenon. Therefore, research belonging under the positivistic tradition has a high degree of *predictability*. Their explanatory models anticipate nothing other than explaining the effects of certain causes (von Wright 1971, p. 3). Most research in the natural sciences belongs to the positivist tradition and uses causal explanatory models.

In contrast, the hermeneutic tradition emphasises explanations that search for an understanding beyond the phenomenon (von Wright 1971, p. 4). Most research in the human and social sciences belongs to the hermeneutic tradition, and therefore, uses intentional explanatory models. Research on the built environment is a combination of both traditions and incorporates aspects from the natural sciences and the social sciences. Therefore, we need to understand and explore the potentials and limitations of explanatory models embedded in both the hermeneutic and positivist traditions.

For his explanatory models, von Wright distinguishes between *necessary* and *sufficient* conditions. The use of these kinds of conditions determines whether the explanatory model is applied to a hermeneutic or a positivist form of research (von Wright 1971, p. 38). His terminology refers to causal explanations from a positivist perspective as simply ‘explanations’ and in a hermeneutic context as ‘understandings’. ‘Explanations’ relate to *sufficient* conditions accounting for the causes of certain *effects*. ‘Understandings’ result from an assessment of *necessary* conditions reasonably associated with *causes*. Causes precede their effects. The notion of time is a decisive, though certainly not sufficient, criterion for the distinction between causes and effects (von Wright 1971, p. 41).

The current challenge for theory building in space syntax is to be aware of the relationship between cause and effect and the intentions behind a cause. Figure 6.2 shows where the focus on the explanation is in these two research traditions. Von Wright’s modal logics contribute to defining the limitations and possibilities to make general theories and show the situations where we cannot make theories and are limited to understandings.

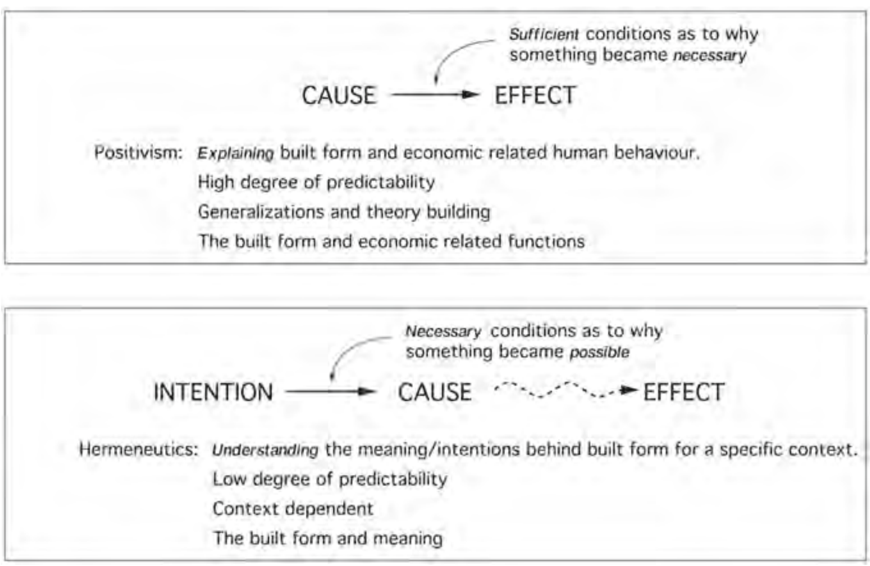

Fig. 6.2 The different focus on the explanations from the positivistic and hermeneutic research traditions

Research into activities in society and how they impact the shaping and forming of the built environment requires a hermeneutic approach. Herein, the purpose is to gain an *understanding* of how activities in society influence the urban form. Research of this kind is context-dependent, and therefore, it is difficult to develop a generalised theory on a society’s influence in producing a particular spatial environment. Conversely, how a built environment’s spatial layout affects human behaviour requires both a positivistic and a hermeneutic approach. For research with regards to space and market rationality, i.e. profit maximising, a positivistic approach makes it possible to gain *explanations* into how a built environment’s spatial layout affects activities in society with regards to movement and to the location of economic-related activities.

6.3 Space Syntax's Positivistic Explanatory Models

In this section, we will demonstrate how some existing theories from space syntax fit into the positivistic explanatory models from von Wright when addressing spatial changes as an effect of physical interventions. Until now, most space syntax research has focused on explaining how a city is set up as an object, irrespective of human intentions and meanings. For this purpose, the built environment is perceived as a set of spaces shaping a configurative spatial system. Each physical change in the built environment affects its configurative spatial system. This is, in contrast, to research in the urban morphology and place phenomenology traditions that are closely intertwined with understanding the human intentions behind artefacts. When dealing with human rationality where intentions are unambiguous, it is possible to predict the effect on human behaviour caused by spatial changes. Market rationality and all kinds of rationality dealing with time and cost efficiency have unambiguous intentions (Van Nes 2017), which makes explanations and theory building possible in line with the positivist research tradition.

There exist three descriptive theories on built environments that are in line with the positivistic research tradition:

(1) The theory of spatial combinatorics (Hillier 1996, Chap. 8)
(2) The theory of the natural movement economic process (Hillier et al. 1993, 1998)
(3) The theory of the natural urban transformation process (Ye and Van Nes 2014)

6.3.1 The Theory of Spatial Combinatorics

This theory deals with calculating spatial combinatorics and deals only with the spatial aspects of the built environment itself. Therefore, human intentions, meanings, and memories are not considered. Through the calculations from the two-dimensional point depth analyses, some elementary principles on urban centrality can be derived. The way public spaces are blocked or the way main routes are free from physical obstacles influences how city centres emerge or fade away (Hillier 1996, Chap. 8). With regard to spatial combinatorics, Fig. 6.3 illustrates two principles regarding what happens when a physical object is placed in an urban space. Here, the principle of centrality is applied and demonstrates that a centrally placed object increases the mean depth more than an object placed at the edge of the geometric figure. In other words, placing a large building in the middle of a central square contributes to the overall segregation of the neighbourhood more than placing the same building at the square's edge. Furthermore, the principle of extension explains that partitioning a longer urban space, e.g. a long street increases the mean depth value more than partitioning a shorter urban space. This implies that blocking long main routes that connect a city's centre to its edges contributes to segregating a city more than blocking short residential streets.

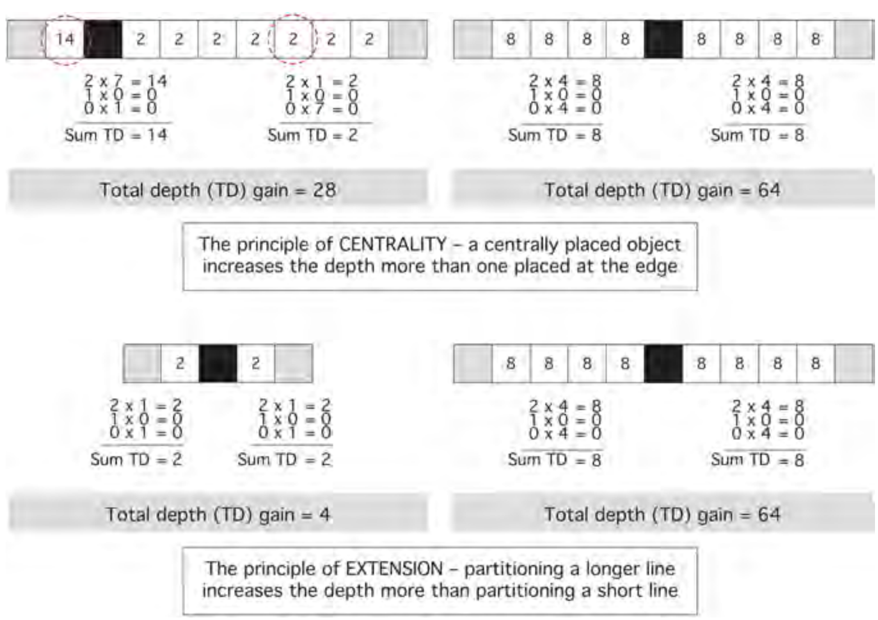

Fig. 6.3 The principle of centrality and extension (redrawn; original: Hillier 1996, Chap. 8)

These principles are in line with how cities grow naturally. A city consists of a very large number of short streets and a very small number of long streets. The function of the long streets is for wayfinding, so that people can orientate themselves from the edges to the centre. Therefore, these long streets are seldom blocked by artefacts when cities grow.

From this principle, we can derive a spatial logic for compact or non-compact cities. Figure 6.4 depicts two principles for what happens in public space when placing different geometric objects in the built environment. The principle of contiguity explains that continuous blocks increase the mean depth value more than separate blocks. This implies that smaller urban blocks contribute to higher spatial integration than large urban blocks. The principle of compactness states that straight blocks increase the mean depth value more than curved blocks. In other words, long building blocks contribute to segregating a neighbourhood more than compact curved buildings. These simple spatial models are the first steps for explaining how various urban spatial configurations provide various degrees of accessibility. Seemingly, the invisible spatial structure between physical objects is something 'active' and has its own laws shaping limitations or possibilities for movement. These simple spatial models contribute to theory building on urban space by providing descriptive principles on spatial 'drivers' for urban centrality.

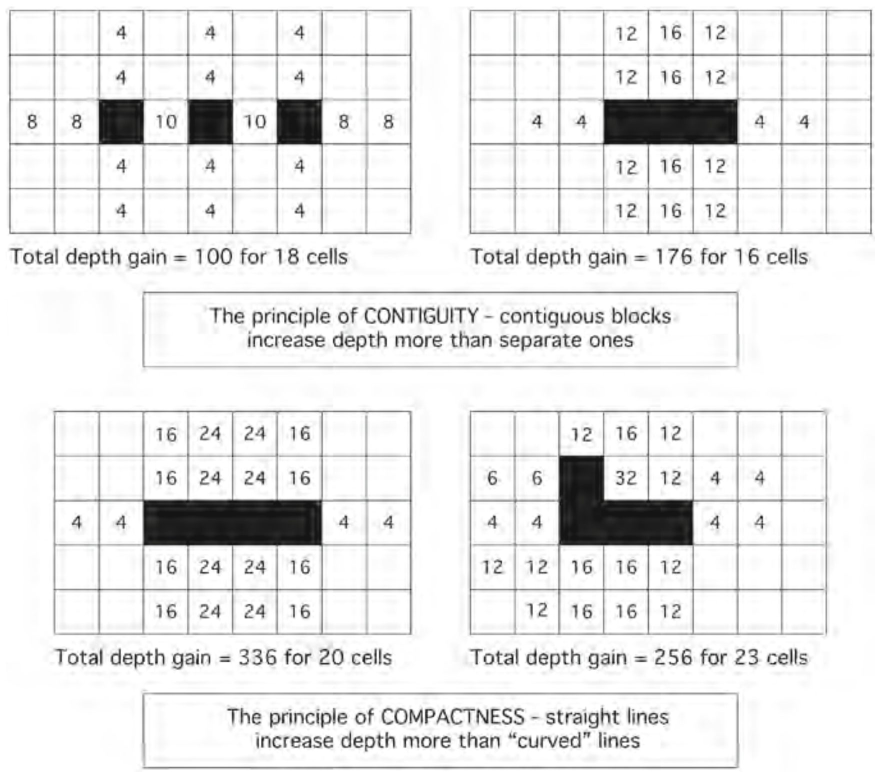

Fig. 6.4 The principles of contiguity and compactness (redrawn; original: Hillier 1996, Chap. 8)

Figure 6.5 shows some examples of different building types affecting the size of urban blocks. Image (a) shows an example of the high-rise flats from the 1960s in a suburb of Amsterdam. The building type contributes to large urban blocks and to a low degree of permeability for people moving through this suburb. Further west in the same suburb, Bijlmermeer, case (b), the "u"-shaped low-rise urban flats contribute to smaller urban blocks compared to case (a). Case (c) shows an image of a suburb in Moscow close to the international airport. The shape of the flats and the urban blocks has similarities to case (a). Case (d) shows the historic city centre of Brasov consisting of small buildings and small urban blocks. This urban area has a high degree of permeability.

Fig. 6.5 Some examples of a compact and non-compact urban footprint: (**a**) high-rise flats in Bijlmermeer in Amsterdam; (**b**) low-rise flats in Bijlmermeer in Amsterdam; (**c**) high-rise flats in Moscow; and (**d**) the historic core of Brasov in Romania

Hillier formulated four principles for the theory of spatial combinatorics that have a clear relationship between cause and effect. These four spatial principles are connected to the geometry of urban blocks, to where they are placed in space, and in what kind of street they are located. Together the placements of physical objects in urban space influence the degree of inter-accessibility, which again is connected to the degree of centrality, urbanity, or anti-urbanity of an urban system. The four principles are:

(1) Principle of centrality: a centrally placed object increases the topological depth more than one placed at the edge.
(2) Principle of extension: Partitioning a longer line increases topological depth more than partitioning a short line.
(3) Principle of contiguity: Continuous, large blocks increase topological depth more than smaller, separate blocks.
(4) Principle of compactness: Straight lines increase topological depth more than 'curved' lines.

These principles are based on mathematical calculations of spatial relationships. They can be linked to Jane Jacob's presumptions (1961) that large continuous urban blocks contribute to longer walking distances compared to short urban blocks. Whereas Jacobs takes into consideration the size of the urban block, space syntax analysis focuses on how the size and shape of the block affects the degree of inter-accessibility of the spaces between these blocks. Spatial inter-accessibility is linked to the theory of the natural movement economic process.

6.3.2 The Theory of the Natural Movement Economic Process

The theory of the natural movement economic process states that the spatial configuration of the street and road network influences the flow of human movement and the location of shops in built environments. The higher the spatial integration of the street network, the higher the flow of human movement, and the more the land along the street network becomes attractive for economic uses. The more people are in the streets, the more shops tend to locate along these streets, and the more shops there are along these streets, the more people are attracted to the area (Hillier et al 1993, 1998). This process changes if the spatial configuration of the street network is changed through physical interventions such as walls (Desyllas 2000) or new road or street links (Van Nes 2002; Van Nes 2021). Figure 6.6 shows the relationship between configuration, attraction (the location of shops), and movement. This theory explains how the built environment functions independently of planning processes with regard to the location pattern of economic activities, human movement through the urban network, and the spatial configuration of the built environment. After all, movement and attractors do not influence the street network's spatial configuration, and instead, it is the street network's spatial configuration that affects the flow of movement and the optimal location for economic activities. For this theory there are four kinds of cause-effect relationships:

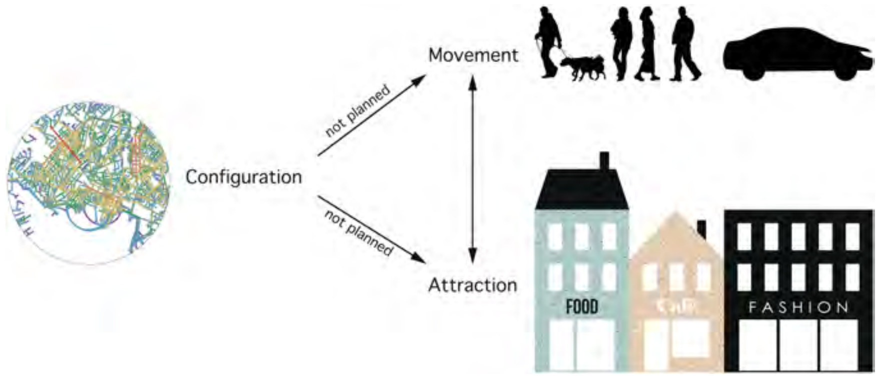

Fig. 6.6 The theory of the natural movement economic process

(1) The spatial configuration of urban space affects the flow of human movement.
(2) The spatial configuration of urban space affects the location pattern of economic activities.
(3) The amount of human movement influences the location pattern of economic activities in the built environment.
(4) The location pattern of economic activities influences the amount of human movement in the built environment.

6.3.3 The Theory of the Natural Urban Transformation Process

The theory of the natural movement process (Hillier et al. 1993, 1998) provides the basis for the theory of the natural urban transformation process (Ye and Van Nes 2014). This theory states that the spatial configuration of the street and road network influences the degree of building density and the degree of multi-functionality of land use. The higher the overall spatial integration of the mobility network on various scales, the higher the building densities (both for the Floor Space Index (FSI) and Gross Space Index (GSI)) and the higher the diversity in land use. Seemingly, the spatial configuration of the street network, as the foundation for steering urban transformations, influences the degree of building density and land use diversity. Likewise, the degree of building density influences in the long term the degree of land use diversity. The first assumptions of these correlations were made after 2010 (Hausleitner 2010; Van Nes et al. 2012) and finally clarified in 2014 (Ye and Van Nes 2014). This theory contrasts with current planning practice in America and in several European and Asian countries. Figure 6.7 shows the relationship between configuration, building density (in terms of FSI and GSI), and degree of land use mixture.

In summary, the theory of the natural urban transformation process *explains* how a built environment functions independent of planning processes with regard to restrictive land use plans, requirements for maximum or minimum FSI or GSI, and the spatial configuration of the street network. The degree of land use mixture depends on both the degree of building density and the spatial configuration of the street network. For this theory, there are three cause-effect relationships:

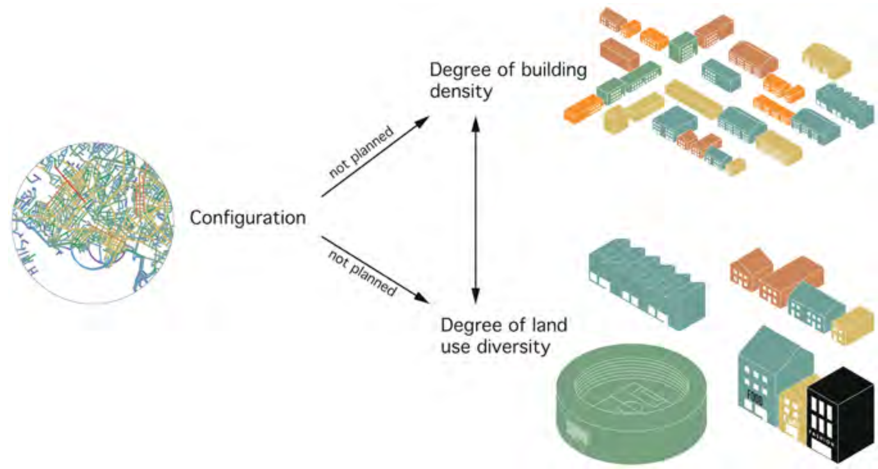

Fig. 6.7 The theory of the natural urban transformation process

(1) The spatial configuration of the urban space affects the degree of building density.
(2) The spatial configuration of the urban space affects the degree of land use diversity.
(3) The degree of building density influences the degree of land use diversity.

Explaining cause-effect relationships clearly belongs under the positivism tradition. In the next section, we will present the conditions between cause and effect for testing the explanatory power of various statements based on space syntax theories. Here we go back again to elementary theories of science.

6.3.4 How Space Syntax Allows Theory Building in Line with the Positivism Tradition

Causal explanatory models seem appropriate for assessing the explanatory power of the theory of spatial combinatorics (Hillier 1996, Chap. 8), the theory of the natural movement economic process (Hillier et al. 1998; Hillier 1999a, b; Van Nes 2002), and the theory of the natural urban transformation process (Ye and Van Nes 2014). The nature of all three theories is that they have cause-effect relationships as their underlying logic.

If we apply the theoretical logic of space syntax to von Wright's causal explanatory model (1971), we see the strength of space syntax theory with regard to generalised theory building. We illustrate this by the application of space syntax to real-life urban examples. The explanation of cause-effect relationships is theory building, but when dealing with intentions behind a cause, one is dealing with understandings, which require context-dependent cases. Space syntax allows both explanations and understandings but depends on the kind of rationality at hand and to what extent we are dealing with only urban space or with urban space and society.

General

Effect (= consequence): The spatial configuration of an urban street network is changed.

Cause (= reason): A new movement route was built.

Context-dependent

Effect (= consequence): The integration values of Friedrichstraße in Berlin increased in 1990.

Cause (= reason): The removal of the Berlin Wall changed the spatial configuration of Berlin's street network.

The above examples illustrate the explanatory power of research results dealing only with physical aspects of the built environment. Also, when adding unambiguous human intentions, both general and context-dependent examples work well.

The intentions of market rationality are clear, namely profit maximising—in the sense of *Homo economicus*—and time efficiency. Therefore, a high degree of predictability can be derived when the spatial layout of the city affects the efficient location of economic-related activities. In general, the development of scientific theories aims at an increasing degree of generality. Hence, only general examples are presented in terms of von Wright's explanatory models for research related to a market rationality. In the following, we use examples from street network research and discuss, based on von Wright's explanatory model, whether a new movement route is a sufficient or necessary condition for changing the spatial configuration system in a city.

Positivism explanatory model

p is a sufficient condition of *q*.

A new road link is a sufficient condition for a change in the spatial configuration system.

Hermeneutic explanatory model

p is a necessary condition of *q*.

A new road link is a necessary condition for a change in the spatial configuration system.

An essential positivist explanatory model requires sufficient conditions for explaining the relationship between cause and effect. Thus, we are interested in the sufficient conditions to explain a certain phenomenon in street network research. In our example, a new road link effectively triggers changes in a given configuration of a spatial system. Likewise, other conditions (e.g. road blockages or walls with closed gates) can result in a configurational spatial change. However, it is sufficient that only one of them comes into being for bringing about changes in a city's spatial configuration system. In essence, research on street networks sets out conditions sufficient for a change in the built environment. In a more refined perspective, von Wright introduces explanatory models as to why something was or became necessary, or, conversely, why something was or became possible. In the "why necessary" type of explanations, sufficient conditions are crucial, and in the "why possible" type, necessary conditions are crucial (von Wright 1971, p. 58). Below, both explanatory models are presented using an example.

Positivism explanatory model

Why something became necessary: A new road link is a sufficient condition for spatial configurable change.

Hermeneutic explanatory model

Why something became possible: A new road link is a necessary condition for spatial configurable change.

The second example appears to be inadequate because necessary conditions are redundant when dealing with cause and effect relations. In essence, space syntax focuses on *sufficient* conditions of changes in urban space using a positivism approach when interpreting the results from the axial and segment analyses. Any kind of change in the urban space is sufficient in such a way as the integration values will change. In line with the positivistic tradition, we focus on the city as an object, free from any meanings, intentions, and memories attached to it. Therefore, the sufficient conditions explain a phenomenon, which is related to cause and effect and not to the intentions behind a cause.

Counterfactual considerations are another means to consider the relationship between cause and effect. Applying counterfactuals is useful to set out what happens if a prediction is not verified. For example, if a new road link were not constructed, no change in the spatial configuration system of an urban area would occur. Conditions of this form are relevant, and no spatial change in an urban street network implies no changes in the dispersal of integration values in a city.

6.4 Space Syntax's Hermeneutic Explanatory Models

As space syntax research has shown, high spatial integration of the street network implies large numbers of people in the streets (Hillier et al. 1993, 1998), high levels of various economic activities (Van Nes 2002), high property prices (Desyllas 2000), high building density, and a high degree of multi-functionality (Ye and Van Nes 2014). We have so far discussed this independent from the influence of different cultures, societal groups, identities, and beliefs, and here we will set out how space connected to a social rationality belongs to a hermeneutic tradition. Social rationality deals with situations in which not all alternatives, consequences, and event probabilities can be foreseen. Research on space and social rationality regarding present or past issues mostly presents explanations embedded in meaningful reasons and consequences. Although causes occur before effects, it is often easier to identify and observe effects. Thus, explanations often set out from the effects and seek to discover their causes. Again, we apply von Wright's logic for our example:

Effect (= consequence): Clashes between various ethnic and religious groups decrease when these groups are located in neighbourhoods that are physically separated from each other.

Cause (= reason): Walls contribute to separating various neighbourhoods from each other.

Of course, this causal explanation is too general and is not uniformly valid. We need context-dependent cases. For example, in the case of Belfast's peace lines, the walls used as separation barriers contributed to reducing clashes between Protestants and Catholics. For the Berlin case, the Berlin Wall separated East and West Germany and aimed to prohibit East German citizens from fleeing to West Berlin. On the other hand, in the case of Tel Aviv and Jaffa, the 'wall' was only on paper, thus a mental boundary, but it had the same effect as a physical wall and Jews and Arabs avoided mingling with each other (Aleksandrowicz et al. 2018). Research concerning social rationality is context-dependent. In order to explain the occurrence of a particular phenomenon, reference to concrete circumstances is mandatory. The case of Jaffa and Tel Aviv's 'paper' wall presents this as follows:

Effect (= consequence): The clashes between Arabs and Jews are reduced in 1944, in Jaffa/Tel Aviv.

Cause (= reason): The administratively planned borders separate the Arab neighbourhoods from the Jewish neighbourhoods.

When constructing a new suburb with the idea of separating Arabs and Jews, it is difficult to derive from its implementation how its residents will behave in the future. It is also difficult to propose any kind of regularity or predictability with regards to the influence of this particular neighbourhood on other urban areas. Moreover, research in the field of space and social rationality requires studying the past in order to gain an *understanding* of *intentions*, which lead, for example, to conflicts or to anti-social behaviour. Interpretations concerning meaning, purpose, and behaviour are ensured from their contextualised appearance, but it seems difficult to assess the explanatory power of cases involving human intentions with causal explanatory models. This kind of research seeks to understand the intentions behind certain behaviours or cultures rather than explaining causes. Subsequently, in research traditions belonging to the human and social sciences, the aim is to understand the reasons, intentions, and motives associated with these causes. Therefore, explanations for forthcoming effects like future urban developments or certain behaviours are not provided. Accordingly, research on space and social rationality can only indicate that certain changes will occur, but not exactly how they will occur.

For the research area of space and social rationality, it seems appropriate to present von Wright's concept of *intentionality* and his model of teleological explanation. It might seem impossible to invest such a model with a certain degree of predictability using our approach; however, a key method for analysing its explanatory power might result from an analysis of the *meaning* of the explanandum (Fig. 6.8) or the phenomenon that has to be understood (von Wright 1971, p. 135).

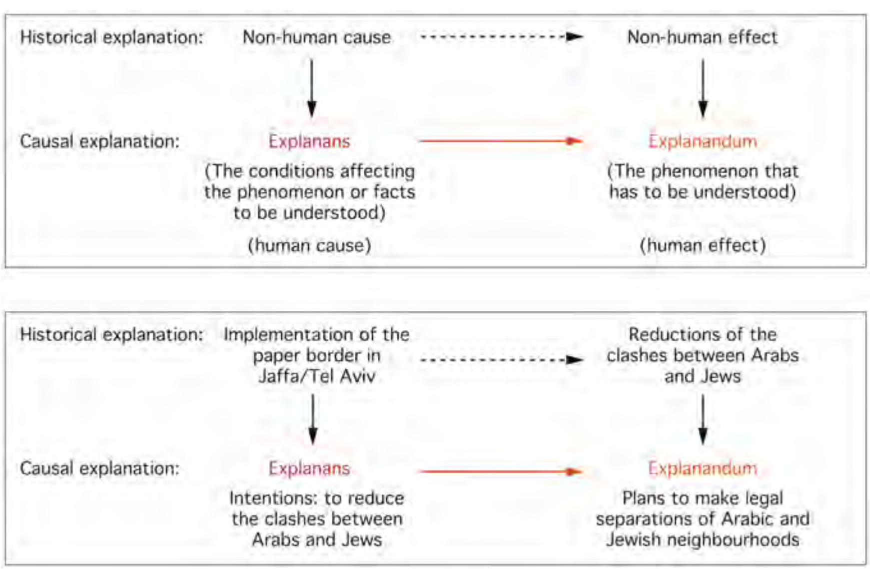

Fig. 6.8 An example of teleological explanations using the Jaffa–Tel Aviv 1944 case

In the Jaffa–Tel Aviv case, when knowing the intentions that brought about blocking the inter-accessibility of the street networks, it becomes easier to account for its effects even it is not possible to predict them on behalf of the intentions. Acknowledging that a historical approach is needed for understanding intentions and behaviour implies that research on space and social rationality can only examine individual cases and cannot outline a 'theory' of human intentions.

Research related to cultural, historical, and social issues is embedded in already existing urban areas. However, it is impossible to predict in a positivistic manner how newly constructed neighbourhoods will function socially. The explanatory power of research on space and social behaviour depends both on human factors like intentions and purposes and on the physical layout of a built environment.

Human intentions or purposes and actual incidents often influence each other. Their nested interactions reiterate. Von Wright illustrates 'quasi-causal' historical explanations of this sort by the model presented in Fig. 6.9 above (von Wright 1971, p. 143) using a context-dependent example. The whole explanation process is split into sub-reasonings, and one explanation and understanding leads to the next until the explanandum is reached. Each sub-result in the process results in a new situation and allows for new intentions and purposes.

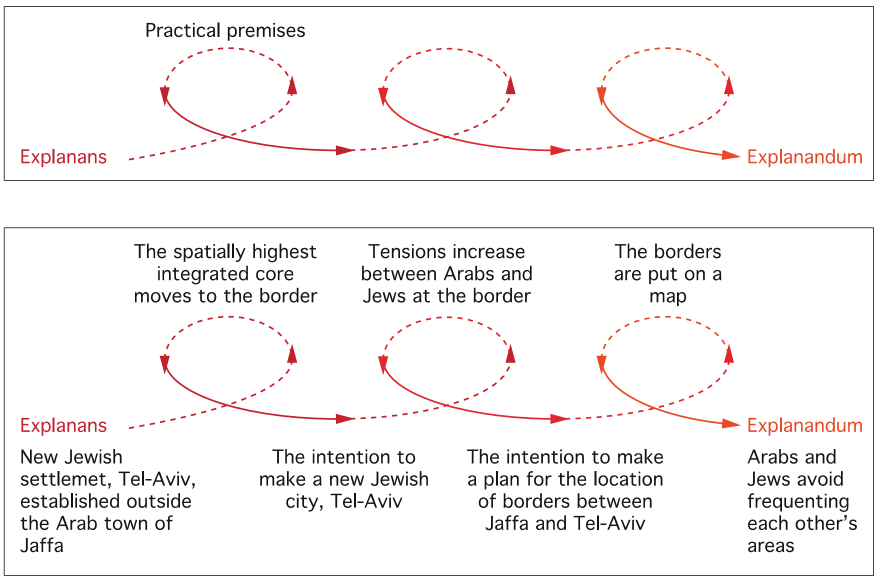

Fig. 6.9 An instance of a 'quasi-causal' historical explanation

Using this model for our example about space and religious conflict is appropriate when an understanding of meaning and intention beyond the implementation of walls in neighbourhoods is at stake. True understanding requires asking what was necessary for something to become possible (von Wright 1971, p. 154). Historical incidents allow for further developments because they transform intentions into effective action, especially by introducing new aspects with new possibilities to influence the course of outcomes (von Wright 1971, p. 155).

Historical explanations are mainly concerned with the *necessary* conditions for how something became possible (von Wright 1971, p. 136). Causal explanations, searching for *sufficient* conditions, do not pertain to research in history or sociology. In the following, we will show how von Wright's explanatory model, including necessary conditions, applies to research on space and social rationality. Because the research of this kind pertains to context-dependent situations, the following disposition parallels these schemata with a particular instance:

Hermeneutic explanatory model

p is a necessary condition of q.

The intention for the Jewish immigrants to build their ideal city was a necessary condition for marking the administrative borders on the map in Jaffa city.

Research on space and social rationality is supposed to reconstruct the past, and therefore, has to search for the main intention as a necessary condition for the development of a certain kind of urban area. In what way the spatial layout of a neighbourhood influences the social behaviour of its users is too complex to be derived and depends on extra-intentional factors. One cannot predict whether a certain behaviour will occur, nor can one assess in what way a certain behaviour will take place. The explanatory power of research on space and social rationality consists only in the identification of the intentions that are necessary for a given course of events.

Our examples for explanations show that research on space and social rationality does not lead to general statements on built environments due to their context dependency. Grasping the sense of a neighbourhood's spatial layout depends on an understanding of the cultural preconditions producing the socio-spatial configuration. A society's ideologies, symbolic values, and attitudes are under constant change, and their articulations vary from one settlement to another. An interpretation of how activities in a society shape urban space thus requires an understanding of both the built environment itself and its position in its comprehensive context.

Interpretation processes that account for such interactions between parts and wholes of physical objects and their meanings are often called hermeneutic circles (Føllesdal et al. 1996, p. 105). For our research on space and social rationality presented here, this form of scrutiny consists of at least the following phases:

(1) Identifying various spatial layouts
(2) Understanding them first in terms of the intentions that necessarily conditioned their existence
(3) Destroying or altering the achieved understandings of built form in terms of the intentions they acquired.
(4) Assessing their relationships with the built environment in its entirety.

Any progress in one of these phases leads to a refined or revised representation of their meaningful existence in subsequent above-mentioned phases. The usefulness of the hermeneutic approach contributes to increased awareness and understanding of cultures and the meanings attached to physical objects and spaces for particular contexts. Here the results from the space syntax analysis are used for understanding the spatial features of particular cultures or the occurrence of a certain kind of human behaviour.

For gaining understandings and making theories on how cities work, there are some simple rules to follow. First, when dealing only with the physical part of the built environment free from human intentions, meanings, and memories, positivistic explanatory models are used. Here explanations and theories can be made based on various spatial combinatorics (demonstrated in Sect. 6.3). When blocking a street, making a new street link, etc. the various spatial integration variables for all streets will be affected, but to different degrees. One physical change is a *sufficient* condition for making something *necessary*. Research of this kind is context-independent and contributes to general *explanations* and universal theories. These theories can explain the future effects of present spatial changes and can explain the spatial set-up of the space syntax analyses of excavated towns. Second, when dealing with human intentions, meanings, and memories, hermeneutic explanatory models are used. Here we are dealing with gaining an *understanding* of a particular phenomenon taking place. Space syntax can only describe the spatial structure and cannot derive future effects from a particular case. Often, research of this kind seeks to identify the *necessary* condition as to why something became *possible* for each particular case. Therefore, space syntax research of this kind is heavily *context-dependent* and has a low degree of predictability and generality. Third, when dealing with human intentions that are *unambiguous*, positivistic explanatory models can be used. Market rationality (profit maximising) and time efficiency are unambiguous intentions. Therefore, it is possible to predict future impacts on economic-related activities and movement flows as an effect of spatial changes to the mobility network.

6.5 Conjunctions and Disjunctions of a Phenomenon

What happens when several causes have to be present so that a given effect can take place? When using more than one condition in the explanatory models, the type of condition changes with regards to positivism and hermeneutics. Positivistic explanatory models deal with sufficient conditions for only one condition and deal with a complex set of necessary conditions when dealing with several conditions in one statement. Conversely, the hermeneutic explanatory models deal with necessary conditions for only one condition and deal with complex sets of sufficient conditions when dealing with several conditions in one statement. This difference in whether we are dealing with necessary or sufficient conditions requires us to focus on whether we are dealing with one or several conditions.

A *complex sufficient condition* consists of *conjunction* of states of affairs (von Wright 1971, p. 39). Given the following example:

Hermeneutic explanatory model

Maybe *p* or *r* alone is sufficient for *q* to occur. But if *p* and *r* occur together, *q* is certain to occur too.

There can be a whole list of conditions, but all of them have to be present for the given effect to take place. Here is an example from space syntax research from Rotterdam (Van Nes and Rooij 2015):

Hermeneutic explanatory model

Maybe *a highly integrated street network* or *intervisible streets* alone is sufficient so that *the presence of women in Rotterdam's streets* will occur. But if *a highly integrated street network* and *intervisible streets* occur together, *the presence of women in Rotterdam's streets* is certain to occur.

This example with a set of complex sufficient conditions pertains to research belonging under a hermeneutic research tradition. All the conditions have to be identified and present for the effect to occur. Moreover, context-dependent situations are required.

Often, these kinds of explanatory models with complex sufficient conditions are used for identifying all of the spatial parameters when describing specific neighbourhoods with social problems. Conversely, in a complex necessary condition *p* and *r* are logically separated from one another. While a *complex sufficient condition* consists of *conjunction* with a phenomenon, a *complex necessary condition* presents itself as a *disjunction*. The following example shows how space syntax analysis on only the physical part of the built environment accounts for complex necessary conditions:

Positivistic explanatory model

Maybe *r* does not require the presence of *p* (unconditionally), nor the presence of *q* (unconditionally); but *r* may nevertheless require that at least one of the two, *p* or *q*, be present.

Positivistic explanatory model

Maybe *spatially configurable change of the street network* does not require the presence of *a new road link* (unconditionally), nor the presence of *a road blockage* (unconditionally); but *spatially configurable change of the street network* may nevertheless require that at least one of the two, *a new road link* or *a road blockage*, be present.

However, for research on spatial combinatorics, sufficient conditions or complex necessary conditions are at stake. Here is one example with the use of the complex necessary conditions. We illustrate it with an example from space syntax research.

Positivistic explanatory model

Maybe *r* does not require the presence of *p* (unconditionally), nor the presence of *q* (unconditionally); but *r* may nevertheless require that at least one of the two, *p* or *q*, be present.

Positivistic explanatory model: Theory of spatial combinatorics

Maybe *increased depth* does not require the presence of *a centrally placed object* (unconditionally), nor the presence of *continuous blocks* (unconditionally); but *increased depth* may nevertheless require that at least one of the two, *a centrally placed object* or *continuous blocks*, be present.

Therefore, complex necessary conditions pertain to research belonging under a positivistic research tradition. Herein cause and effect relations are explained and theories are built that account for all kinds of built environments. In the following sections, we will reflect upon what space syntax has contributed to theory building and to our understanding of how built environments work.

6.6 Research Connected to Space Syntax in the Positivism and Hermeneutic Traditions

In the following sub-chapters, we will describe how space syntax has contributed to understandings and explanations of urban space and social, as well as economic-related activities. Before going further, we repeat the following before discussing what parts of space syntax research belong under a hermeneutic or positivistic approach:

(1) Positivism: uses *sufficient* conditions when there is only one condition in an explanation, and a *complex set of necessary* conditions when there are several conditions present in an explanation. Positivistic explanatory models are used when dealing with objects free from human intentions, meanings, and memories and with unambiguous human intentions such as market rationality and time efficiency.

(2) Hermeneutics: uses *necessary* conditions when there is only one condition in an explanation, and a *complex set of sufficient* conditions when there are several conditions present in an explanation. Hermeneutic explanatory models are used when dealing with objects with human intentions, meanings, and memories and to understand the local social and cultural context.

6.6.1 Three Spatial Parameters for Urban Centrality

For an urban street network, integration analysis depicts the location of vital urban centres. Urban centres are located along the highest spatially integrated streets, and if the spatial configuration of the street structure changes, the location of urban centres might also change.

Hillier (2009, 2012) refined the concept of centrality for cities as pervasive centrality, whereby centrality functions diffusely throughout the network at all scales (including closeness and proximity to smaller and much larger centres from a certain location within the city). In this context, space syntax makes a link between emergent structure and spatial agency, where a city's emergent structure is a law-governed process of the network of spaces that links buildings together (the morphological component). In turn, the spatial agency in itself has effects on the functional patterns of the city or the behaviour of the people. At first sight, centrality seems to be clear and stable, and the central area and its boundaries seem well defined. All we have to do is to reveal the spatio-economic layout. However, as soon as we take temporal aspects into account, the idea of stable and clear centres seems to fade, and they shift, expand, shrink, or change their focus (Yamu 2014, 2020). The location of urban centres depends on how the spatial structure of the street and road network changes over time.

Space syntax is able to quantify the spatial properties between urban blocks in at least three ways connected to centrality, namely metric distance, topological distance, and geometric distance. The question now is how these various types of measures contribute to knowledge on urban centrality.

Metric centrality

Metric centrality implies that an urban centre is located in the middle of a built environment with the shortest metric distance to all other points in that area. This measurement is free from temporal aspects such as travel time and aspects related to travel time such as congested junctions, traffic lights, complex roundabouts, and bad street or road surface quality. To be located metrically in the middle of a settlement does not always mean having the most inter-accessible location.

Topological centrality

Topological centrality deals with the spatial configuration of the street and road network in terms of the number of direction changes. A centre that is located topologically in the middle of a built environment has the fewest direction changes to all other streets in comparison with any other streets of that built environment. The more broken up a street network is in a built environment, the weaker the spatial conditions become for generating a vital economic centre. Topological centrality is about the degree of accessibility in terms of the fewest direction changes. Urban areas with a high degree of topological centrality have the highest degree of to-movement potentials. In these areas, shops tend to cluster and the rental and property prices tend to be higher than other areas in the same city.

Geometric centrality

Geometric centrality deals with changes in angular directions when moving from anywhere to anywhere else. A centre that is located geometrically in the middle of a built environment has the fewest angular deviations to all other streets in comparison with any other streets of that built environment. Geometric centrality is about how the main route network links a city's edges and local areas towards its centre through the least deviation in angular direction. Urban areas with a high degree of geometric centrality have the highest degree of through-movement potentials. These streets tend to have the highest flow of movement. Shops tend to locate themselves along these streets in order to catch the random through travellers.

Metric, topological, and geometric centralities concern the spatial issues of a built environment. Other concepts of centrality are required to describe the social and economic activities taking place inside urban centres. In general, there is a difference between economic and cultural centrality.

6.6.2 Economic and Cultural Aspects Related to Urban Centrality

An economic centre is defined as the place where trade, shopping, and finances take place. The aim for these kinds of activities is to be both in a central metric, geometrical, and topological position to all potential customers. This phenomenon can be explained with positivistic explanatory models because we are dealing with market rationality where the human intentions are unambiguous. Here we are dealing with sufficient conditions and complex sets of necessary conditions.

As research has shown, the optimal position of an economic centre depends on the structure of the street network (Bruyns et al. 2007, p. 35). The spatial configuration of an urban street network on a micro and macro scale seems to determine the distribution of shops. A successful shopping area has both a globally and locally strategic position in a built environment (Hillier 1999b, p. 119). Not only the most integrated streets on a local and global scale decide where shops locate themselves, but also a shopping street's degree of connectivity to its direct side streets. If an economic centre's optimal position changes through changes in a street network, the location of this centre is likely to change too (Hillier 1999b, p. 110ff; Van Nes 2002 p. 287ff). Likewise, changes to the street network affect the flow of human movement. These processes occur in a context free from a state-controlled economy, regulations on land use, and political, religious, or organisational constraints.

Berlin's old and new high street Friederichstraße, discussed in Chap. 2, provides an example of how changes in the street network configuration affect the location pattern of shops. At present, this street is undergoing the multiple effect process where it is slowly becoming the high street of the newly reunited Berlin. First Friederichstraße became a well-used route after the removal of the Berlin Wall in 1989. Then the first shops established themselves, which attracted more pedestrians, which in turn, led to more new shops along this street.

Economic centrality is not something static, and 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 1999b, p. 108). Therefore, an economic centre is heavily dependent on a street structure that relates to both topological and geometric centrality. Accessibility to potential customers is the main issue, and thus high spatial integration of the street network is a sufficient condition for economic centrality.

The way human beings act and behave in urban spaces depends on their motives and intentions. In most cases, the underlying intentions behind human being's actions are difficult to predict. Therefore, their behaviour after urban interventions can also be difficult to predict. With regards to market rationality, the intentions seem to be unambiguous because they concern profit maximising. Therefore, it is possible to predict where economically motivated activities will take place because they have to be in an optimal location in order to survive in a competitive market (Van Nes and Yamu 2018).

To date, research has shown that the location of shops, retail outlets, and national and international firms and the location of urban centres depends on a high degree of integration of the street network on various scales (Hillier 1999b; Hillier et al. 1993, 1998; Rocco and Van Nes 2005; Van Nes 2005; Mohammed and Van Nes 2015; and Van Nes 2002). Likewise, land values and rents tend to be influenced by the various integration values of the street network (Desyllas 2000). High degrees of accessibility, visibility, adjacency, permeability, and reachability are all complex necessary conditions for creating vital urban centres and for generating economic activities within them.

Figure 6.10 shows space syntax analyses of Coventry from 1940 and 1999. In the 1960s and 1970s, large changes to the street and road network were made, and these affected the degree of spatial integration of the town centre. Before WWII, Coventry had a highly integrated and vibrant pedestrian-based town centre. After the implementation of the inner ring road, the town centre consisted mostly of a large shopping centre accessible from the ring road. The intention of the ring road was to reveal the town centre to through traffic. However, the effects of the ring road were that the streets inside Coventry's shopping centre were 'dead' after opening hours (Van Nes 2021). Obviously, changes in the street network can affect the location of the economic centres in the built environment.

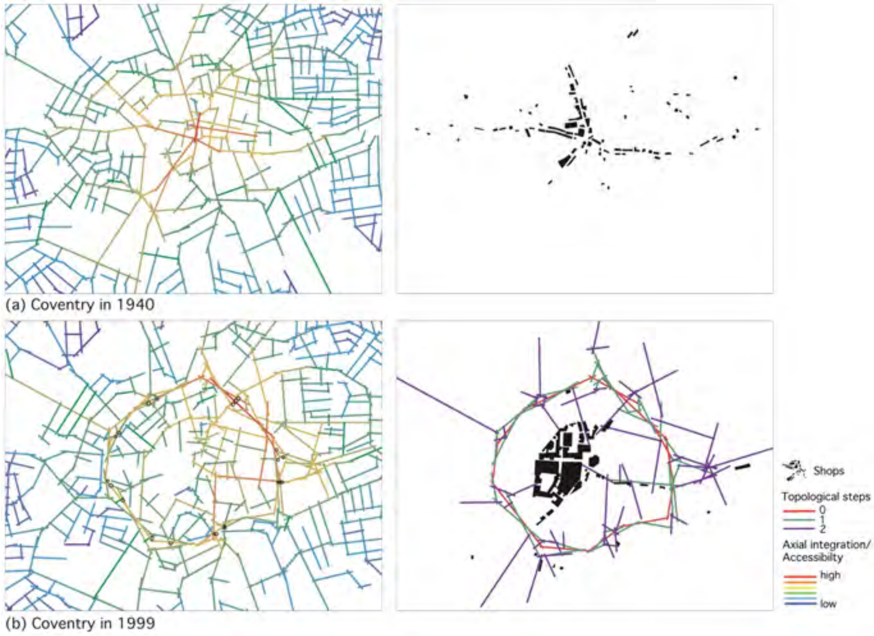

Fig. 6.10 Global integration analyses of Coventry before (**a**) and after (below) implementation of a ring road with the location pattern of shops (**b**) depicting the shift of centrality over time

As research has shown, land use development and building densities adjust themselves according to the degree of street network integration in built environments in a natural urban transformation process. If an urban area has low spatial integration of its street and road network or is poorly connected to its surroundings, the area tends to be mono-functional, have imbalances in the FSI and GSI of the built mass, and lack street life and diversity of economic activities. Conversely, an urban area with high spatial integration of its street and road network tends to be multi-functional with high density of the built mass and having a vibrant street life (Ye and Van Nes 2014; Van Nes et al. 2012). Therefore, the spatial structure of the street and road networks matter in how urban areas transform over time.

Figure 6.11 shows four different urban transformation stages of four Dutch towns, all of which have around 100,000–200,000 inhabitants. The first settlements of the planned new towns of Lelystad and Almere took place in the 1970s. Zoetermeer was a small village that expanded to a large town in the 1960s and 1970s, whereas Haarlem is an old city dating back to the Middle Ages. The areas classified as suburban and low urban have low spatial integration of the street network on all scale levels, have low building density, and are mono-functional urban areas. Conversely, the middle and highly urban areas have high scores on all spatial parameters. The urban areas labelled as ‘in-between’ are under different stages of urban transformation. In most cases, the degree of street network integration has middle or high values, whereas the degree of building density and land use diversity has low or middle values.

These findings can furthermore be connected to the theory of natural urban transformation process. This theory is inspired by a common understanding that roads exist on average for thousands of years, a building typically stands for about 100 years, and the functions inside buildings tend to change frequently (Van Nes 2002). This theory can be verified by selecting a set of new and old towns with similar sizes and regional positions but belonging to different urban transformation phases from newly built to long-settled. The application of space syntax, MXI, and Spacematrix methods on Norwegian (De Koning et al. 2017), Dutch, and Chinese cases (Ye and Van Nes 2014) showed how street network integration, building density and typology, and degree of land-use mixture interact with each another in different phases of an urban transformation process.

There are some aspects of urban centrality that touch on the limits of space syntax. Studies on built form and meaning also deal with place character and architectural styles. Places with a large concentration of historically important buildings and monuments from the past are defined as cultural centres. The artefacts’ meanings and the traditions related to them can be understood from the technical, social, cultural, and economic activities that took place in the past (Rossi 1983; Moudon 1997). Thus, studies on cultural centrality have to be approached from multiple angles. Here we are oscillating between a hermeneutic as well as a positivistic approach.

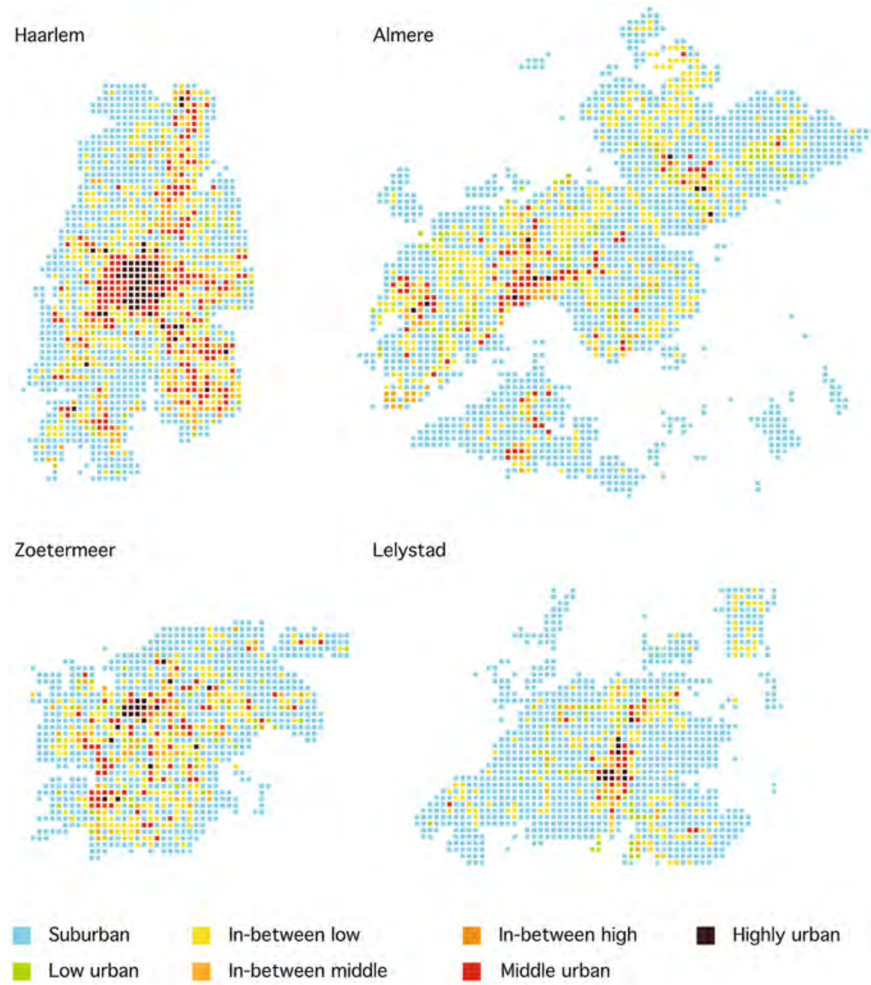

Fig. 6.11 Correlations between space syntax, MXI, and Spacematrix for three new Dutch towns and one old Dutch town (Ye and Van Nes 2014)

Cultural centrality can be multifaceted and can include, for example, religious, spiritual, trading, political, administration, or education centres. Many old European cities have a large and intact historical city centre with several significant artefacts with attached collective memories. In the past, many of these centres had a strong position in terms of politics, trade, and cultural activities. These activities from the past mostly have left their mark in monuments, for example, sets of buildings and street patterns. The establishment of cultural centres often occurred along spatially highly integrated street networks in the past. Later on, through city growth, many of these cultural centres lost their spatially central positions. However, intact historical urban centres function as attractors for cultural activities such as museums, arts and crafts, tourism, concerts, workshops, performances, etc. All of these activities and their artefacts seem to create the atmosphere and sense of a particular place (Rossi 1983; Norberg-Schulz 1980,1971). These kinds of places tend to become attractors for tourism, even though these places have lost their spatially central positions through urban growth and changes in the overall street network structure.

Figure 6.12 shows examples of cultural centrality and economic centrality. Amsterdam's central square (the Dam) is an example of cultural centrality. As the city grew, its topological and geometrical position changed. However, the centre has a high concentration of historically significant buildings with high architectural qualities, intact streetscapes and channels, and artefacts with high levels of collective memories. Conversely, the ZuidAs in Amsterdam is an example of pure economic centrality. After the implementation of Amsterdam's ring road, the area became the most spatially central location in Amsterdam as well as in the whole Randstad. The land along the southern part of Amsterdam's ring road attracted various advanced product and service companies along with foreign directed investment companies. Since the 1990s, the area has changed from a more or less no-man's land into the main financial and business centre of the Netherlands.

Fig. 6.12 Example of economic centrality (the business district at the ZuidAs in Amsterdam) and cultural centrality (Dam square in Amsterdam's historic centre)


ZuidAs - Amsterdam's economic centre


Dam Square - Amsterdam's cultural or touristic centre

Space syntax does not analyse place character or spatial order, but spatial structure. The method is able to analyse the spatial configuration of past street patterns from old maps and to correlate the results with the location of remaining significant old buildings. Often the locations of these kinds of buildings are determined by strong economic centres, with their accordingly highly integrated street networks from the past. Therefore, the application of space syntax on old maps provides explanations or understandings as to why these centres were highly vital in the past in comparison with the present situation. Cultural centrality implies an understanding of cultures, built forms, and meanings based on past human intentions. Therefore, there exist no theories on these issues. Instead, we have to deal with a context-dependent social rationality and the intentions behind a cause, which will be discussed in the next section.

6.6.3 Dealing with Understandings: Context-Dependent Space Syntax Research in Line with the Hermeneutic Tradition

What has space syntax contributed to the understanding of the social effects of spatial segregation? In general, segregated streets have more complex routes to all other streets in a built environment, and these spatial features can affect how human beings perceive, behave, and orientate in built environments. In contrast with market rationality, where the intentions tend to be unambiguous, social rationality concerns a wide range of rationales with a wide range of intentions. In the following sections, we reveal the explanatory power of some results from space syntax research where theory building is not an issue due to context dependency. Here we are limited to only gaining understandings about a phenomenon. As mentioned earlier, we are dealing here with necessary conditions and a complex set of sufficient conditions.

6.6.3.1 Space and Crime

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 and anti-social behaviour and create social segregation. Even though incidents can be understood from a spatial point of view, knowledge of space and crime depends on understanding the behaviour of an area's inhabitants and having insight into the social composition of the residents. Sometimes the social composition of the inhabitants can overtake the spatial generative power. If a large number of social disadvantages are concentrated in a highly integrated residential area, this can lead to increased crime and vandalism (Rueb and Van Nes 2009).

An account of anti-social behaviour in terms of the extrinsic properties of space requires studying already established areas. It is about how a built environment's spatial organisation can disturb or encourage the natural relationship between residents and strangers.

Even though research on space and crime is heavily context-dependent, some common features are found in European built environments. Seemingly, neighbourhoods with street networks that are visually broken up and with few dwelling entrances constituting the streets are often affected by crime (Hillier and Shu 2000, p. 232; Hillier and Sahbaz 2005, p. 456; Van Nes and López 2010). The same investigations prove that spatial organisation can generate movement according to co-presence and co-awareness in built environments. Where the local integration of a street network is high and the number of people frequenting the streets is high, the lower the burglary risk tends to be in European cities.

Causes for crime and anti-social behaviour in European cities seem to depend on at least the following spatial conditions:

- Poor correlations between connectivity and the local and global integration of the nearby environment.
- The segregated areas are many topological steps away from integrated streets.
- The spatial structure in the area is deep in relation to itself and in relation to the whole system.
- The spatial relationship between private and public space includes a large number of semi-private and semi-public spaces.
- There are a few doors and windows facing the street.

All of these spatial parameters generate spatially enclosed building blocks with high privacy, but without general social control and lacking natural co-presence and mutual surveillance (Hillier 1996, pp. 188, 194 and 201; and López and Van Nes 2010). The design of architectural space can thus affect the use of space, and this issue seems to touch upon the problem of architectural determinism. Architectural determinism claims that the built environment determines social behaviour, and therefore it can be possible to predict how an urban area will function after it is built. It is difficult to assess the question of to what extent a space syntax approach is a form of architectural determinism. Whether crime or social malaise will occur in spatially segregated areas or not naturally depends on the social compositions and behaviours of their inhabitants. Therefore, we have no 'theory on space and crime.'

A space syntax approach, on the other hand, can at least identify the spatial properties that can help us to understand why some already established urban areas have a high level of crime and social problems. These identified spatial properties provide precise understandings of how spatial configuration plays a part in broader social processes of perceived and actual decline. Thus, a space syntax approach can show that the spaces of a built environment can affect human behaviour (Hillier 1999a, p. 184ff). A space syntax approach contributes to an understanding that the means a built environment provides are physical, while its end results are functional—not visa-versa, as claimed in many writings on built environments.

Gaining understandings of space and crime requires an understanding of the local context. For each local context, the aim is to identify the necessary condition behind every cause for a chain of incidences. For understanding the intentions behind each separate cause, a complex set of sufficient conditions is needed for explaining the conjunction of the phenomenon space and crime of a particular place.

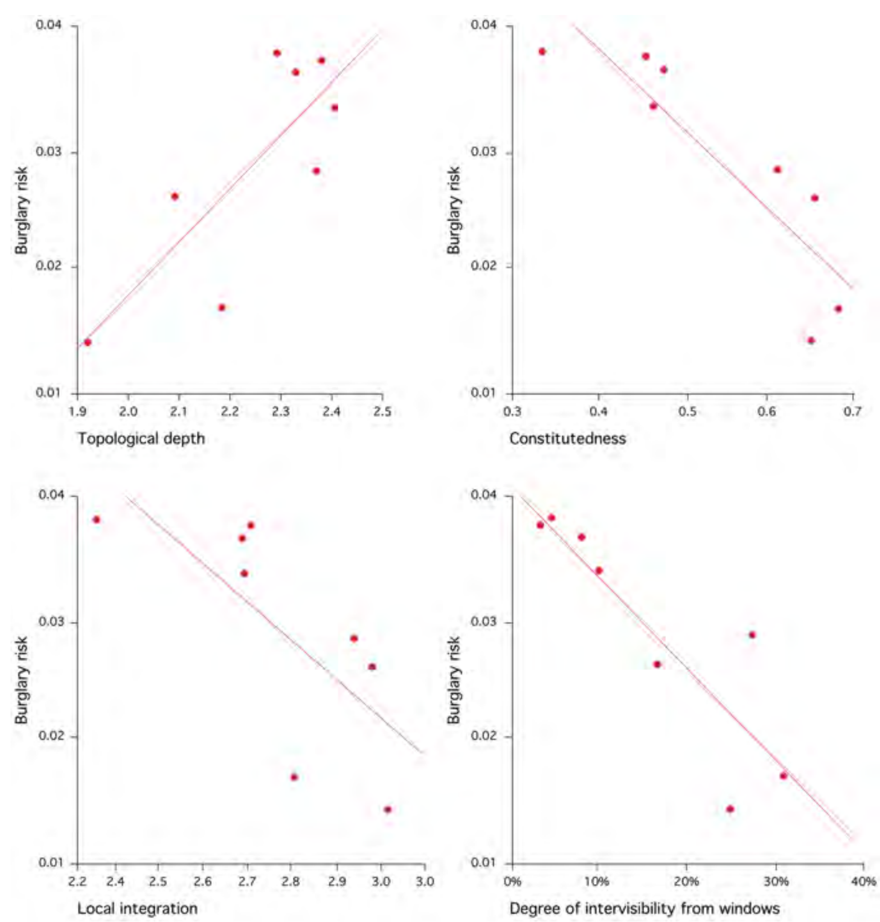

Fig. 6.13 Scatterplots showing the correlation between burglary risk and various spatial parameters in the Dutch towns of Gouda and Alkmaar

Hermeneutic explanatory model: the conjunction of phenomenon

Maybe p, r, s, or t alone is sufficient for q to occur. However, if p, r, s, and t occur together, q is certain to occur too.

Here we illustrate this with an example from research on space and crime in the Dutch towns of Gouda and Alkmaar (Van Nes and López 2010). We use the scatterplots in Fig. 6.13 as an example.

Hermeneutic explanatory model: The case of Gouda and Alkmaar

Perhaps the high number of direction changes (topological depth) from the main routes, the low local integration, the unconstituted streets, or the low intervisible streets was sufficient for the high burglary risk in Gouda and Alkmaar. However, when these four aspects occurred together, high burglary risk was sure to occur too.

6.6.3.2 Space and Social Integration Versus Social Segregation

As research has shown in the Netherlands (Van Nes and Aghabeick 2015) and Egypt (Mohammed et al. 2015), there is a correlation between the degree of spatial integration and the degree of social integration. Seemingly, spatial segregation contributes to social, as well as ethnic segregation among the users, while spatial integration supports the socio-economic integration of various social and ethnic groups.

A neighbourhood with low spatial integration of its street network on various scales and with a low degree of intervisibility of entrances and windows shapes the opportunities for social segregation. Segregated urban areas consist of a labyrinthine and broken up street network, dead-ends, and poorly intervisible streets. Social segregation occurs not only between various ethnic groups, but also between gender and age among the area's users. A neighbourhood with these spatial characteristics and with a large number of low-income non-western immigrants easily gains a reputation as a 'ghetto' (Van Nes and Aghabeick 2015). In contrast, when a neighbourhood with these spatial characteristics has a large number of high-income people, it easily gains a reputation as a 'gated community'.

Conversely, a neighbourhood with high spatial integration on the main routes going through the area, combined with all local residential streets being connected to the main routes and a high degree of intervisibility between entrances and windows on the ground floor level, generates social integration between various social and ethnic groups. Often visitors frequent the area due to a large number of exciting immigrant shops offering exotic products along spatially integrated main routes. A neighbourhood with these spatial characteristics and with a large number of non-western immigrants easily gains a reputation as a 'multicultural' neighbourhood (Van Nes and Aghabeick 2015).

A tree-structured street network with separate pedestrian movement routes contributes to spatially segregated residential areas with few opportunities for various types of people to interact. A network-structured street system contributes to the opposite. Hence, spatial segregation contributes to ethnic segregation. In spatially segregated areas, an emergence of a 'bubble within a bubble' takes place. The size of the personal space, or 'bubble', for various cultures plays a smaller role in spatially integrated main streets than in segregated streets (Van Nes and Aghabeick 2015).

Seemingly, the design and layout of the built environment affect how immigrants can integrate into the socio-economic life of the host country. There is a link between ethnicity, spatial behaviour, and spatial segregation. The degree of spatial integration influences the various ethnic groups' behaviours due to differences in cultural expressions of spatial behaviour and differences in cultural survival tactics.

Tearing down buildings and replacing them with new buildings or redistributing the inhabitants does not solve the problem of 'ghettos' on a longer term, and there is a need for understanding the relationship between spatial layout and the behaviour of various ethnic groups. Likewise, there is a need to understand which spatial parameters can generate socio-economic integration between various social groups. It can be possible to aggregate various vibrant multicultural urban areas where the immigrants shape their opportunities and interact with the culture and economy of the host country. "The mosaic of subcultures requires that hundreds of different cultures live, in their own way, at full intensity, next door to one another. But subcultures have their own ecology. They can only live at full intensity, unhampered by their neighbours, if they are physically separated by physical boundaries" (Alexander et al. 1977). A large variation of cultures contributes to making vibrant neighbourhoods. Seemingly, the underlying factor is the spatial layout of the neighbourhood that influences whether a neighbourhood gains a reputation as 'ghetto' or 'multicultural'.

Gaining understandings of social segregation and urban space requires insights into each particular culture of each social and ethnic group from a particular neighbourhood. For each local context, the necessary condition or complex set of sufficient conditions as to why something became possible needs to be identified. Here we illustrate a complex set of sufficient conditions for the Rotterdam case.

Hermeneutic explanatory model: the conjunction of phenomena

Maybe p, r, or s alone is sufficient for q to occur. However, if p, r, and s occur together, q is certain to occur too.

Hermeneutic explanatory model: The Rotterdam case.

Maybe spatial segregation, unconstituted streets, or a high number of low-skilled non-Western immigrants is sufficient for the neighbourhood in Rotterdam to gain a reputation as an urban ghetto. However, if spatial segregation, unconstituted streets, and low-skilled non-Western immigrants occur together, the reputation of the neighbourhood is certain to gain the reputation as an urban ghetto.

The same exercise can be done for a multicultural neighbourhood:

Maybe spatial integration, constituted streets, or a high number of low-skilled non-Western immigrants is sufficient for the neighbourhood in Rotterdam to gain a reputation as a multicultural neighbourhood. However, if spatial integration, constituted streets, and a high number of low-skilled non-Western immigrants occur together, the neighbourhood is certain to gain a reputation as a multicultural neighbourhood.

Figure 6.14 shows a small part of the registrations of various types of immigrants in the public spaces of a neighbourhood in Rotterdam. As can be seen, where the spatial integration of the street network is high, in combination with intervisible streets with a high density of entrances, there is also a high variation in the ethnicities of the people in the streets. As soon as the streets become segregated, combined with a low density of entrances, social segregation takes place.

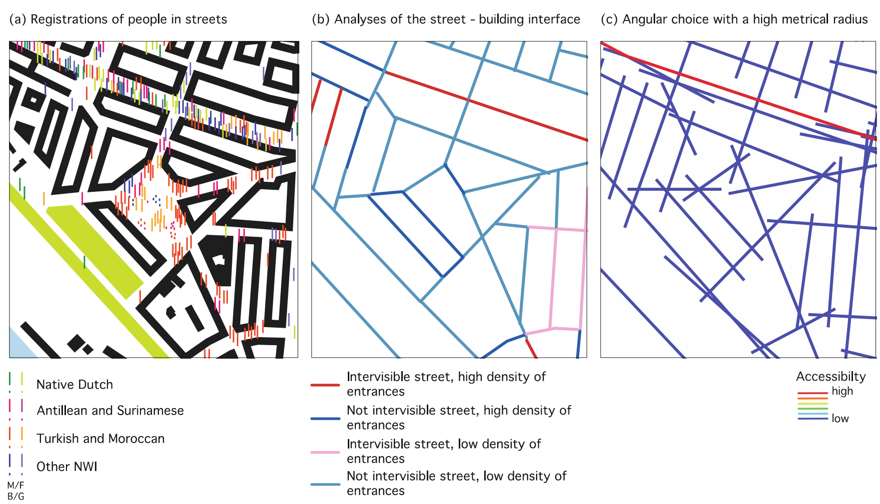

Fig. 6.14 Registrations of the ethnicities of people in public spaces (**a**) with various degrees of entrance densities and intervisibilities (**b**) and choice analysis with a high metric radius (**c**). *Source* (Van Nes and Aghabeick 2015)

6.6.3.3 Space and Gender

Research has shown that women and men use space differently in different cultures. However, a common feature is that women tend to avoid urban public spaces that are spatially segregated and that lack intervisibility and constitutedness (Nguyen and Van Nes 2014; Hardner et al. 2012; Van Nes and Rooij 2015).

Another study showed that neighbourhoods with poor connections between buildings and streets and with segregated streets generated social segregation among ethnicities, genders, and ages of users. Women were more frequently seen walking in vibrant, integrated streets and very rarely in the most segregated streets. Men dominated the segregated streets (Van Nes and Aghabeik 2015). Van Nes and Rooij's research in 2015 showed that vibrant streets were perceived to be safer and that the street network and micro-scale relationship between streets and buildings played a role in making such streets lively. Neighbourhoods lacking street network integration and intervisibility contributed to unsafe streets.

Research on preventing sexual harassment in built environments needs to add data on the degree of presence of women and men in the streets. Otherwise, the outcomes can lead to misguided strategies for improvement. Divergent strategies have been proposed for designing safe cities. Oscar Newman proposed in 1972 that spaces should be designed with large amounts of semi-public spaces separating inhabitants and visitors (Newman 1972). Conversely, Jane Jacobs proposed in 1960 that streets should be open for inhabitants and visitors at all times and that eyes from buildings on streets ensure natural surveillance. Maintaining urban safety is fundamental for vital street life, and only a few cases of violence in a street are enough to generate avoidance, thus contributing to unsafe streets (Jacobs 1960).

Two different scenarios for eliminating gender-based violence in streets can be imagined. The Newman-inspired scenario consists of urban areas for exclusively male or female use, and shopping, entertainment, education, and jobs are all clearly divided by the gender of their users. Clearly, no gender mixture in streets means no opportunities for sexual violence of men towards women. The Jacobs scenario presents a gender-mixed city where the vivacity of streets ensures their safety. In the latter, the seemingly utopian goal of ending sexual gender-based violence depends on not-entirely known factors of the physical environment and their relations with human behaviour, not to mention culture, education, and many other socio-economic aspects.

In a research project on space and sexual violence against women in Rotterdam from 2012 to 2017, correlations were found between the occurrence of sexual crimes, the amount of people and the amount of women in the streets, local integration, street function, and temporal aspects. Non-residential streets were safe during the day, but became dangerous during the night. Mixed land use was safer than mono-functional areas. A high degree of intervisibility of entrances generated a high degree of natural surveillance, resulting in greater safety in the streets. Residential streets with higher flows of people had fewer incidents than mono-functional commercial blocks, and commercial blocks had higher numbers of incidents after the shops closed due to the lack of surveillance (Miranda and Van Nes 2020).

As expected, women's avoidance strategies for crime prevention contributed to the reduction of incidents. However, they also contributed to a gendered space where the public urban spaces were not accessible for half of the population and led to misleading research results in which gated communities were considered to give the safest results. As recommendations for urban planning and policy practice, urban design including residences on both sides of streets and with good intervisibility between entrances on the ground floor level is needed. In commercial areas, diverse land use with dwellings and commercial functions is recommended (Miranda and Van Nes 2020).

Figure 6.15 shows some examples of 'gendered space' dominated by men and 'gender balanced' spaces in the Oud Mathenesse neighbourhood in Rotterdam. The typical gender-balanced streets are the shopping streets, whereas segregated and unconstituted streets tend to be male dominated (Van Nes and Rooij 2015).

Fig. 6.15 Examples of 'gendered spaces' dominated by men in images (**a**) and (**b**), and 'gender-balanced' spaces in images (**c**) and (**d**)

Research on space and gender is context-dependent. The attitude towards women varies from culture to culture, and these affect the various behaviour patterns of women in urban spaces. A complex sufficient condition applied in the case above is as follows:

Hermeneutic explanatory model: the conjunction of phenomena

Maybe p, r, or s alone is sufficient for q to occur. However, if p, r, and s occur together, q is certain to occur too.

Hermeneutic explanatory model: The Spangen case in Rotterdam

Maybe an integrated street network, intervisible streets, or mix of active functions on the ground floor level is sufficient for gender-balanced street life in the Spangen neighbourhood in Rotterdam. However, if an integrated street network, intervisible streets, and mix of active functions on the ground floor level occur together, gender-balanced street life will occur in the Spangen neighbourhood in Rotterdam too.

6.6.3.4 Space and Cultures

Urban design is often more concerned with appearance and aesthetics than with the interconnected logic of public, semi-public, and private spaces. It is primarily driven by a project's intention, cultural preferences, and ideologies. Little attention is paid to the new housing area's social function after it has been built, and the focus is simply on what sells and on short-term profits. Herein, the use of space syntax for urban design and planning can contribute to an understanding of how different types of people behave in new forms of urban areas (Major et al. 1999). Sometimes a project's intentions and ideologies do not correspond with its users' behaviours.

Why do many modernistic urban areas tend to be either gated communities or social-problem neighbourhoods? Segregated modernistic urban areas with high-income residents tend to be surrounded by fences, camera surveillance, or guards for protecting their properties. Presumably, most large modernistic housing estates tend to be designed by trans-spatial people, but they are populated mostly by spatially dependent people.

Spatially dependent people are the unemployed, the newly arrived immigrant, the housewife, the retired, the child, and the adolescent. They are dependent on what the vicinity offers because they spend a lot of time in and around their homes. Conversely, the trans-spatial people are students and working people. Often trans-spatial people have a social network that is not particularly place-bound or located in the vicinity of their homes, such as associations, clubs, organisations, etc. In their leisure time, trans-spatial people tend to participate in their activities within a much larger metric range than spatially dependent people (Rueb and Van Nes 2009). Therefore, the vicinity of trans-spatial people's own neighbourhood is not as important as it is for spatially dependent people. The spatial arrangement of evolved towns and cities seems to offer a complex set of sufficient spatial conditions for spatially dependent people, whereas the spatial arrangement in many post-War, modernistic high-rise neighbourhoods seems to be suitable for trans-spatial people. However, in most European countries, these post-War, high-rise flats are populated by spatially dependent people.

In general, the rationale behind how and where different types of people choose to live varies between cultures and nationalities. When investigating these aspects, a complex set of sufficient conditions is needed to understand a particular context. However, research on space and cultures is heavily context dependent.

Hermeneutic tradition: the conjunction of phenomena

Maybe p, r, or s alone is sufficient for q to occur. However, if p, r, and s occur together, q is certain to occur too.

As an example, we can apply the hermeneutic explanatory model to the case study of Jewish settlements in Manchester and Leeds in the nineteenth century, studied by Laura Vaughan and Alan Penn in 2001. The authors investigated the spatial features of the Jewish immigrants' settlement patterns when arriving in their host countries. As Vaughan and Penn found, the immigrants tended to locate themselves at the edge of economically active areas. This made it possible for the immigrants to participate in the economy of the host country and to slowly integrate into the local culture. Because Vaughan and Penn's study focused on urban areas in the nineteenth century, it provides knowledge about immigrants' behaviour and the distribution of poverty in evolved urban areas. As Vaughan and Penn's study shows, the socially privileged lived along the locally integrated main streets, whereas the lower classes were located 1 or 2 topological steps away from these streets. Immigrants also settled themselves 1–3 topological steps away from these main streets in order to have a chance for getting a job from the socially privileged (Vaughan and Penn 2001).

Hermeneutic explanatory model: The Manchester and the Leeds cases.

Maybe a neighbourhood with an integrated street network, economically active urban areas, or provision of cheap dwellings 1–3 topological steps away from integrated main streets was sufficient for Jewish immigrants to settle in Leeds and Manchester. However, if there was a neighbourhood in Leeds and Manchester in which these conditions occurred together, Jewish immigrants were certain to settle themselves in these areas.

6.6.3.5 Space and Political and Ethnic Conflicts

In studies on political and ethnic conflicts, space syntax can only identify and describe the spatial features of where these types of conflicts take place. For example, in Belfast, the intentions to reduce the religious conflicts between Protestants and Catholics contributed to the construction of the peace lines. Research of this kind requires an understanding of the historic background of a certain culture and the political context as to why these walls were constructed. Space syntax can only describe the spatial features of the situation before and after the construction of the peace lines.

In contrast, for the Berlin Wall case, there were no cultural clashes. Here space syntax can be used to describe the spatial features on the location of various functions related to each political ideology. During the physical division of Berlin between 1961 and 1989, housing and political institutions were constructed along the spatially integrated streets in East Berlin. After the reunion of Berlin in 1989, the ground floor functions within these buildings were transformed back to shops. In a state-controlled economy, the incentive for shop owners to maximise their profits was lacking. Thus, the economic activity component of the theory of the natural movement economic process was distorted. Whereas in a free market economy, the marketplace generates capitalistic activities, in the communist ideology of Karl Marx, it was common practice to locate residences and political institutions along the most integrated streets in city and town centres. This Marxist ideology was used in the rebuilding and regenerating of Eastern Block cities behind the Iron Curtain (Van Nes 2002, p. 276).

Whether or not the spatial setup in built environments can provoke political activities is difficult to comment on, and systematic research on this issue is lacking. However, political forces and organisational constraints can overpower spatial forces in built environments. In a state-controlled economy, there is almost no incentive for profit maximising. According to the ideology of former communist countries, a market square or city centre was perceived as a generator of "capitalistic activities" (Lefebvre 1991, p. 101ff), and therefore, large housing estates were often built in their historic city centres to reduce the possibilities for these so-called market activities. The former East German centres of Alexanderplatz in Berlin and the Dessau city centre provide examples of how a political system of this kind can overpower the generative power of the natural movement economic process. In the same way, a strong planning system on different levels—national, regional, or municipal levels—as well as organisational constraints can block the natural choice to locate economic activities at strategically optimal locations. Below we use Dessau centre during the Deutsche Demokratische Republik (DDR) period as a context-dependent case to show an explanatory model related to the effects of a political system.

Hermeneutic explanatory model: the conjunction of phenomena

<Maybe p, r, or s alone is sufficient for q to occur. However, if p, r, and s occur together, q is certain to occur too.>

Hermeneutic explanatory model: The Dessau centre case during the DDR period from 1945 to 1989.

Maybe *the intention to obstruct capitalistic activities*, *the intention to solve the dwelling shortages,* or *the intention to rebuild the destroyed city centre* alone was sufficient for *there being no shopping activities in Dessau centre between 1945 and 1989*. However, if *the intention to obstruct capitalistic activities*, *the intention to solve the dwelling shortages*, and *the intention to rebuild the destroyed city centre* occurred together, there was certain to be *no shopping activities in Dessau centre between 1945 and 1989*.

In a research project on how diverging ideologies impact the location of functions in relation to spatial integration, four different settlements were analysed in the Norwegian archipelago of Svalbard. These northernmost permanently inhabited settlements in the Arctic region are located 1,300 km from the North Pole. Two of these are Norwegian settlements. Longyearbyen and Ny-Ålesund were founded as coal-mining towns, and today they are international polar research stations. The other two, Pyramiden and Barentsburg, are Russian coal-mining towns constructed during the former Soviet Union. All four towns are separated from each other due to the extreme climate and landscapes. Therefore, they represent unique cases for understanding the relationship between economic systems, two diverging political ideologies, and built form and function. Each town has its own local community with limited possibilities to interact with the other towns.

The space syntax analysis reveals that political ideology influences the types and distribution patterns of public functions. Figure 6.16 shows a space syntax analysis of Longyearbyen and Pyramiden. In capitalistic, liberated economy types of settlements, public functions along well-integrated streets consist of commercial facilities such as shops, bars, restaurants, Vinmonopolet (Norwegian state monopolised alcohol sales shops), offices, and educational, governmental, and cultural institutions. Because commercial functions are lacking in (former) soviet/communist settlements, housing, cultural, and social facilities, as well as Lenin's statue are located along the most integrated streets in communistic, state-controlled economy types of settlements. These results show that space syntax is used here to describe and identify the spatial features of space use based on different ideologies and cultures. Research of this kind is heavily context-dependent and requires an understanding of the political ideology at issue (De Koning and Van Nes 2019a, b).

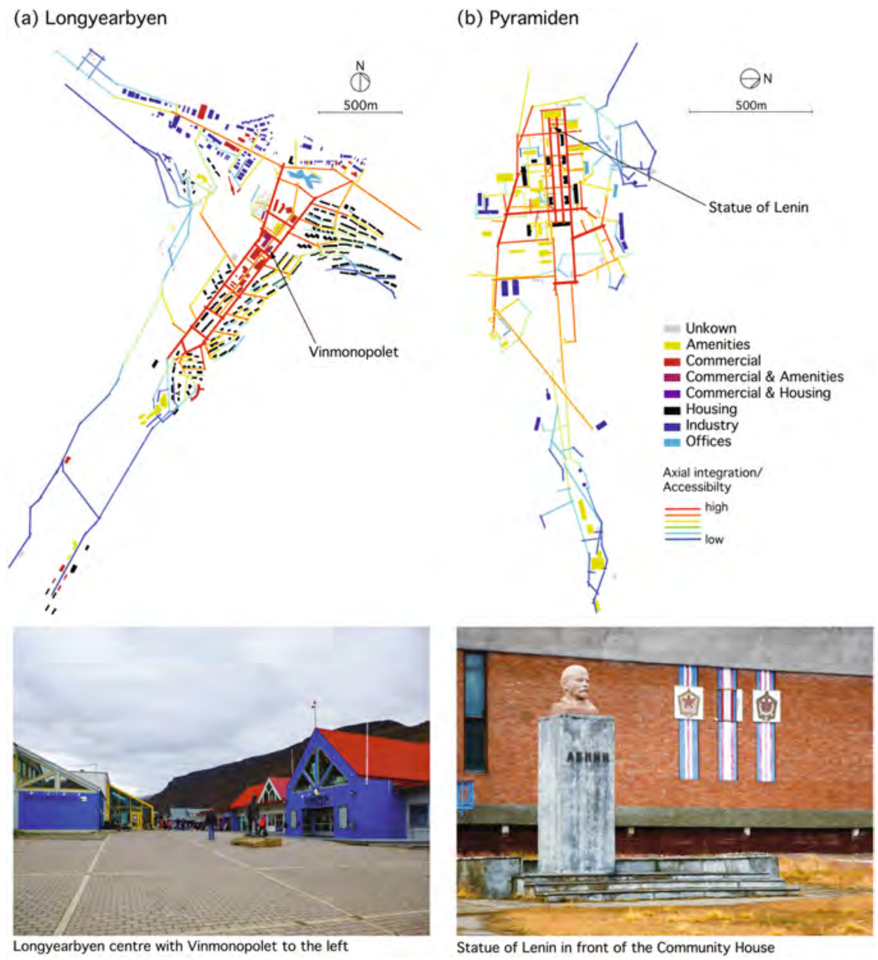

Fig. 6.16 Global integration analyses of the towns of Longyearbyen and Pyramiden showing the locations of functions (De Koning and Van Nes 2019a, b)

For Longyearbyen, the street with the highest spatial integration is a sufficient condition for the location of the supermarket with the alcohol sales point Vinmonopolet. For Pyramiden, the intention to make the Lenin statue visible to the inhabitants was a necessary condition for the location of the Lenin statue at the highest integrated street.

Understanding the location pattern of activities in the centre of Pyramiden requires a hermeneutic approach, whereas the explanation for the commercial activities in Longyearbyen requires a positivistic approach.

Hermeneutic explanatory model: the necessary condition

p is a necessary condition for q.

Hermeneutic explanatory model: The explanatory model for the location of the Lenin statue in Pyramiden

The intention to be a showcase for the ideal communistic settlement is a necessary condition for *the location of the Lenin statue in Pyramiden's most integrated space.*

For Longyearbyen, the street with the highest integration is a sufficient condition for the location of the supermarket with the alcohol sales point. This is in line with the theory of the natural movement economic process.

Positivist explanatory model: the sufficient condition

p is a sufficient condition for q.

Positivist explanatory model: The Longyearbyen case.

The street with the highest spatial integration of the street network is a sufficient condition for *the location of the supermarket with the alcohol sales point in Longyearbyen.*

In a study about ethnic conflicts, it was shown how a cognitive boundary with no physical presence has affected life in the cities of Jaffa and Tel Aviv for many years. The cognitive border existed not only during its time of existence (1921–1950), but for many decades after it was erased from all official documents. In 1921, the national aspirations of Jews in Jaffa, embraced by the local British Mandate government, triggered a segregation process that resulted in an official administrative split of Jaffa's urban area. In this way, the 'Hebrew' city of Tel Aviv on Jaffa's northern parts was created. This administrative division had a clear ethnic character. The entire city was divided into clearly defined 'Jewish' and 'Arab' geographical entities, and this influenced the development of the two municipalities as well as the daily lives of their populations.

Figure 6.17 shows a normalised segment integration (NAIN) of Jaffa and Tel Aviv from 1944 with the paper border (left) and without the paper border (right) (Aleksandrowicz et al. 2018). After the 1948 War in Palestine, which led to the flight of almost all of Jaffa's Arab population and the annexation of the Jaffa area to Tel Aviv, the united city continued to resemble a divided city. The former areas of Jaffa remained relatively underdeveloped and neglected for decades (Aleksandrowicz et.al 2018). By combining spatial analysis and historical research, this study revealed how the 'paper boundary' that was drawn between Jaffa and Tel Aviv, in 1921, transformed the life of Arabs and Jews in the two cities in a way that undermined the physical unity of the urban fabric and the spatial potential of its street network.

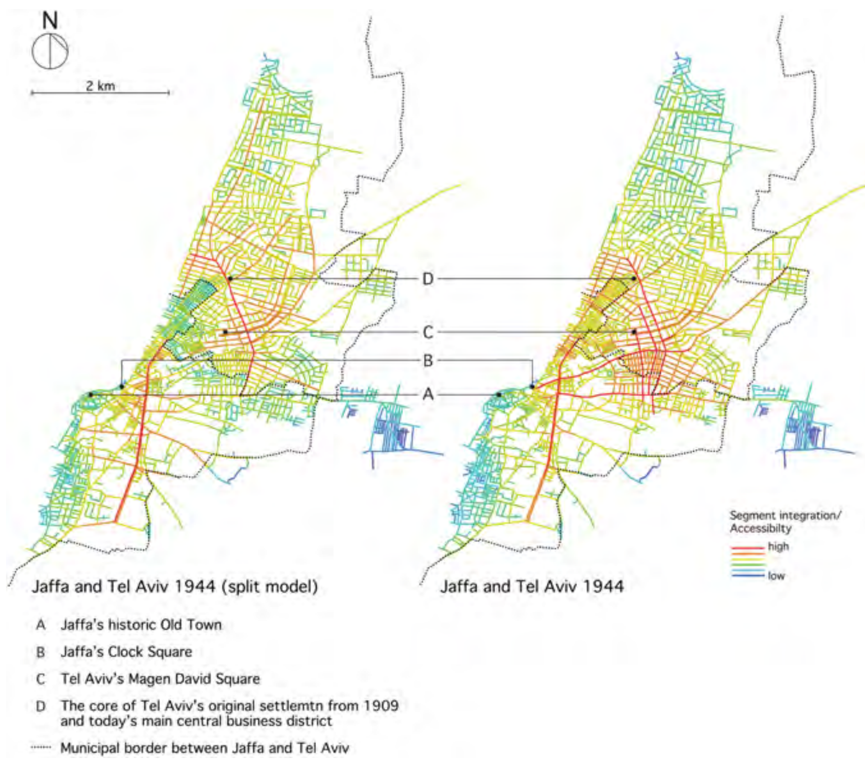

Fig. 6.17 The division of Jaffa and Tel Aviv, in 1944—(left) NAIN analysis of Jaffa and Tel Aviv, computed including the 'paper boundary'; (right) NAIN analysis of Jaffa and Tel Aviv, where the unmanipulated axial map was computed (Aleksandrowicz et al. 2018)

The creation of the municipal border led to the cognitive marginalisation of the spatially centrally located Manshiya neighbourhood, and later to its deterioration and eventual destruction. Ironically, the destruction of Manshiya gave a belated physical expression to the historic cognitive separation between the centres of Jaffa and Tel Aviv, working against the wish to unite the two cities into a single urban entity after 1948 (Aleksandrowicz et al. 2018).

Hermeneutic explanatory model: the conjunction of phenomena

Maybe p, r, or s alone is sufficient for q to occur. However, if p, r, and s occur together, q is certain to occur too.

Hermeneutic explanatory model: The Jaffa–Tel Aviv case.

Maybe *the intention to create the Hebrew city*, *the intention to make an ethnic division between Jews and Arabs*, or *the intention to make an administrative division* alone was sufficient for *the paper borders to be drawn in 1921*. However, when *the intention to create the Hebrew city*, *the intention to make an ethnic division between Jews and Arabs*, and *the intention to make an administrative division* occurred together, *the paper borders from 1921* were sure to be drawn too.

Research on space and political or religious issues requires an understanding of the underlying ideologies for each particular context. Everything outside market rationality, namely the necessary conditions for where a particular culture or political ideology places their main symbols, needs to be identified. The same is true for the complex set of sufficient conditions.

6.7 Context-Dependence: How Space Syntax Theories Can Be Distorted

Space syntax offers specific concepts on urban space that can be used when analysing built environments' spatial changes over time independent of political and cultural contexts. Therefore, space syntax is able to describe the spatial properties concerning where certain activities take place within specific political or cultural contexts.

Shops do not always locate themselves along the highest integrated street, and therefore, the local planning context needs to be investigated in these cases. Likewise, the flow of human movement does not always correspond with the degree of spatial integration. This yields a representation of the local cultural or political context. Figure 6.18 illustrates how the theory of the natural movement economic process can be distorted by political and organisational constraints or by ethnic conflicts. The Netherlands, for example, has a strong planning system that works well at the national level, provincial level, and local level. It is, for example, difficult to locate or to invest in highly integrated areas when they are affected by national protection plans or conflicting municipal interests (Bruyns et al. 2007, p. 86).

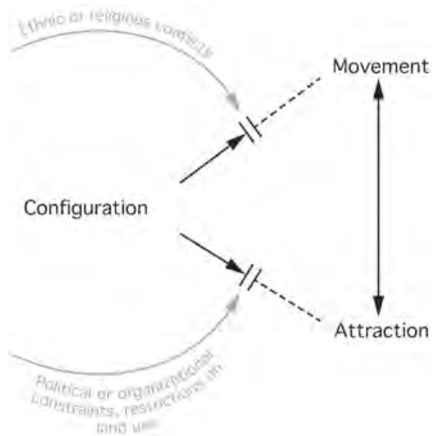

Fig. 6.18 Interferences in the theory of the natural movement economic process

In contrast, Norway has a weak planning system on all levels. Therefore, urban development is steered by market forces and the municipality functions as a facilitator and mediator for the development of industrial areas, new housing estates, and shopping malls (Falleth et al. 1995). Thus, a country's planning system or political forces can influence the location pattern of economic-related activities. These aspects have to be taken into account in research as well as in planning of urban areas.

Highly integrated urban areas do not always have a high degree of building density or a high degree of land use diversity. Likewise, high building density does not always entail multi-functional land use. Figure 6.19 shows the distortions in the theory of the natural urban transformation process. Gaining understandings of all of these distortions depends on each local or national context. There might be rigid restrictions on the local planning regulations, restrictions from conservation authorities, or laws and rules that block the desired intentions in the planning process.

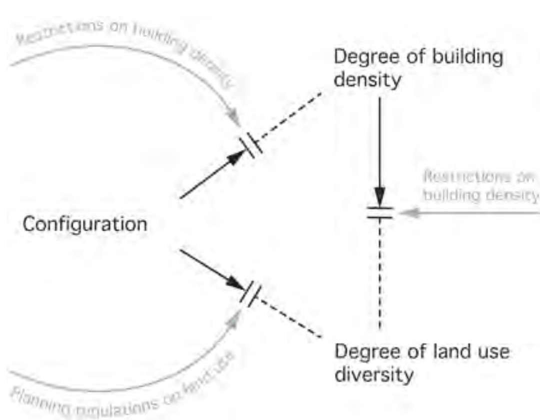

Fig. 6.19 Interferences in the theory of the natural urban transformation process

Research on these issues requires an understanding of a country's planning systems and its associated laws and policies. Likewise, understandings of a particular culture and tradition can provide explanations on various interferences. Extreme natural conditions (flooding or land-slide risks) or religion (practices and rituals) also contribute to regulations that might distort the relationship between integration, movement, and the location of attractors. It is all about identifying the necessary condition or complex set of sufficient conditions for each local context.

6.8 A Significant Piece Towards a Comprehensive Theory on the Built Environment

What does space syntax add to studies on the built environment? At the very least, space syntax offers concise spatial tools to measure spatial changes in built environments independent of context-related situations where cultural aspects must be taken into account (Yamu et al. 2021). Therefore, it is able to find some spatial evidence for various presumptions and observations.

What can space syntax not grasp in studies on the built environment? Even though space syntax offers precise spatial concepts for one to operate with, it cannot analyse the place character, the sphere, the ambience, or the symbolic meaning of the built form. Likewise, explanations and understandings as to why a settlement was established at a certain natural location cannot be offered using space syntax analyses. 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 into a society's cultural background and spiritual traditions in the present as well as in the past.

According to David Seamon, understanding the built environment as an integral structure of human life must consider the following three dimensions: geographical ensemble (the physical environment), people in place (human actions, meanings, and intentions), and genius loci (the spirit of the place) (Seamon 2011). The space syntax method is able to analyse the spatial structure of the geographical ensemble and correlate these results with registrations of certain kinds of activities by people in place. These activities relate mostly to human actions and certain kinds of human perceptions. However, the symbolic meaning of urban form and a place's genius loci cannot be grasped by space syntax. According to Seamon, the added value from space syntax is that the method can demonstrate that the spatial arrangement of the built environment can describe lively and well-used public spaces or empty and lifeless public spaces. The experience of these issues relates to the phenomenological experience of a place (Seamon 2020, p. 7).

While researchers taking a phenomenological or architectural extensionalistic approach seek to describe the underlying essential qualities of human experience and the world where these experiences occur (Seamon 1994, p. 37 and Seamon 2012), researchers with a space syntax approach seek to identify the spatial conditions for lively or quiet urban squares, streets, neighbourhoods, etc. Understanding the spatial conditions of pedestrian flow rates and degree of urban vitality is also an essential component for understanding the sphere of a place. This aspect is lacking in much of the literature on place phenomenology. When developing a systematic and comprehensive architecture theory where all kinds of aspects concerning how human beings exist in their life world are taken into account, space syntax is one essential part in providing an understanding of the life of places. Even though Norberg-Schulz criticises taking a quantitative approach in studies on the built environment (Norberg-Schulz 1967, p. 202), a space syntax approach can at least provide some exact evidence on how some spatial components of the built environment create lively or quiet places. Therefore, generalisations and theory building on built environments requires multiple research approaches incorporating conflicting epistemological and ontological assumptions (Seamon 2011).

Are there intentions in the way the built environment is constructed? Or are there intentions behind how human beings behave in the built environment? Intentions seem to play a role in constructing the elements shaping a place's character. These elements are defined to be the architectural style of buildings and their ornaments such as the shape and forms of windows, doors, plinths, roofs, and walls. Other artefacts such as the texture of the streets, windows, fountains, etc. also shape a place's character. However, studies concerning place structure tend to focus on the observed human behaviour rather than on human intentions and spiritual traditions. The intentions can be found in the kind of rationality people have in the way they behave in urban space and how they organise the spatial set-up for their daily activities. As Hillier and Hanson write, a space syntax approach is about understanding "the social content of spatial patterning and the spatial content of social patterning" (Hillier and Hanson 1984, pp. x–xi). This is a small, but significant contribution towards a comprehensive theory on built environments.

6.9 Epilogue: A Thought Experiment for the Sustainable City Debate

How can the theoretical aspects of space syntax be applied in the sustainable city debate? In this epilogue section, we carry out a thought experiment on how spatial parameters can encourage or limit sustainable urban transformation and sustainable mobility means. We further connect the sustainable city debate to existing space syntax theories and understandings on the relationship between space and society.

The challenge is that sustainable development concerns both normative and descriptive issues, and here we are dealing with present as well as future needs. In order to predict future needs, a descriptive approach is needed from a present context. We have to explain or understand what a sustainable city is as an 'object' and how this 'object' can generate sustainable ways of behaviour and sustainable urbanisation processes. Sustainable urbanisation processes can include low energy use for transport, high walkability potentials ('last mile connectivity'), low consumption of nature resources, low degree of urban sprawl into the countryside, safety, possibilities for social contact, healthy cities, and a natural mixture of all types of people in public spaces.

To date, precision in the spatial elements for describing a sustainable city is missing, and this lack of precision of the spatial elements leads to a lack of spatial analysis methods, which in turn, leads to a lack of evidence on the relationship between the built form and the sustainable behaviour of its users. This again leads to weak explanations on what a sustainable city is, even though such explanations are needed to make operational policies and to develop plans for enhancing sustainable urbanisation processes. However, some attempts for describing urban sustainability were made at the end of the 1990s. The compact city model is proposed to encourage sustainable ways of living (Roger 1999; Jenks et al. 1996). However, precise definitions of the compact city's spatial components are missing, and mostly normative statements on how to plan and build a sustainable city have been proposed. Understanding how spatial forces can generate sustainable urban processes is lacking in most writings on urban sustainability connected to the debate on urban compactness.

Urban compactness can be approached from a space syntax point of view because compactness is a topological property. In a very loose manner of speaking, the word compact describes that which is closely and firmly united, pressed together, dense, fine-grained, and packed into a small space (Encyclopaedia Britannica 1955). The answers might result in an understanding of how the spatial configuration of an urban street network generates movement and visibility and how it influences the dispersal of economic and social activities.

Most writings on urban sustainability and compact cities describe the problem cities are facing today with regards to sustainability (Roger 1999; Jenks et al. 1996; Calthorpe 1993). Most authors offer quick normative proposals as to how one should design a compact city. However, what is missing in these writings is a concise understanding of how compact cities function with regards to social and economic activities and to the power of the urban street network itself for generating human movement by foot or vehicle and the subsequent social and economic effects of this.

According to the Brundtland report, one of the basic environmental problems of modern cities is high energy use for transportation—generally speaking, private car dependency (Brundtland Commission 1987). Private car dependency not only relates to a lack of available and efficient public transport, but also to the spatial structure of the street and road network. This spatial structure influences the way people move, either by foot, public transport, bicycle, or by car, and how urban functions are dispersed. Building density and a mixture of activities first and foremost depend on the spatial structure of an urban street network. The relationship between the density of the built mass and transportation is another key to achieving a sustainable city (Rådberg 1996; Næss 2006a, b; Saglie 1998), and the higher the density of the built mass, the greater the mix of various urban functions and the greater the energy savings for transport per person (Roger 1999; Næss 2006b).

However, how a street and road network's structure can generate private car dependency is seldom taken into account in current research and planning practice.

Social interaction and physical movement certainly shape a built environment, and there are interdependencies between the physical built environment and both economically and socially motivated movement. Thus, physical form and social activity influence each other. Urban compactness thus should be understood in terms of movement and interaction and greater inter-accessibility of urban functions within a short metric distance.

An account of compactness and sustainability in configurative terms has to be descriptive because it concerns both structural and social aspects. While Alexander (1965) concentrated on structural aspects and Jacobs (1960) accounted for social aspects, a space syntax approach offers mathematical means to consider the two aspects at the same time. Compactness is thus understood in terms of space.

6.9.1 Describing Compactness with Space Syntax

The following examples will demonstrate how a compact vital city can be described in a concise and sustainable manner. In his book *Towards an Urban Renaissance*, Richard Rogers illustrates some principles on compact urban centres (Roger 1999, p. 53). Compact urban centres are indicated as grey circles concentrated around a public transport hub. The grey colour indicates high urban compactness, probably in terms of high density of the built mass. The finer spatial content inside these circles is missing, and Rogers's illustration does not show how these centres can function socially and economically in a sustainable manner. Likewise, a concise understanding of how each centre relates to its surrounding areas and the whole city is lacking. In general, the fine-grained street grid and its interconnectivity are not taken into consideration at all.

Figure 6.20a shows how compact urban centres are described in most planning and policy documents. Often strategic development plans for densification consist of colouring the appointed areas in a darker colour than the rest of the city. In most cases, these areas tend to surround metro or train stations. The aim is to show the areas where the density of the buildings can be increased. However, fine-grained urban data on how the local street network is connected to the public transport hub are often lacking.

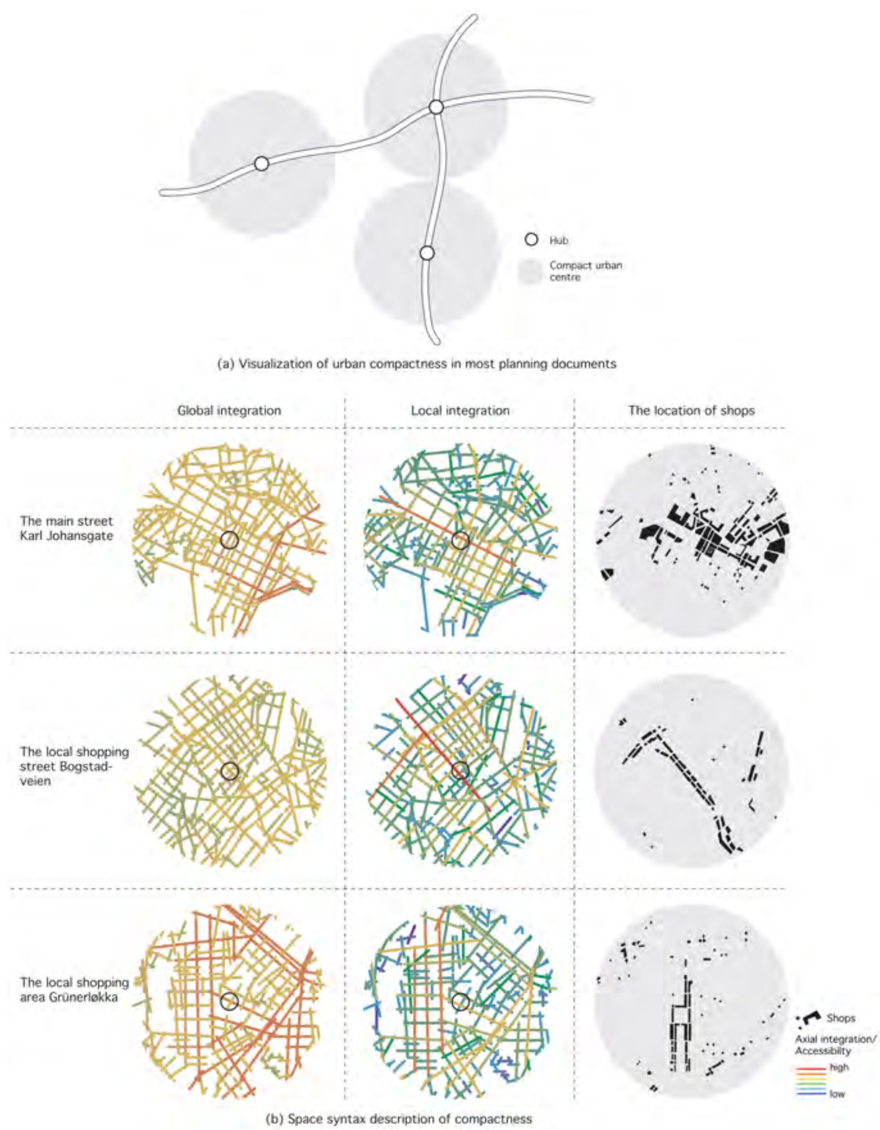

Fig. 6.20 A way of visualising urban compactness in most planning documents (**a**) and a space syntax description of urban compactness in terms of degrees of spatial integration in the pedestrian-based shopping areas in Oslo (**b**)

Below in Fig. 6.20, local and global integration analyses are shown within a radius of 1 km of the street networks of the three main pedestrian-based shopping areas in Oslo. The highest local integration is on the main shopping streets. The location patterns of the areas' shops are shown at the right side of the figure. The black ovals indicate large shopping centres. All of these areas have in common that they provide a dense and well-connected street network within a short metric distance of 1 km. This is an indication of compact sustainable urban areas. The density of the street network is high and the local and global integration values are also high.

Figure 6.21 depicts two car-based shopping centres located at the globally highly integrated Ring road 3 in Oslo. The local integration values and the density of the street network are low in these two areas. The street network has a tree structure, and the building density is low. This does not encourage movement by foot. Urban centres with this kind of spatial structure are examples of unsustainable urban areas due to their low degree of walkability. In comparison with the grey circles used in most planning documents (Fig. 6.20 top), a space syntax approach (Figs. 6.20 bottom and 6.21) shows both the fine-grained detail of the street and road network and their degree of inter-accessibility on a local and city-wide scale.

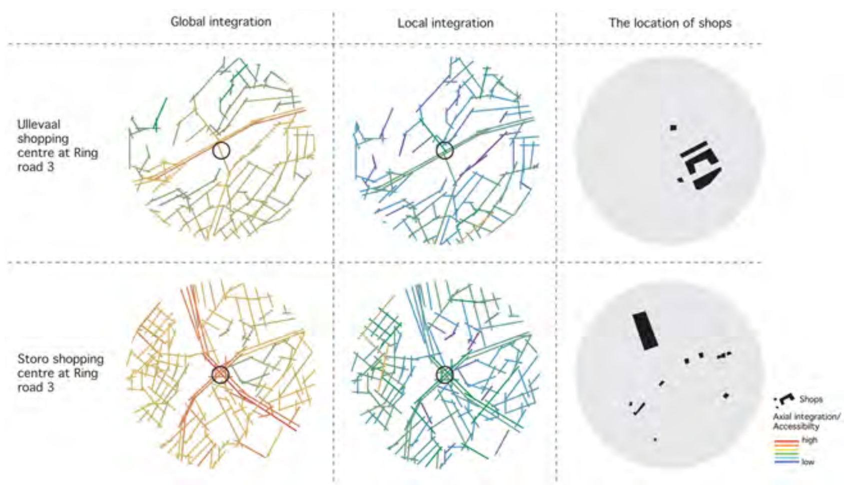

Fig. 6.21 A space syntax description of urban compactness in terms of degrees of spatial integration in two car-based shopping centres in Oslo

To illustrate the differences, Fig. 6.22 shows figure-ground diagram of Bogstadveien as an example of a pedestrian-based shopping street and Storo Senteret as an example of a car-based shopping centre in Oslo. The street network density, building density, and land use diversity are high in the Bogstadveien area, whereas they are low in the Storo Senteret area. All buildings have entrances and windows facing towards the streets in Bogstadveien. Conversely, most of the areas around Storo Senteret are covered by asphalt and are car dominated. The area is known to be pedestrian unfriendly, and the large shopping centre is turned inward. Storo Senteret has few entrances, and they are hard to find for pedestrians. For the car drivers, access to the shopping centre is direct from the parking garage.

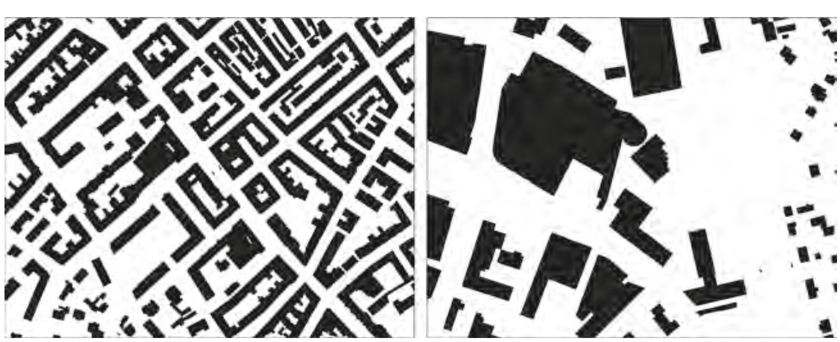

Fig. 6.22 Left: Bogstadveien as an example of a pedestrian-based shopping street. Right: Storo Senteret as an example of a car-based shopping centre

Furthermore, in recent research with the case studies of Zürich in Switzerland and Bergen in Norway, correlations were found between the street network configuration and energy use for transport. Neighbourhoods with high values for the angular choice analysis and with a low and high metric radius have low values on energy use for transport. These kinds of spatial configurations enhance walking, cycling, and the use of public transport. The highly integrated main routes are suitable for implementing public transport means such as trams or buses. Conversely, neighbourhoods with low values on angular choice with a low metric radius enhance private car dependency. Likewise, the same accounts when the neighbourhood has high values on the angular choice values but low values on the angular choice with a high metric radius (De Koning and Van Nes 2019a, b).

Hence, criteria for successful compact pedestrian-based urban centres imply high density of the street network within a short metric distance and interconnectivity between local streets, main routes, and the road network of the whole city. The spatial structure of the mobility network can thus encourage or block sustainable modes of transportation. Therefore, large interventions on the mobility network can affect the socio-economic life in cities.

In traffic planning, there is, however, a contradiction between traffic safety and social safety. Banning cars from urban centres contributes to ‘dead’ town centres, in particular after shops are closed. On the contrary, having high car-accessibility to urban centres contributes to traffic accidents and high levels of noise and pollution. Seemingly, the key is to ‘humanise’ the private car in planning practice with the purpose of retaining lively streets and economically vital town centres. Otherwise, overly intense restrictions on private car use in town centres can contribute to the development of out-of-town shopping centres along the highways.

In Copenhagen, the influence of Jan Gehl’s research has contributed to a new shift in planning. The concept ‘To Copenhagenize’ consists of reducing the role of the accessibility of private cars and enhancing walking and cycling. The role of the road engineer is reduced, and the focus is on creating urban spaces as places to stay and perform social activities rather than just spaces to travel through (Gehl 2010, p. 13).

In this context, the construction of new road links can have a comprehensive impact on a city’s spatial structure and socio-economic activities. Whether or not a new road enhances sustainable means of mobility depends on at least two factors—the kind of street network the new road is imposed upon and how this imposition comes about. Therefore, the methods applied here and the results thus obtained can be useful for predicting certain consequences of new road projects.

So far, rigid traffic safety standards seem to steer how new motorways or main routes through urban areas are interconnected to their local vicinity. In addition to this, research using space syntax can shed some light on the role of the road engineer in urban development. The road engineers create the necessary spatial framework for the socio-economic life in built environments. It all depends on how their planned new road links segregate, integrate, connect, or disconnect the urban areas they are imposed upon. Thus, everything depends on various degrees of connectivity, adjacency, visibility, and accessibility (Van Nes 2021). In addition, the effects of the relevant kinds of changes can be explained in terms of changes in the location patterns of shops and retail outlets as well as the various means of mobility—whether they are sustainable or not. In this case, the theory of the natural movement economic process with the spatial configuration of the street network as a sufficient condition is relevant for explaining the impact of the spatial changes of the street network on built environments.

6.9.2 The Street-Building Interface and Its Impact on Street Life and Safety

During the last two decades, living in central urban areas has become popular in Europe, and this ‘urban renaissance’ has contributed to an increase in estate and property prices in inner city areas. Many people are seeking urban areas with high social, cultural, and spatial diversity; short distances from dwellings to work, leisure, and cultural activities; and the ability to take advantage of all the opportunities a city has to offer (Roger 1999). In addition, these trends are in line with new planning policies where the aim is to densify existing built-up areas instead of increasing urban sprawl into the countryside. The idea is that high diversity and density of various kinds of land use, functions, and cultural activities will contribute to vital and lively urban areas and economic growth (Roger 1999, p. 45). However, the topological spatial relationship between private and public space and its impact on urban street life is a forgotten aspect in most contemporary writings on compact cities, urban design, and urban planning.

Architects tend to emphasise the feeling of privacy within the context of modern living in their design projects. Examples of the kinds of built environments these tendencies generate can be seen in Fig. 6.23. Often an explanation can be found in the individualisation process of human beings over the last 60 years in western society. There is a belief that there is a need for a high degree of privacy when a large group of people are living together in a small number of square metres. The effect is that dwelling entrances and windows are hidden away from public streets.

Fig. 6.23 Modern building facades turned away from streets

Micro-spatial relationships on the street plinth level play a significant role in the socio-economic life of human beings. The architecture of building openings shapes the spatial possibilities or limitations for visibility, accessibility, and permeability and thus influences the various degrees of contact possibilities between the private and public spheres. In particular, urban renewal projects, modern housing areas, and new large-scale urban development projects tend to lack adjacency, permeability, and intervisibility between buildings and streets. This has negative effects both on street life and the degree of perceived safety of these areas. Jacobs already advocated that buildings should have 'eyes on the streets' in the 1960s. In addition, streets with buildings lacking 'active frontage' reduce the attractiveness of walkability in neighbourhoods, which again enhances private car dependency and perceived unsafe streets. Figure 6.24 shows an example of a recently finished neighbourhood in Delft. The 'active frontages' are orientated towards the back gardens where the private life takes place, whereas the entrances on the homes' front-sides are turned away from the streets.

Fig. 6.24 Modern residential area in Delft. The dwelling and the private life are oriented towards the canals (left) on the house's backside, while all the streets are unconstituted on the home's front side (right)

High values on the FSI are not always a condition for safe and lively streets. In the 'vertical city' of Hong Kong, there are several examples of new housing projects that are not well connected to the street. Even though the number of apartments is high, there is little street life at the street plinth level (Hwang 2006). Stacking apartments often contributes to vertical sprawl, but degrees of street life seems to depend on how these flats' entrances are connected to the street. However, the degree of interconnectivity and the topologically shallow public–private interface is often forgotten. All of these activities depend on the spatial configuration on the plinth or built-up street sides. Figure 6.25 shows images of a recently finished housing project near Shanhanguan in China. The number of inhabitants in this neighbourhood is high, but the streets lack shops and places for contact.

Fig. 6.25 Images of a vertical neighbourhood in Shanhaiguan in China

The micro-spatial conditions of the street segment are inter-related to the macro-spatial conditions of the city's street network. The definition and operationalisation of the micro-scale conditions is, however, still in a preliminary phase and is an area that can be improved upon in the near future. At the very least, some concepts useful in urbanism have been introduced and have brought significant aspects into the urban sustainability and compact city debate. This is not only important for urban research, but also for the design and planning of our cities.

The quality of the building–street interface in our built environments seems to be affected by a division of responsibilities. The road engineer is concerned only about the street and road dimensions, whereas the project developers are concerned with the maximum short-term profits they can get from their plots. The municipality lacks operational concepts and tools to ensure safe and vital streets in their policy and planning documents and in the way building permissions are given.

If we connect all of these above-mentioned issues to theory building and complex conditions (see Sect. 6.5), street life and the perception of safety appear to be dependent on a complex set of sufficient conditions. Perception of safety seems to depends on the presence of people in the streets. Here we use von Wright's conjunction of a phenomenon, and again we are dependent on a particular case. Here we use the results from a research project on the perception of the street safety of six different neighbourhoods in Bergen centre (Rønneberg Nordhov et al. 2019).

Hermeneutic explanatory model.

Maybe *p*, *r*, *s*, *t*, or *u* alone is sufficient for *q* to occur. However, if all of them occur together, *q* is certain to occur too.

Hermeneutic explanatory model of the Bergen case

Maybe *constituted streets*, *short topological depth between private and public space, highly intervisible streets, high density of entrances*, or *high street network integration on all scale levels* alone is sufficient for *the locals' perception of safe streets in Bergen*. However, if all these spatial aspects occur together, *the streets will be perceived as safe by the locals in Bergen*.

6.9.3 Spatial Structure, Configuration, and Sustainability

At least since the time of the Industrial Revolution, we have seen how comprehensive technical inventions have affected the spatial structure of built environments, and conversely how spatial products have affected social and economic behaviour. Humans are able to change their built environment, and they have purposes and intentions in doing so. It is not always clear what the intentions are, but those concerning economic activities strive for profit maximising. This makes it possible to predict some of the impacts on society based on the spatial structure of the built environment.

Alexander Cuthbert claims that writings in the urban design discipline should make a connection to political economy. As he writes, "The more recent form—spatial political economy offers promise in that its fundamental concern with the processes through which social space is produced, reproduced, transformed and exchanged, intersects neatly with how specific forms of social space arise" (Cuthbert 2007, p. 211). Aiming at the creation of urban areas that can develop in a sustainable way cannot ignore the behaviour of producers and consumers and the way the built environment influences them. From a space syntax point of view, understanding what an urban area's sustainable development consists of depends on an appropriate account of the geometrical and topological structure of its street network.

City growth can affect the global integration core and the development of local integration cores. A space syntax approach can help to understand why the location of the vital main centre changes and why from a spatial point of view the old centre becomes segregated. In many cases, large amounts of resources are used to revitalise segregated old historic urban centres. These activities consist of putting new functions in old buildings, restoring historic buildings, shining up the street-scape and squares, and making policies to adjust new buildings to existing ones. What is missing in most plans and policies of this kind is a genuine understanding of how improvements to the interconnectivity of the street network and the topological relationship between private and public space can generate vital urban activities in these areas.

In the Netherlands, there is a tendency to regenerate whole residential areas thirty years after realisation. Often these areas are classified by the government as 'problem neighbourhoods' due to a high concentration of youngsters, immigrants, or the socially under-privileged. Most of these areas are post-war social housing areas with poorly integrated and unconstituted streets and with large numbers of semi-private spaces (Van Nes and López 2013). Resources are often put into restructuring these areas, but the focus is mostly on the intrinsic properties of space in terms of changing the building materials and architectural styles, shining up the parks and the playgrounds between buildings, adding some new programmed activities into the neighbourhood, etc. (Van Nes and López 2013). Recently, a strategy has been to stimulate a gentrification process by enhancing a large variation of social composition of the residents. Houses are provided for residents from all social classes in society, from the rental apartments for low-income residents up to luxury apartments or houses for sale to high-income people. So far, these strategies have not proven to be successful. The key seems to be to deal with urban 'space' before implementing urban 'form' in these neighbourhoods.

The relevance of compactness for urban sustainability can be assessed more adequately in spatial configurative terms than in other less formal terms. This is because a space syntax approach has operational terms to distinguish the spatial parameters of the built environment as an object shaped by societal processes, and conversely how this object influences various socio-economic processes. An approach of this kind assesses in what way economic and social behaviours are influenced by spatial configurative changes, and conversely, how they, in turn, influence such changes. Urban compactness can be described in spatial configurative terms as a street and road network's various degrees of inter-accessibility and how this network is connected to the whole city on local and global scales.

A high density of streets within a short metric radius and their high degree of inter-accessibility on various scale levels in an urban street network contributes to vital urban centres and residential areas. It is not enough to just encourage high density in urban areas by increasing the number of dwellings and the locales for economic activities or just a generally higher density of the built mass. It is the density of the street network, its degree of interconnectivity between main routes and local street network, its degree of permeability and visibility from adjacent buildings, and its local and global position in the whole system that enhances walking and sustainable modes of mobility such as public transport. The density of lively residential areas seems to be a by-product of the density of the urban street network and the dispersal of integration values within the network.

If a compact urban area is conceived of as having a dense and well-connected street network, both on a local and on a global scale, and high intervisibility between buildings and streets, then compactness of this kind is a complex set of sufficient conditions for generating sustainable urban processes in terms of a low degree of energy use for transport (public transport, walkability).

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—in other words, whether the built environment turns out to be sustainable or not. Generating sustainable mobility means from a spatial point of view a chain of coincidences, and there are several physical aspects of the built environment that have to be present at the same time.

High density of a highly connected and integrated street network within a short metric distance and high street inter-visibility have to be present at the same time in order to generate walkability, street safety, and low energy use for transport (De Koning and Van Nes 2019a, b). If a street is highly integrated, but all buildings do not have entrances and windows on the ground floor towards the streets, this will negatively affect the degree of walkability and the perception of street safety. Blind walls and buildings turned away from streets are perceived to be unsafe.

Seemingly, the spatial structure of the street network on various scale levels matters for achieving some of the United Nations sustainable development goals. Reduced 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 wellbeing). Streets enhancing gender balance touch upon goal 5 (gender equality), whereas safe streets and possibilities for micro-economic activities touch upon goal 11.

6.10 Exercises

Exercise 1

Write down your research question(s). Reflect upon whether your research question has a descriptive or a normative approach.

Exercise 2

Given the following logical structure:

p is a <u>sufficient</u> condition for *q*.

p is a <u>necessary</u> condition for *q*.

Discuss which one of these two modal logics formulas is right for the following statements:

(a) High spatial integration of the street network is a _____ condition for high pedestrian flow rates.
(b) The intention to reduce the clashes between Protestants and Catholics was a _____ condition for the construction of the peace walls in Belfast.
(c) The removal of the Berlin Wall was a _____ condition for the emergence of Berlin's main shopping street Friederichstraße.
(d) Placing an object in the middle of a square is a _____ condition for segregating this square.
(e) A highly integrated street is a _____ condition that shops will locate themselves along the street.
(f) Short urban blocks are a _____ condition for generating more people in streets.
(g) Implementing long buildings is a _____ condition for segregating urban space.
(h) The intention to preserve the old street structure is a _____ condition for the conservation plan of the Friederichstad area in Berlin.
(i) A new road link is a _____ condition for changes in the integration values of the street network.
(j) The intention to improve the accessibility to Trafalgar Square was a _____ condition for implementing the new pedestrian plan.
(k) The intention to reach as many customers as possible is a _____ condition that shops will locate themselves along the highest accessible streets in a city.
(l) The intention to relieve the town centre from through traffic was a _____ condition for constructing the ring road in Coventry.

(m) High density of the built mass is a _____ condition for a high degree of land use diversity.
(n) The intention to implement the planning ideals from the CIAM 1933 conference was a _____ condition for implementing a segregated street network in Oosterwei in Gouda.
(o) The Eiffel Tower is a _____ condition for the city image of Paris.

Exercise 3

Below are some complicated statements. Try to fill in whether it is a necessary or sufficient condition. Or where it is impossible to use either. Explain why.

(a) A landmark is a _____ condition for a place's image.
(b) A compact city is a _____ condition for generating sustainable mobility means.
(c) A dense urban street network is a _____ condition for a high degree of walkability.
(d) A segregated street network was a _____ condition for the high occurrence of crime in Oosterwei in Gouda.
(e) The lack of intervisibility of entrances and windows towards streets is a _____ condition that women avoid frequenting these kinds of streets.

Exercise 4

Given the following advanced logical structures below:

Conjunction of a phenomenon: Maybe p or r alone is sufficient for q to occur. However, if p and r occur together, q is certain to occur too.

Disjunction of a phenomenon: Maybe q does not require the presence of P (unconditionally), nor the presence of r (unconditionally); but q may nevertheless require that at least one of the two, p or r, be present.

Discuss below which of the above formulas is suitable for the statements below. Explain why you chose them. First, we show one example:

p = straight lines, r = partitioning a longer line, q = increased depth.

Maybe *increased depth* does not require the presence of *a partitioning of a longer line* (unconditionally), nor the presence of *straight lines* (unconditionally); but *increased depth* may nevertheless require that at least one of the two, *a partitioning of a longer line* or *straight lines*, be present.

Here in this case the statement above is a disjunction of a phenomenon with a set of complex necessary conditions.

(a) p = high spatial integration on all scale levels, r = constituted streets, q = Street life in London
(b) p = high local integration, r = high global integration, q = high flow human movement through cities
(c) p = high spatial integration, r = high degree of function mixture, q = high building densities
(d) p = diverging political ideologies, r = construction of the Berlin Wall, q = disappearance of shops along the Friederichstraße in Berlin
(e) p = spatial segregation, r = low building densities, q = mono-functional areas
(f) p = the highest globally integrated road in Beijing, r = Mao was an important leader for China for many years, q = location of the large picture of Mao at the main entrance of the Forbidden City in Beijing
(g) p = street constitutedness, r = high local and global integration, q = high degree of walkability
(h) p = road blockages, r = new road link, q = spatial configurative changes of the street network

Exercise 5

Describe what kind of approach your research belongs under. Is it positivistic or hermeneutics? Describe why?

Exercise 6

Describe what part of your city centre is a cultural centre or an economic centre.

Exercise 7

Describe the theoretical findings from your research. Do the results from your research explain a phenomenon or do they contribute to an understanding of a phenomenon? Give reasons as to why.

Exercise 8

Describe with your space syntax analyses what parts of your own city can be considered to be sustainable or not in terms of encouraging sustainable mobility means, safety, and street life. Identify at the end the parts where you have to use:

(a) necessary conditions
(b) sufficient conditions
(c) complex sufficient conditions (Conjunction of a phenomenon)
(d) complex necessary conditions (Disjunction of a phenomenon)

6.11 Answers

Exercise 2

2a: sufficient, 2b: necessary, 2c: necessary, 2d: sufficient, 2e: sufficient, 2f: sufficient, 2g: sufficient, 2h: necessary, 2i: sufficient, 2j: necessary, 2k: sufficient, 2l: necessary, 2m: sufficient, 2n: necessary, 2o: necessary.

Exercise 3

3a: neither, because it is not connected to a particular place.

3b: neither, because the term 'compact city' is vaguely defined.

3c: neither, because walkability depends on the cultural background and other spatial or physical parameters such as pavements, street constitutedness, etc.

3d: neither, because there could be other spatial and social parameters.

3e: neither, because it is not connected to a particular place.

Exercise 4

Conjunction, 4b: Disjunction, 4c: Conjunction, 4d: Conjunction, 4c: Disjunction, 4f: Conjunction, 4g: Conjunction, 4h: Disjunction.

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Space Syntax Applied in Urban Practice

7

Contents

Abstract

In this chapter, we discuss the application of space syntax in consultancy for urban planning design and practice. First, we present the scientific challenges to tying general understandings and theories to urban planning and design practice. Some elementary principles for communicating results from research and theories to practitioners are demonstrated. We further explain the principles for successful master planning and the principles for designing vital and safe public realms related to the use of space syntax. This is followed by a discussion on how to avoid common errors when planning for vital neighbourhoods and cities. We present examples from practice where space syntax has played a major role. These include regenerating Trafalgar Square in London, evaluating various proposals for a new road link in the Dutch city of Leiden, developing strategies for the whole province of North Holland, and densification strategies in the Norwegian town of Bergen. In the conclusion, we discuss major pitfalls when applying space syntax to urban design and planning projects in practice. Exercises are provided at the end of the chapter.

Keywords

Urban planning and design practice • Option testing • Baseline studies • Vital and safe neighbourhoods and cities

Key Concepts

Urban design consultancy • Baseline studies • Principles for vital and safe public realm design • Scenario and option testing

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Learning Objectives

After studying this chapter you will

- have knowledge about how to connect space syntax theory and methods to urban planning and design practice;
- have an understanding of how space syntax is applied in urban planning and design practice;
- be familiar with the principles for designing vital and safe public realms, and
- be able to carry out an urban diagnosis and prognosis approach with scenario and option testing.

7.1 From Theory to Practice—The "What Happens if…" Relationship

How we apply space syntax in practice is based on results from established theories and research. The application of the space syntax method does not necessarily reveal the 'right' design solution or optimal answer to spatial challenges, but it can to some extent predict the socio-economic impacts of urban planning and design proposals. The theory of spatial combinatorics, the theory of natural movement (economic process), and the theory of the natural urban transformation process give (Ye and van Nes 2014) indications on how an urban design might function after implementation. Hence, the space syntax method can provide detailed analyses of the spatial configurative changes the design proposal will bring about (Yamu et al. 2021). However, drawing final conclusions on the indications of the socio-economic effects is heavily dependent on a variety of conditions. First of all, baseline analyses of the current context must be made. The interpretations of the analyses depend on existing space syntax theories and on research results related to the problems that need to be solved. Second, you have to be aware of the limitations of space syntax, for example, issues related to social rationality, place identity, and various cultural contexts cannot be addressed through space syntax.

Space syntax is not capable of making normative statements about what the optimal design solution is. Instead, the primary aim of space syntax is to find out what is desired to be achieved and what actually can be achieved with the urban design proposal. Once a variety of spatial options have been tested with space syntax, possible effects—in connection with current theories on space and spatial relationships and on space in relation to movement and economic developments—can be derived (Yamu et al. 2021). Thus, it all depends on the following question: "*What happens if …*"

If I do *this*, the effect will be *that*.

If I want *this*, I had better do *that*.

With regard to context-dependent situations, where insights into local culture, laws, and regulations are important, we are dealing with the following types of statements:

If I want to do *this*, I have to gain knowledge on the local culture, setting, users' intentions, and decision-makers' intentions first

If I want to do *this*, I have to understand that the particular local context might block the intended and wanted effects.

To create a well-functioning built environment, *space* has to be dealt with before the *form*. This means that the planning and design of urban areas have to deal with the pathway network first (Seamon 1994, p. 36). If people's movement through the urban street network generates land use patterns correlating with various spatial integration values, urban design proposals can be tested to get an indication of the potential degree of (vital) urban street life. If the land use intensity is affected by the volume and density of people in the streets, then space syntax analysis allows one to assess effects for the future potential for street life connected to land use. If the spatial conditions are assessed, then the design of the built form can be carried out. Space syntax can help urban planners and designers in their decision-making for well-functioning urban designs because it reveals the hidden spatial structures of various design proposals for the same area (Karimi 2012).

However, the space syntax jargon can often be difficult to use in communication with urban planners and designers. The challenge is to create a consistent and understandable space syntax language that allows for easy communication with practitioners and space syntax novices from urban planning and design and other disciplines. Thus, a simple visual and diagrammatic language is often key for the successful communication of space syntax results. Space syntax results have to be understandable, for example, by road engineers, urban planners, urban designers, architects, criminologists, decision-makers, and project developers. As a support tool in communication, the question 'What happens if…' is often very helpful. It can also be formulated as 'If we do this, the effect will be that.' This can be applied to the master planning principles, as well as to the safe public realm principles. Applying space syntax to urban planning and design scenarios to answer the 'What happens if…' question is referred to in the space syntax jargon as 'option testing'.

7.2 Spatial Principles for Designing Vital and Safe Public Realms

In the following, we introduce nine spatial principles for designing vital and safe public realms. These principles include recommendations from a city and neighbourhood scale to a micro-scale. For these principles, the 'What happens if…' relationship also applies. However, the presented principles are limited in their methodological setup, and this non-exhaustive 'checklist' only seeks to provide a guideline for creating safe, lively, and economically vibrant neighbourhoods. The principles are based on the following observations from research and practice (Van Nes and López 2010, 2013). Neighbourhoods with a relatively high crime rate compared to neighbourhoods with a low crime rate generally have their main routes running through their local centres. A well-integrated and well-connected main road encourages a diverse micro-economy, and it supports a natural surveillance mechanism due to a mix of different types of people. Furthermore, the position of buildings and the locations of windows and entrances, including active functions on the ground floor level, can create safer and more vital neighbourhoods with a higher degree of social control.

Let us not forget that the social composition of residents, their lifestyles, and their decisions are important factors in ranking the priorities for spatial improvements in neighbourhoods. Spatial parameters matter in the socio-economic performance of a neighbourhood. It is all about how the spatial layout contributes to reducing criminal opportunities, shaping a natural social control mechanism, and shaping opportunities for social interactions and a flourishing micro-economy. The nine principles for creating a vital and safe public realm are as follows:

(1) *Main routes passing through neighbourhoods*

Main routes have to go *through* neighbourhoods instead of *around* neighbourhoods. This assures that visitors travel through the neighbourhood and thus become potential customers to the neighbourhood's micro-economic market of local businesses. Further, visitors add to the natural surveillance mechanism of the neighbourhood due to their presence. The variety of different types of people in the streets throughout the day creates a safer neighbourhood, but social safety is often sacrificed in favour of traffic safety. If main routes are planned and implemented to go around a neighbourhood, the effect will most likely be segregated and mono-functional neighbourhoods (Fig. 7.1).

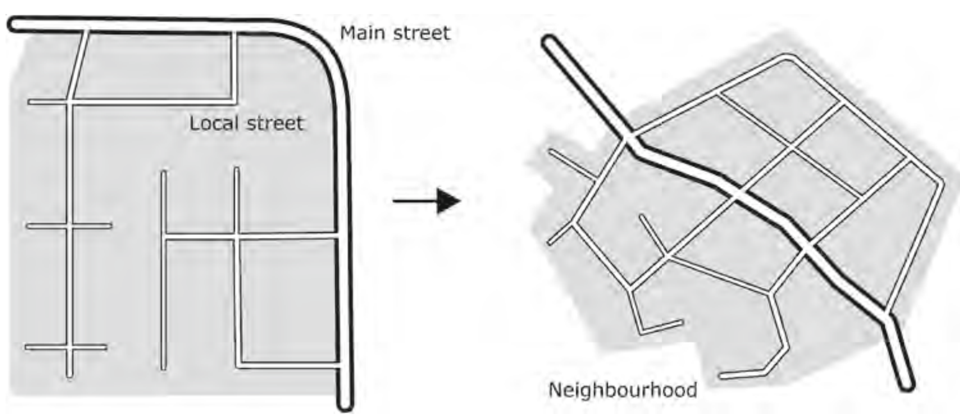

Fig. 7.1 Sketching two different locations of main roads. Planning for the main road to go through the neighbourhood (right) facilitates the spatial potential for the neighbourhood's street life and micro-economy. Where the main road goes around a neighbourhood, neither the social nor economic potential is realised (left), and segregated and mono-functional neighbourhoods are promoted

(2) *Main routes passing through local centres*

This principle is completed by the premise that main routes also have to run through local centres or at least be located tangentially to them. Local vital centres often have a well-connected, dense local street network with a variety of shops and micro-scale businesses. This urban spatial feature is often found in pre-war neighbourhoods. When the main routes run around the local centre, local shops and facilities tend to be limited. Either a local supermarket with necessary supplies or no shops at all are found in such neighbourhoods. This urban spatial feature is often connected to a post-War, modernist neighbourhood (Fig. 7.2).

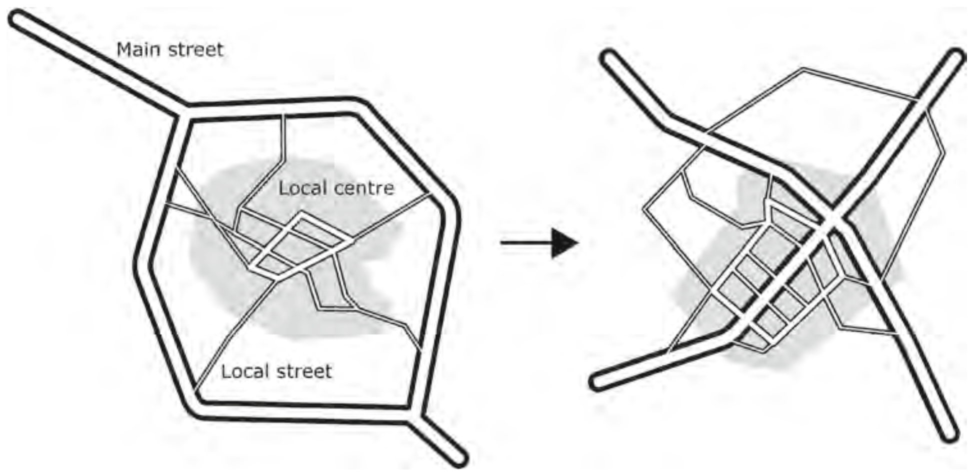

Fig. 7.2 If the intention is to generate successful local centres with a vital micro-economy and visitors performing a natural surveillance function for social safety, then plan main routes to run through an existing local centre (right) and avoid main roads that go around the local centre (left)

(3) *Enhance the network structure of the local urban street pattern*

A network structured generates higher local inter-accessibility compared to a tree structure. Thus, the greater inter-accessibility will contribute to a greater presence of people in the streets. When the main road is located centrally and goes through a neighbourhood or local centre, it creates greater inter-accessibility between locals and visitors and other through-travellers. Again, main routes located through existing centres support a high variety of shops, and therefore, a successful micro-economy. A main route running alongside the edge of a neighbourhood with a tree structure contributes to a sluggish micro-economy. Enterprises located along these main routes often have car-based accessibility (Fig. 7.3).

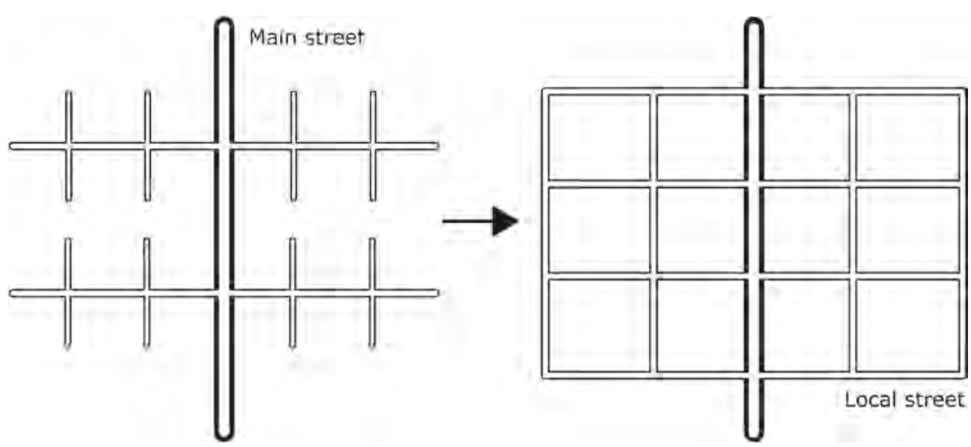

Fig. 7.3 Enhance a network structure (right) instead of a tree structure (left) for the local street pattern. This will generate high local inter-accessibility

(4) *Connect the main routes to all adjacent local streets*

Connecting local main routes to all local streets allows for pedestrian-based shopping streets with a large variation of shops and micro-scale businesses (Fig. 7.4). If the main route has only a few connections to local streets in close vicinity to each other, this creates opportunities for car-based shopping centres. These kinds of shopping centres tend to be located at junctions where the main route(s) are tangential to a neighbourhood. This contributes to mono-functional land use.

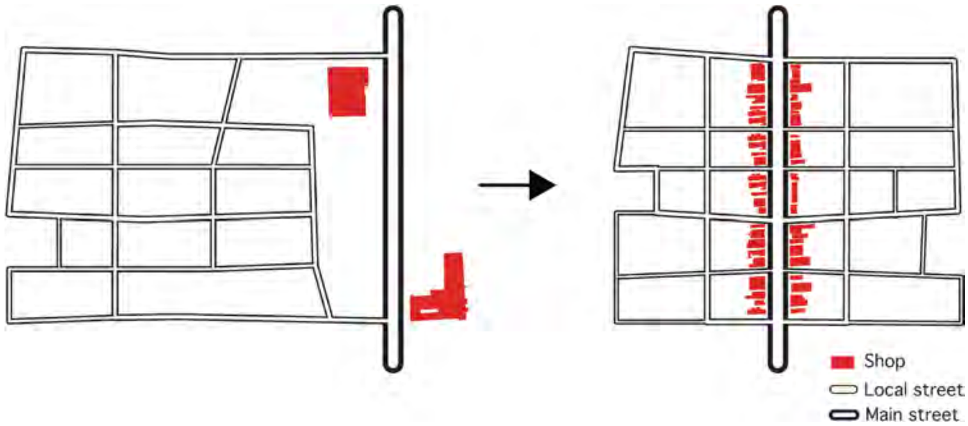

Fig. 7.4 The main route has to be connected to all adjacent local streets if the intention is to enhance a large mixture of functions with a high degree of flow of people (right). The main route only loosely connected to adjacent local streets enhances car-based shopping development (left)

(5) *Have buildings with windows and entrances facing towards the street*

Avoid blank walks along streets. Buildings facing the streets enhance the natural surveillance mechanism between buildings and streets. Conversely, buildings with no windows or entrances, buildings with blank walls, or blank walls only along streets contribute to a lack of social control between buildings and streets. This is due to people's avoidance of these streets as part of their routes through neighbourhoods. This invites anti-social behaviour (Fig. 7.5).

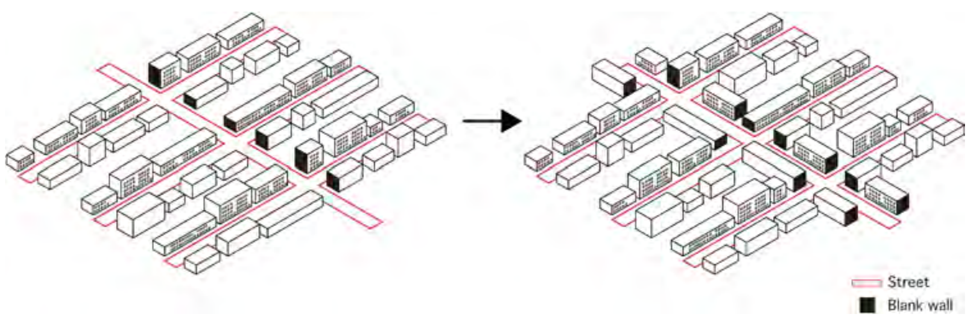

Fig. 7.5 Avoid buildings with only short sides facing towards streets (left). Enhance buildings with the long side facing towards streets (right)

(6) *Enhance active functions on the ground floor of buildings*

Active functions on the ground floor of buildings such as shops, offices, or dwellings contribute to a co-presence of people inside the building and in the street. This co-presence of people adds to the natural surveillance mechanism, and people inside the building can keep an eye on the street. In contrast, passive functions such as storage and parking garages on the ground level contribute to people-empty streets and a perceived lack of safety (Fig. 7.6).

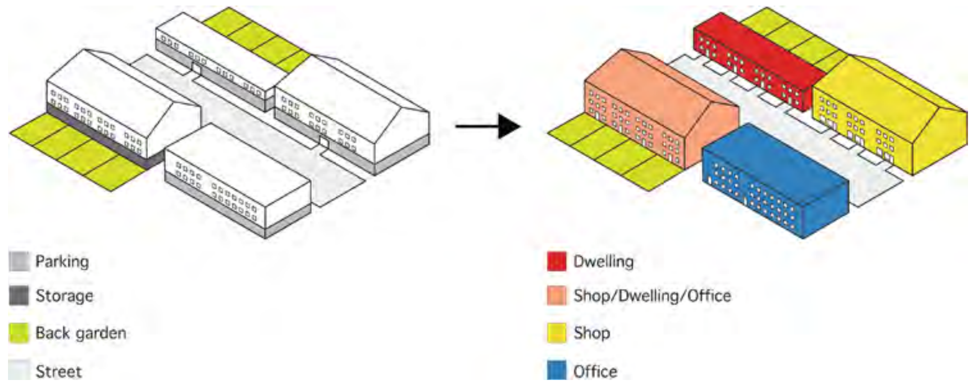

Fig. 7.6 Enhance active functions on the ground level to create a high level of co-presence of people inside the building and in the street. People inside buildings can have an eye on the street. Passive functions leave streets empty

(7) *Connect windows and doors directly to the street*

Doors and windows directly connected to the street on the ground floor level add to a natural surveillance mechanism and perceived safety. Streets with a lack of directly connected windows and entrances to the streets are often empty and have a lack of social control and are perceived as being unsafe (Rønneberg Nordhov et al. 2019) (Fig. 7.7).

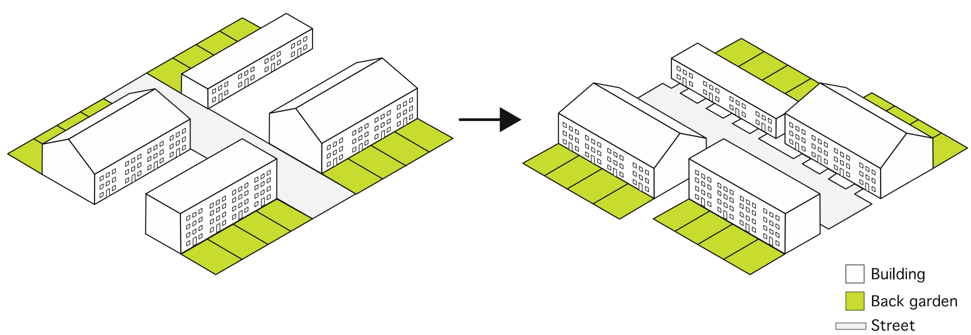

Fig. 7.7 Windows and entrances directly connected to the street on the ground level contribute to 'eyes on the street' (left). This is a natural surveillance mechanism between buildings and streets

(8) *Create a high degree of intervisibility*

Entrances and windows of buildings at ground level, directly connected to the street and facing each other, create a high degree of intervisibility. In cases where the implementation of intervisibility is not possible, planning constituted streets supports a natural surveillance mechanism. Unconstituted streets contribute to empty streets with a high degree of anti-social behaviour and an unsafe feeling (Rueb and van Nes 2009) (Fig. 7.8).

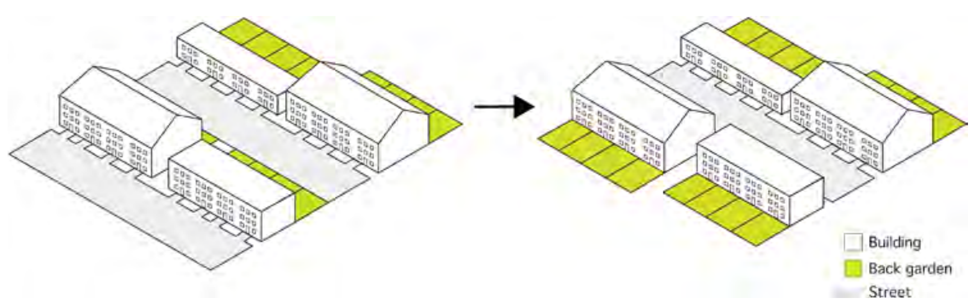

Fig. 7.8 A high degree of intervisibility in a street (right) and no intervisibility in a street (left)

(9) *Create direct connections between public and private spaces*

Enhancing a high degree of direct connections between public and private spaces enhances social control and natural surveillance between residents and people's activities in streets. A large number of semi-public or semi-private spaces between a dwelling and a public street contributes to a lack of street life and the feeling of gated communities (Fig. 7.9).

These principles are seemingly applicable for most countries because they are all about spatial interfaces on various scale levels. However, in some countries, poverty issues make these micro-scale principles difficult to implement. Examples of this can be found in many South American cities, and to some extent in some African cities. Therefore, the local social and cultural context needs to be studied carefully.

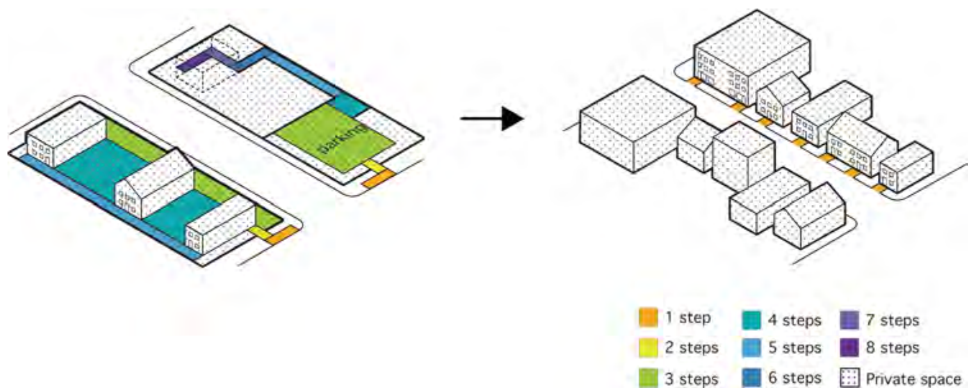

Fig. 7.9 The topological depth between the private and public space has to be shallow when the intention is to enhance street life (right). Large semi-private and semi-public spaces support deserted streets (left)

7.3 Learning from Past Errors

Most important when applying space syntax in urban design projects is to learn from past errors. This will further develop the application of space syntax in practice for designing well-functioning spaces while avoiding falling into the same traps as in the past. However, there exist a large number of urban projects around the world that have been built from the 1970s onwards that do not function as intended. In particular, three main errors from modern urban design and planning practice can be identified by the application of space syntax analyses (Karimi 2009):

(1) *Implementing urban motorways instead of urban boulevards*

On a macro-scale level, the first error is that urban planners, urban designers, and in particular, road engineers implement urban motorways as main streets instead of urban boulevards that focus on pedestrians. The spatial parameters of a vital and vibrant main street are an integrated street with both vehicle and pedestrian movement that is well connected to its vicinity, as well as to the whole city. Local and global movements are mixed in the way buildings and streets are permeable to one another. Instead of the old well-connected main street, urban motorways or fast highways with high traffic safety standards separating global and local movement are implemented in urban areas. There is no permeability from adjacent buildings and streets to these urban roads or highways. The effect is a suppressed movement economy that is based on private car dependency (Karimi 2009). Figure 7.10 illustrates the main boulevard in Stockholm and an urban motorway in Brussels.

On a micro-scale level, we tend to plan parking streets instead of dwelling streets. The parking of cars dominates the streets instead of shaping opportunities for all kinds of people to use and be in the streets. When the cars are parked at a 90- or 45-degree angle to the street, the cars dominate the streets. When the cars are parked parallel with the streets, the streets facilitate a balance of users (Fig. 7.11).

Fig. 7.10 Example of an urban main street in Stockholm (left) and an urban motorway in Brussels (right)

Fig. 7.11 Example of a balanced residential street (left) and a car-parking street in the Netherlands (right)

(2) *Separation of land uses into zones*

The second error that often occurs in modern(istic) planning practice is the separation of land uses into zones. In historic town centres, there is a mix of land uses in short walkable distances to one another, which minimises journey lengths. In modern planning practice, land uses are zoned into different areas, which creates longer journeys than in historic urban areas. The effect of these kinds of plans is a street and road network with complicated movement routes from everywhere to everywhere else (Karimi 2009). The metric length of the street and road network is much longer than in traditional urban area. A street network of this kind enhances private car dependency, which contributes to new and often inefficient urban strategies for how to handle increasing private car ownership.

Figure 7.12 depicts the historic and modern centres of the town Delft in the Netherlands. The active transport modes of walking and cycling between the various functions in the historic centre are more efficient compared to the use of car and tram as the best transport mode for the modern centre in Delft. This tendency can be identified in many cities around the world.

Fig. 7.12 Traditional urban areas tend to have a mixture of dwellings and commercial and office functions, whereas modernistic urban areas embrace separation of functions. This is illustrated in two examples in Delft, the historic centre (left) and the modernistic centre De Hoven Passage in Poptahof (right)

(3) *No active frontages*

On a micro-scale level, the third error in modern architecture practice is a lack of active frontages. Newly implemented buildings in urban areas are anti-urban in the way these buildings are not street dependent (Karimi 2009). Their entrances and windows are turned away from the public street, and this tendency can be identified in both shopping and residential buildings. Old urban buildings have windows and doors facing towards the streets and are directly permeable from the street. These kinds of buildings support a high degree of walkability and street safety.

In present modern architectural practice, buildings tend to have blind walls or blank frontages facing the street. Often, new residential areas and shopping centres are built to facilitate private car accessibility at the cost of short pedestrian journeys. In short, the social urban life between buildings is replaced with transport. Figure 7.13 shows an example of a traditional urban dwelling and a modern urban dwelling. For the modern urban dwelling, the main access to all the apartments is provided through one main open port. The main entrance is from the back yard of the building.

Fig. 7.13 Example of a traditional urban dwelling in Delft (left) and a new urban dwelling in Greifswald (right)

Figure 7.14 shows the same principles for a traditional shopping street where all shops have direct access to the street and a modern shopping mall with only one main entrance to all the various shops located inside the building.

When these three main mistakes on three different scales appear, the effect is that newly implemented urban areas tend to consist of fast highways separating mono-functional areas from each other with buildings that lack active frontages. Knowledge derived from space syntax research and applied to urban design, in general, is fruitful for creating successful urban areas by applying a people-centred design approach.

The generative socio-economic dynamics of urban space to some extent allows the prediction of certain socio-economic effects of urban planning and design proposals. Furthermore, a post-evaluation of implemented urban planning and design proposals for projects where space syntax consultancy was involved contributes to theory building and methodological development. The application of space syntax in consultancy goes hand in hand with research results where space syntax is used.

Fig. 7.14 Example of building facades in a traditional shopping street (left) and a modern shopping building (right), both located in Utrecht

7.4 Examples from Practice

In the middle of the 1990s, the first applications of space syntax in consultancy practice were carried out. At that time, segment analysis was not yet developed. In urban planning and design practice, the time span from consultancy, to concept, to developed design, and finally to construction can take—based on the size of the project—up to decades. This and the complexity of the projects also define the timeframe for the decision-making process in terms of stakeholders, finances, and political will and administration from a local to a citywide level.

Space Syntax Ltd. London in collaboration with the Space Syntax Laboratory at the University College London has carried out several consultancy projects with the purpose of improving the urban public realm from individual neighbourhoods to large metropolitan areas. Examples of projects are the master plan of Jeddah, the redesign of Woolwich Squares in London, the regeneration of the areas around King's Cross Station in London, the upgrade of the Old Market Square in Nottingham, the evaluation of the location of the Millennium Bridge in London, and the creation of spatial strategies for the Chinese city of Changchun, among others. Further information can be found on Space Syntax Limited's website.

In the following, we discuss four projects, namely the public realm design for Trafalgar Square, the new highway link through the Dutch city of Leiden, the strategic plan for railway stations for North Holland, and the use of space syntax in densification strategies in the Norwegian city of Bergen. The examples are used to show how space syntax is applied in various urban design, strategic planning, and consultancy projects.

7.4.1 Public Realm Design for Trafalgar Square, London, United Kingdom

The space syntax method was applied to the redesign of Trafalgar Square in 1996, which was led by the architect firm Foster +Partners. This project is so far one of the most successful realised projects where space syntax played a major role in the decision-making process, and it serves as one of the first strong examples of how space syntax works in practice. Both before and after the square renewal, people observations and registrations were carried out. This allowed the designers to test the 'before and after' space syntax model against empirical data. In the 1990s, only axial analyses and one-point isovist analyses were applied.

The initial analysis of pedestrian patterns showed that locals avoided the centre of Trafalgar Square and that tourists failed to make the journey between Trafalgar Square and Parliament Square. The pedestrian movement model by Space Syntax Ltd. London team allowed a quick diagnosis of the problems throughout the master plan area. Departing from there, design solutions were developed (Fig. 7.15).

Fig. 7.15 Trafalgar square in 1996. Most of the space was empty most of the time. *Source* Stonor (2011)

The empirical data from people observations and the space syntax axial analysis showed that most of the pedestrian flow took place at the edges of the square. Accessibility to the square was complicated and street crossings were dangerous. In addition, the heart of Trafalgar Square was only reachable by entry points consisting of two staircases running along a wall and facing away from the entry points of the square. Figure 7.16 highlights how the movement was pushed around the edges of the square due to the physical design of the space (left). The design strategy was to bring movement to the heart of the square via a central staircase and the design proposal enhanced the natural movement through the body of space.

An axial map of the pedestrian routes was made, and the before and after traces and axial model depict the revitalisation of Trafalgar Square. As can be seen from Fig. 7.16, both axial models are coherent with the empirical data. The global axial integration analysis of the square is coherent with the results from observations of people's routes. After the design implementation, the spatial integration of the square increased and people are now moving through the body of the square (Fig. 7.17).

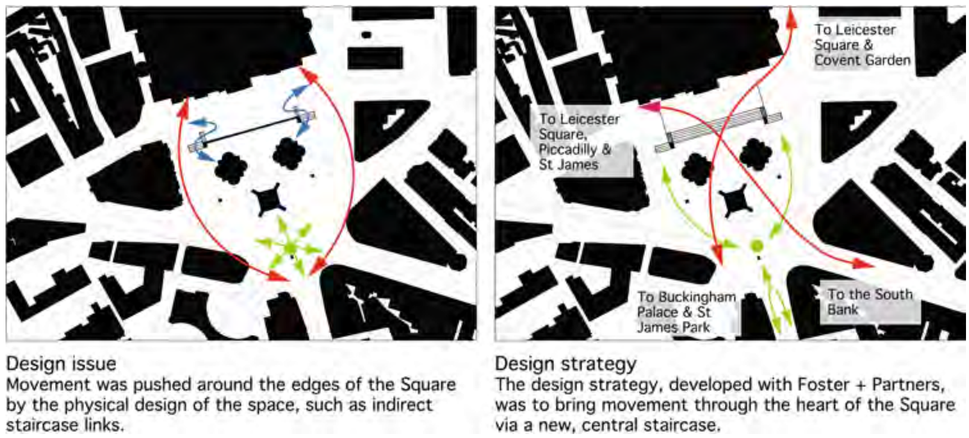

Fig. 7.16 The spatial challenge and design strategy for Trafalgar Square. (original: Stonor 2011; redrawn by authors)

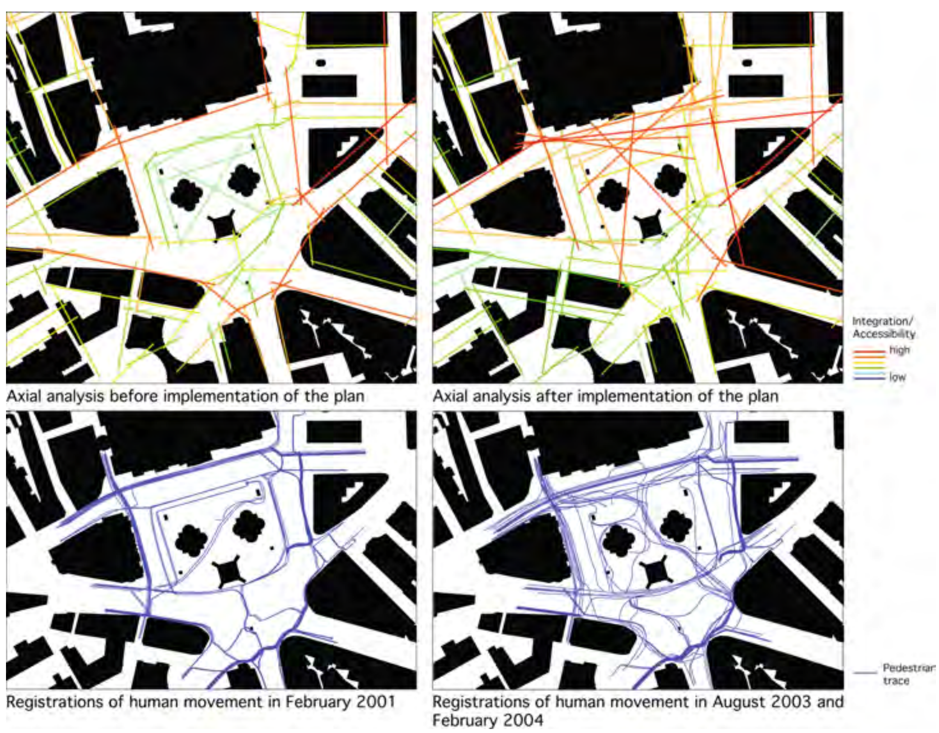

Fig. 7.17 Axial model and pedestrian movement registrations before and after the design implementation for Trafalgar Square in London (Dursum 2007). *Source* Space Syntax Ltd. London

Space Syntax Ltd. London and the Space Syntax Laboratory at the University College London own detailed registrations of pedestrian flows in several central areas in London. These registrations are correlated with results from space syntax analyses and highlight that the higher the numerical integration value, the greater the numbers of people in the streets. This knowledge allowed the prediction of how the urban design proposal for Trafalgar Square might increase or decrease the presence of people for each path (Fig. 7.18).

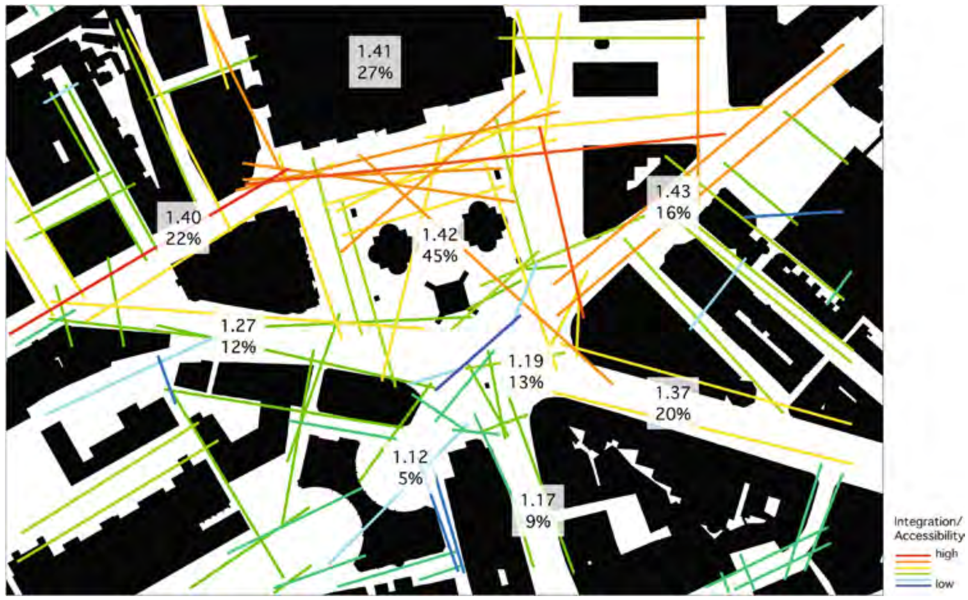

Fig. 7.18 The forecast model for a potential increase in the co-presence of people for every route for Trafalgar Square after the design implementation. (original: Stonor 2011; redrawn by authors)

For the redesign of Trafalgar Square, the gallery with the previous staircase had to be removed to install the central staircase, which required permission from London's conversation authorities. For communication and negotiation in the decision-making process, in addition to the evidence-based models, 3D visualisations of the future impact including people's usage were also made. Figure 7.19 (left) shows a Photoshopped image used for convincing decision-makers, and (right) the first day of opening of the redesigned square based on space syntax methods and theories. Today, Trafalgar Square is very well used by locals and tourists.

Fig. 7.19 The Photoshopped image of Trafalgar Square used for convincing the decision-makers (left) and a photo taken the first day of opening (right). *Source* Space Syntax Ltd. London 2011

The Trafalgar Square project proved that space syntax works well for urban design projects, and since the renewal, the square has become an important meeting place for tourists as well as for locals. The key was to improve accessibility to the square and to 'steer' the natural pedestrian flow through the square instead of around it. Since 2010, Space Syntax Ltd. London has been involved in numerous projects on the redesign, regeneration, and improvement of urban areas on various spatial scales.

7.4.2 Evaluating a New Road Connection Through the City of Leiden, the Netherlands

The space syntax method was applied in a brainstorming workshop for option testing of new road links for the Dutch city of Leiden in 2005 (Van Nes 2007). This project started with a workshop with various stakeholders, researchers from TU Delft, urban designers, and representatives from the province, the municipalities, and the Dutch Ministry of Housing (VROM). The focus of the space syntax analyses was to test out how various new proposed road links might affect existing and new potential centres on a citywide scale.

Leiden is located between two highways, both running in a north-south direction. However, effective east-west connections are lacking for Leiden, as well as for its surrounding municipalities. During rush hours, the city suffers from heavy congestion on all its main routes. For 20 years the decision-makers in the region were discussing how and where to implement an effective east-west connection. In 2005, four different proposals were discussed during the workshop. As an experiment, an axial global integration analysis was conducted for the existing situation (the baseline study) and for four different alternatives for the new road link named W4 (option testing).

Figure 7.20 shows a global axial integration analysis of Leiden with its surrounding municipalities. The most integrated axes are the highways and some routes leading into the centre of Leiden. As can be seen from the map, the city centre is easily accessible from the northern highway. There the Bio-science park is located. The white dots show the locations of the headquarters of various large company headquarters. These companies tend to be located in locally integrated town centres or at integrated nodes along the highway.

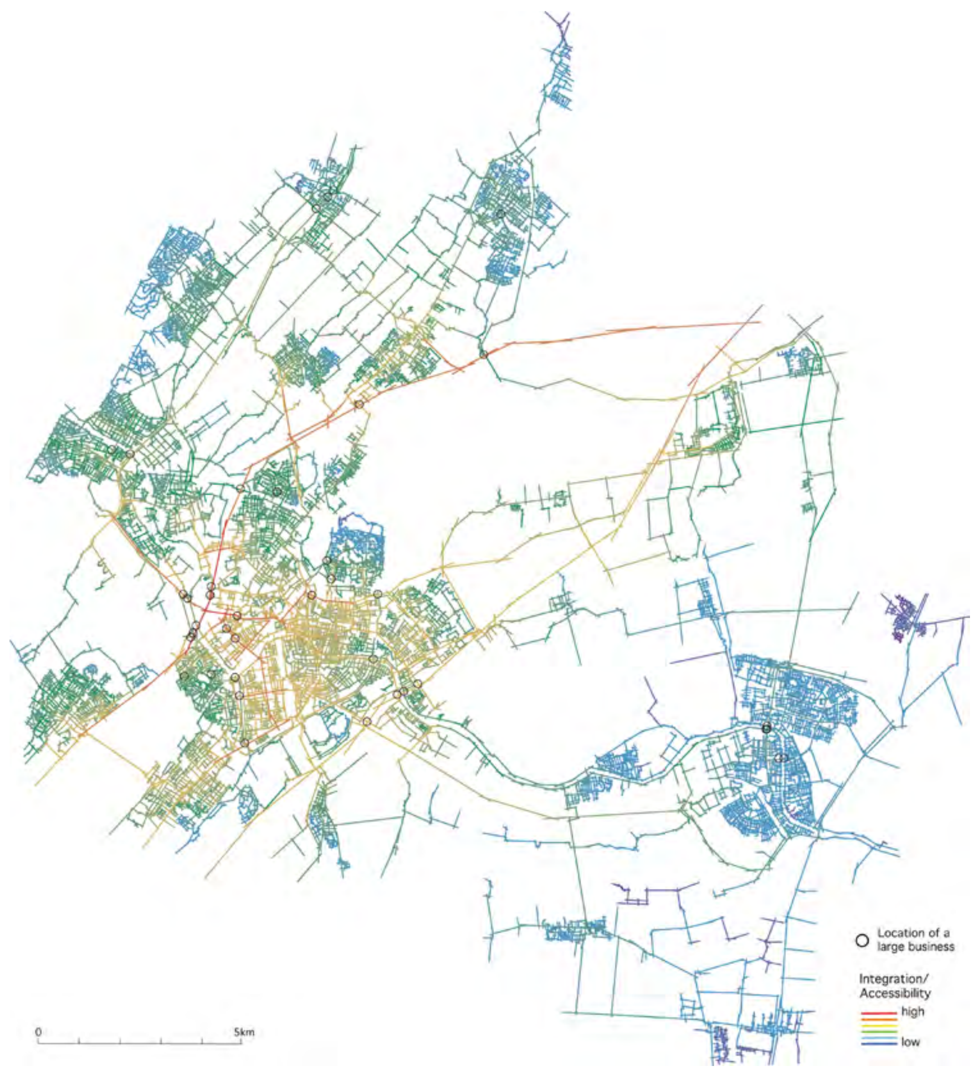

Fig. 7.20 Global integration analyses of Leiden with its surrounding municipalities in 2005 (the baseline map)

Figure 7.21 shows the results on how these road alternatives might affect the vitality of Leiden's existing centres. Here the global axial integration analysis is used. The location of potential economic centres depends on how the road link is inter-connected to the local main route network and how accessible the main city centre is from the new road link. Strategies 1 and 2 contribute to improving the vitality of the existing old historical city centre of Leiden, whereas strategies 3 and 4 contribute to the emergence of new economic centres located along the highways (Van Nes 2007).

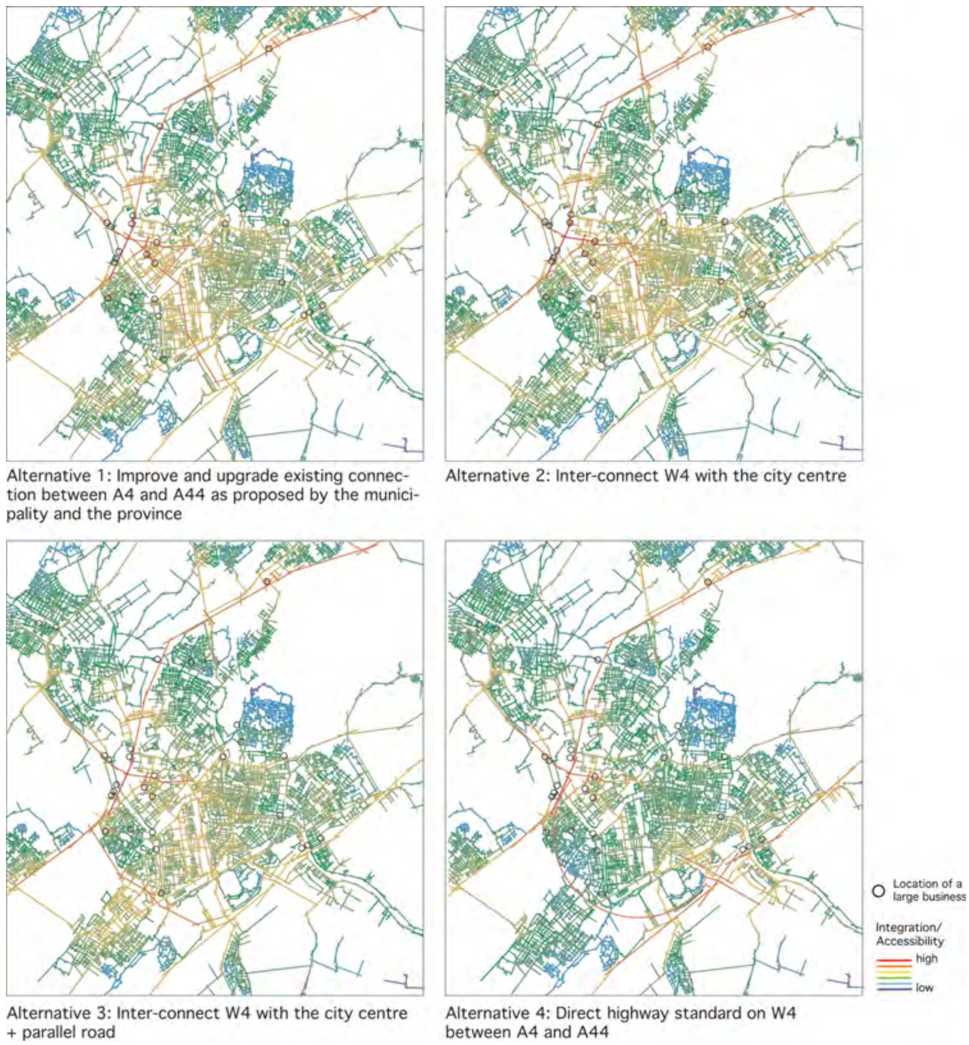

Fig. 7.21 The use of space syntax in testing out how various new road links might affect the centralities in Leiden (option testing). The black circles indicate large businesses

The space syntax analyses of the impacts of various proposed road links through Leiden from 2005 were done using the axial sight line method. Later on, in 2011, the discussion was centred around alternatives 1 and 3. The province of South Holland wanted alternative 3, while the business owners with their local action group wanted alternative 1. Alternative 1 consisted of a tunnel under the existing avenue (Churchill Avenue) for through traffic, with the local traffic being distributed on the avenue that is well connected to all streets in the vicinity. The business owners feared that they would lose customers with alternative 3 and asked for a new scientific report that they could put on the table for the decision- makers. Alternative 3 consist into lead all the car traffic away from the city centre.

Therefore, in 2011, space syntax analyses with angular weighting and a detailed description of how each of the alternatives might affect the various local centres were carried out. The results of the angular weighting of the segments showed the same results as in the 2005 analyses; alternative 1 would increase the vitality of all centres, whereas alternative 3 would do the opposite (Van Nes and Stolk 2012a, b).

In spite of the evidence from the space syntax analyses, the decision-makers chose alternative 3. This solution is in line with the road building planning and implementation practice carried out over the last 50 years. Space syntax was then too unknown for the decision-makers, and they were relying on the traffic modelling prognoses carried out by the road engineers. At present, the construction of the new road link (alternative 3) is on-going, and we are waiting to see how this will affect the various centralities in Leiden in the future.

7.4.3 The Densification Strategy Plan for Bergen Municipality in Norway

The space syntax method was also useful in the overall densification strategies for the Norwegian city of Bergen in 2016 (De Koning et al. 2017). Here, two researchers from Western Norway University applied angular choice analyses with a high and a low metric radius. The focus of the space syntax analyses was to test out the spatial accessibility profile of various neighbourhoods with aggregated angular choice analyses and to use the results of the analyses to give recommendations for densification strategies.

The project was initiated by Bergen municipality, which wanted to explore *where* and *how* to densify in existing urban areas. The aim was to use the outcomes in future land use and policy planning as a strategy for densification in the central areas of Bergen. Inspired by the 'Denser Stockholm' project (Spacescape 2013), a 'Spacescape' analysis was made using a 'densification pie chart' to identify both the need for densification and *where* there is freedom to make it happen. *How* to densify in those areas depends on the degree of accessibility of the street network and public transport, as this inquiry showed. To that end, the space syntax method was included in the research project.

The project started with the identification of the types of densification actions proposed by the municipality. Three types of densification actions were identified: *intensification*, *transformation*, and *expansion*. The intensification strategy entails identifying densification potentials in existing urban areas without changing the entire built environment. The transformation strategy concerns identifying and assessing densification potentials of larger urban areas that would require a functional transformation, such as harbour fronts, goods terminals, and industrial estates. The expansion strategy intends to find densification opportunities in previously unbuilt areas within the city borders. In the Bergen case, these are often found on the mountain slopes, where development had not previously been considered due to costly technical challenges (De Koning et al. 2020).

Following the theory of the natural movement economic process (Hillier et al. 1993, 1998), it is to be expected that the highest potentials for densification outside the city centre are found around the main routes, the local centres, and the public transport stops. Local discrepancies may be found and can likely be attributed to the unique landscape elements such as the mountain slopes and fjords surrounding the city. These elements are also responsible for the characteristically capricious road pattern in the city, which follows height lines to keep gradients acceptable from a road-engineering point of view.

Figure 7.22 shows the baseline studies of Bergen with a normalised angular choice analysis with a high metric radius (5000 m) and low metric radius (500 m). First, the results were imported into GIS, and the various space syntax values were

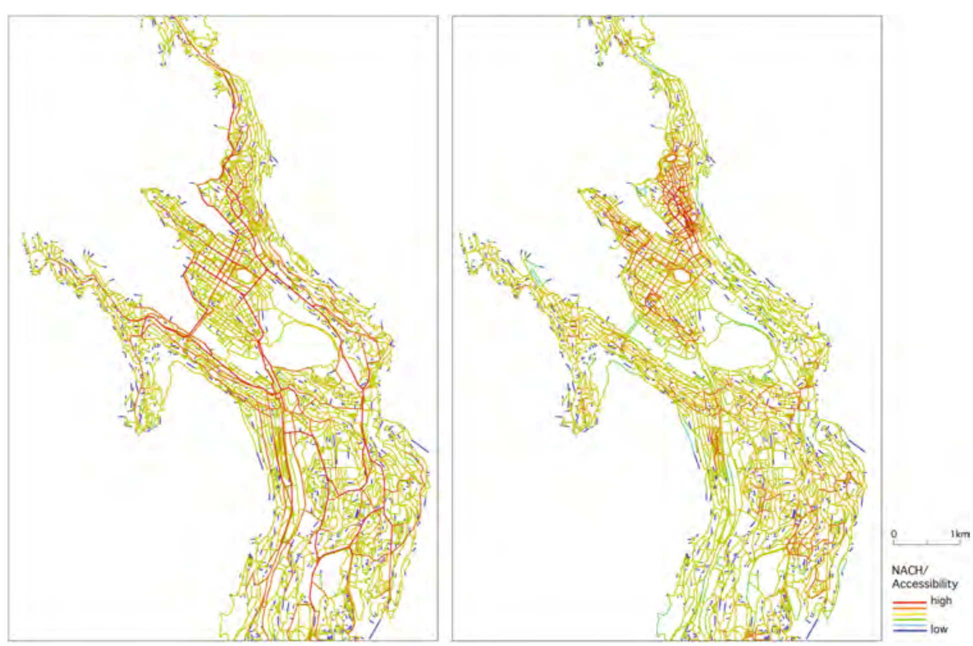

Fig. 7.22 Normalised angular choice analyses of the current situation of Bergen with a high (left) and a low (right) metric radius

added to the adjacent plots. The lines with the highest values decided the values of the plots. Then the space syntax values were grouped into high and low values on the plot level for both normalised choice analyses. This is the basis for aggregating both spatial analyses with one another.

Figure 7.23 shows the outcomes of aggregating the angular choice analyses with a high and low metric radius. Four different types of urban areas are shown. For each of them, different densification strategies can be made for Bergen on where and how to densify. They are all dependent on the degree of local and global accessibility of the street and road network.

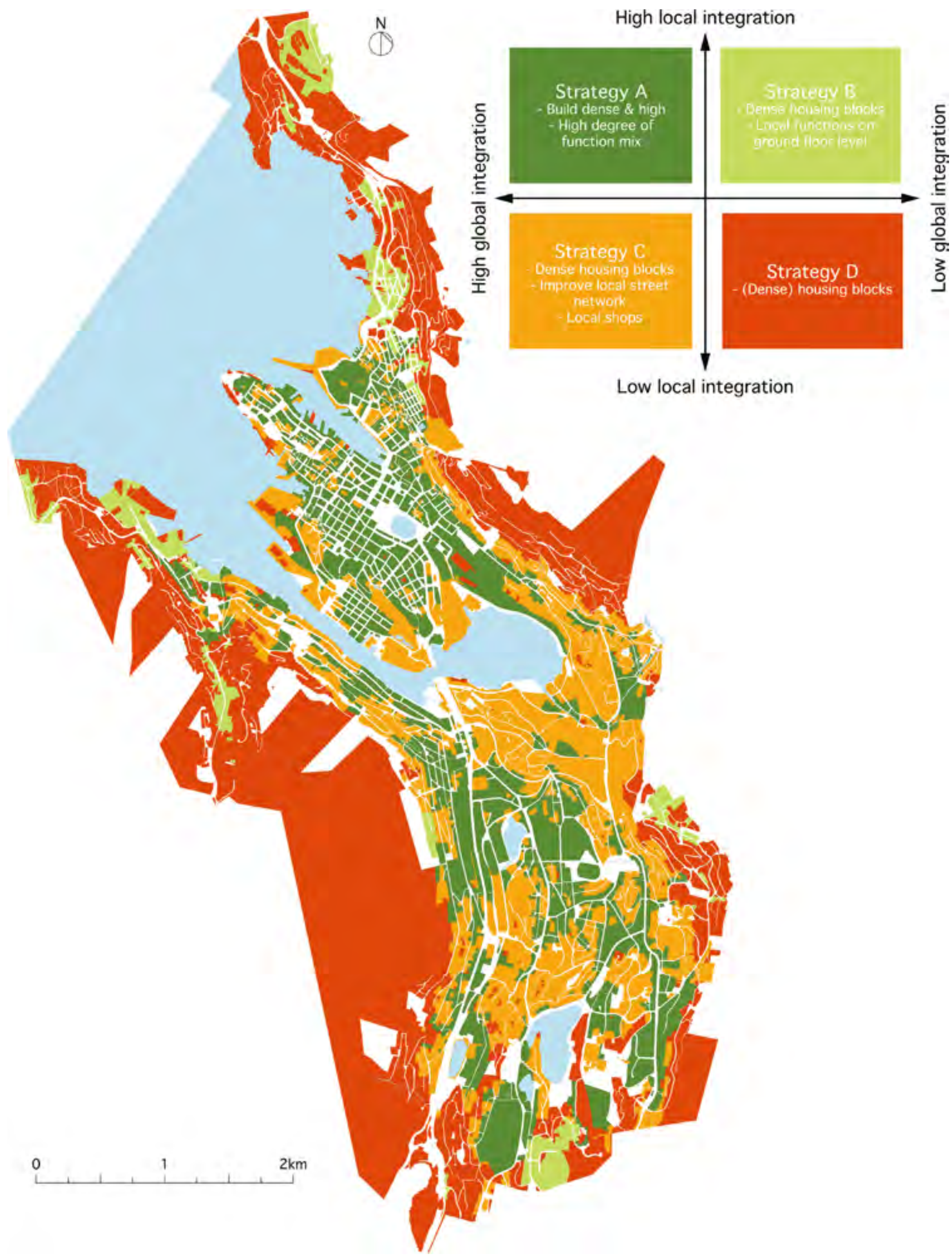

Fig. 7.23 Densification strategies in Bergen

The strategy A areas have high local and high global choice values of the street and road network. Often these areas are located in city centres with high degrees of function mixture and high densities of buildings. Where extra space becomes available, these areas can be transformed with a high density of built mass. This can include high-rise buildings. The aim is to provide land use plans that allow a wide range of different usages, in particular on the ground floor level. Areas suitable for this kind of development in Bergen are the city centre, the harbour areas around the city centre, and the old industrial areas.

The strategy B areas have high local, but low global choice values of the street and road network. These areas are often found in the local centres in small neighbourhoods. Where there is space, these areas can facilitate high densities of dwellings with ground floor spaces for shops, small businesses, and services. Depending on the local circumstances, high-rise buildings can be considered as an option. As an example, the Sandviken area has many old wooden houses only 2–3 floors high. The type and style of buildings give this area a particular place character, and new buildings will have to adjust to the existing building stock in scale and style to avoid damaging the place identity of that area. Areas suitable for this kind of densification are the various local centres outside Bergen centre. Most of these small local centres are situated along the main routes leading through various urban areas. Areas located along the light rail line also belong in this category.

The strategy C areas have low local, but high global choice values of the street and road network. Often these areas are suffering from car traffic from the roads running through the areas. These locations are suitable for high densities of housing. Where possibilities exist to create a locally integrated street network, local shops on the ground floor can be facilitated. An example of such an area is in old industrial areas.

The strategy D areas have low local and low global choice values of the street and road network. These areas are mostly located in quiet residential areas. Where there is space to develop, high densities of only dwellings are desirable. These areas have a low degree of accessibility and are, therefore, unattractive for shop owners. Examples of these kinds of areas are found around the lakes and harbour areas.

Only four groups were used in this strategy report. It is also possible to use nine different groups where high, medium, and low values of global and local integration are combined. This would enable the application of more detailed strategies. In this case, however, being in the beginning stage of collaboration with the municipality and in a planning process where multiple NGO's, property owners, and stakeholders are involved, operating with four different categories is more practical than nine. In addition, the various densification strategies for each of the nine categories would need to be defined in a language understandable for practitioners.

At the end of the day, the conclusions of the report were not added to the strategic plan. Space syntax was still too unknown for some of the employees. Two years later, articles in the local newspaper are still criticising the municipality for a lack of an overall plan. However, there is a change going on in the Norwegian planning practice, where the aim is to move away from urban sprawl and towards dense cities with vibrant street life. Even though the report ended in a drawer for this project, space syntax will probably be used in future discussions for densification with good urban qualities.

7.4.4 Regional Strategic Plan for North Holland, the Netherlands

Space syntax was applied in the development of a strategic plan for the province of North Holland in the Netherlands in 2008. Egbert Stolk and Akkelies van Nes from the Faculty of Architecture, TU-Delft were asked to carry out a space syntax analyses of the road and street network for the whole province. The purpose was to use these analyses to develop the new strategic plan—entitled "National Policy Strategy for Infrastructure and Spatial Planning. Making the Netherlands competitive, accessible, liveable and safe"—as a guideline until the year 2040.

This province has a total area of 2,670 km^2 and a population density of 1,000 people per sq km. The Dutch capital city Amsterdam and the international airport are located in North Holland. Most urbanised areas are in close proximity to Amsterdam and Haarlem, known as the 'Randstad', whereas the northern part of the province is more rural. The strategic plan has the purpose of solving traffic congestion problems in the urbanised areas inside and around Amsterdam (Provincie Noord Holland 2008).

The focus of the space syntax analyses was on the accessibility to the vicinity of all 57 railway stations in the province of North Holland. The railway stations vary from larger metropolitan stations, airport stations, intermodal hub stations, and local stations with one small train station building to train stations with only a ticket machine.

It is often believed that a railway station itself attracts economic activities such as shops and offices. However, the spatial configuration of the local street and road network in a railway station's vicinity is seldom taken into consideration (Mulders-Kusumo 2005). Some stations are easily accessible by foot or public transport, while others can only be reached by private car. The aim of the analysis was to assess how sustainable the public transport network for the whole region is in terms of accessibility on various scales. In general, two well-known methods are highly suitable for such an application—the node place value model (Bertolini 1999) and space syntax (Hillier 1996). Luca Bertolini's node place value model is based on correlating the degree of functionality and the degree of local place qualities for individual transport nodes in different places. Accordingly, a station functions well when the node value and the place value are high.

The parameters for the node values are variation of mobility types, frequency of public transport system of a hub, the accessibility of the network connected to the node, and the number of mobility means that can reach the hub. The higher the variation of mobility means, the higher the frequencies on the time tables during the day, and thus the higher the node value. The parameters for place value are dependent on the number of functions accessible in the vicinity of the node—such as offices, dwellings, or shopping—and the way the functions are connected to each other. The higher the number of functions and services within a short walking distance from a station, the higher the overall place value. Multi-functional nodes have a higher place value compared to mono-functional nodes.

Van Nes and Stolk (2012a, b) state that the precise definition of elements in the node place model is lacking and that the operationality of the method is rather weak. First, the quantification of functions for the node value and the quantification of different transport modes and frequencies are not clearly defined. Second, the weighting of the various parameters is also lacking. Currently, there is some testing going on to improve the node place model. The advantage of using the space syntax method for the assessment of all train stations and their spatial relations to their vicinity is that the quantitative aspects of the space syntax method are consistent. Moreover, by combining angular choice with high and low metric radii, the place value can be quantified. According to the theory of the natural urban transformation process, areas with high spatial integration on all scale levels in the vicinity of a railway station tend to have a high building density and a high degree of land use diversity.

Therefore, the application of space syntax angular choice analysis with metric radii and angular mean depth was applied to generate an accessibility profile for all 57 railway stations. Back in 2008, the segment integration was not yet applied in space syntax research (Fig. 7.24).

In a more detailed analysis, accessibility for each train station within a radius of 1 km—which equals a 15 min walk—was analysed using the following space syntax measures and radii: Segment angular mean with a depth radius N, segment angular mean depth with a topological radius of 3, angular choice with a metric radius of 800 m, and angular choice with a metric radius of 9,000 m.

Figures 7.25 and 7.26 show the results of the various space syntax analyses of two of the 57 stations. For every station, the accessibility profile for a radius of 1 km from the station was analysed. As can be seen from the analyses of the Purmerend station (Fig. 7.25), the station is regionally well connected but locally poorly connected. Purmerend is a new town, and all the local streets have low values for the various local space syntax analyses. Conversely, the Amsterdam station (Fig. 7.26) has high values on all the space syntax analyses. Therefore, the local and regional accessibility is well supported by the local street network where the railway station is embedded.

From the accessibility profiles, all 57 train stations were classified into five different types:

- Type 1: Regionally and locally well connected to its vicinity
- Type 2: Regionally well connected but locally poorly connected to its vicinity
- Type 3: Regionally and locally well connected, but poor pedestrian accessibility
- Type 4: Regionally isolated, but locally well connected
- Type 5: Regionally and locally isolated.

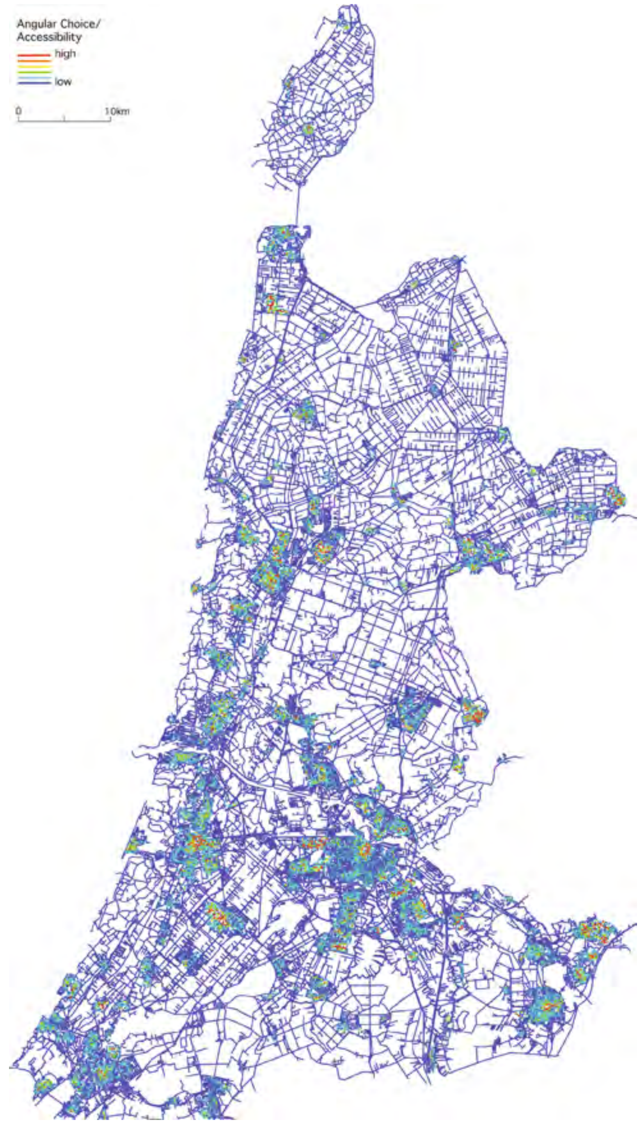

Fig. 7.24 Space syntax model from North Holland using the angular choice measure with a metric radius of 800 m

Figure 7.27 shows all five types of railway stations plotted on a map, and based on the type of accessibility profile of the railway station improvement strategies were proposed with regard to new housing areas and local accessibility to railway stations. A recommendation for facilitating new housing developments in a sustainable way is to locate them within walking distance from an existing train station. For the type 1 and 2 railway stations, the goal is to enhance a locally integrated and well-connected street network for new housing developments. The strategy for the type 3 railway station is to improve pedestrian accessibility, while the strategy for the type 4 railway station is to keep the street and road network as it is, but to enhance housing densification close to the railway station. The type 5 railway station needs to have a locally well-connected integrated street network close to the station, but only if there is a need for more residential areas in the province.

In our examples, the new town of Purmerend has a type 2 railway station and thus needs improvement in walkability within its vicinity. Amsterdam central station is a type 1 railway station, where the spatial structure of the street and road network in the vicinity supports accessibility to the central station at all scale levels.

The images in Fig. 7.28 show Haarlem station as an example of a type 1 and Sandpoort Noord station as an example of a type 5 station. Type 3 represents the newly implemented railway stations in new towns or suburbs, where pedestrian accessibility within the station's vicinity is forgotten. The street and road network is integrated on a local scale, but pedestrians have to walk complex routes to access the station. The transition station (Amsterdam Sloterdijk) and the airport station (Schiphol Airport) are typical type 2 stations, and small old historic towns (e.g. Enkhuizen) often have a type 4 railway station.

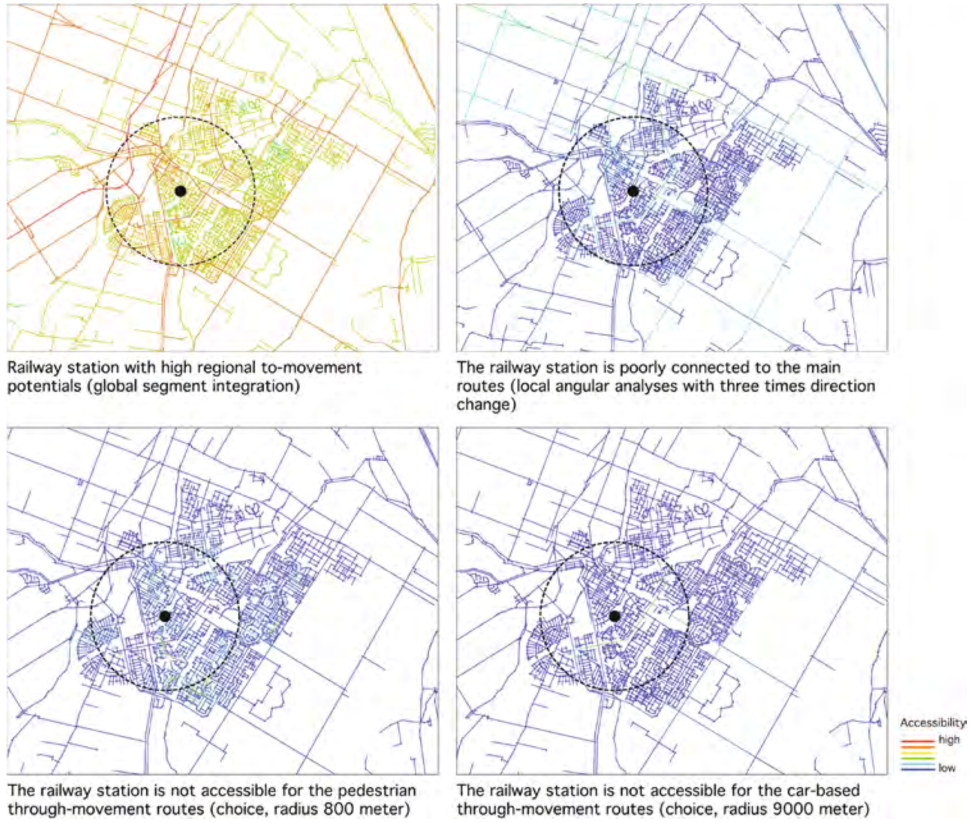

Fig. 7.25 Accessibility profile for the new town of Purmurend's train station, north of Amsterdam. The train station is locally poorly connected but regionally well connected

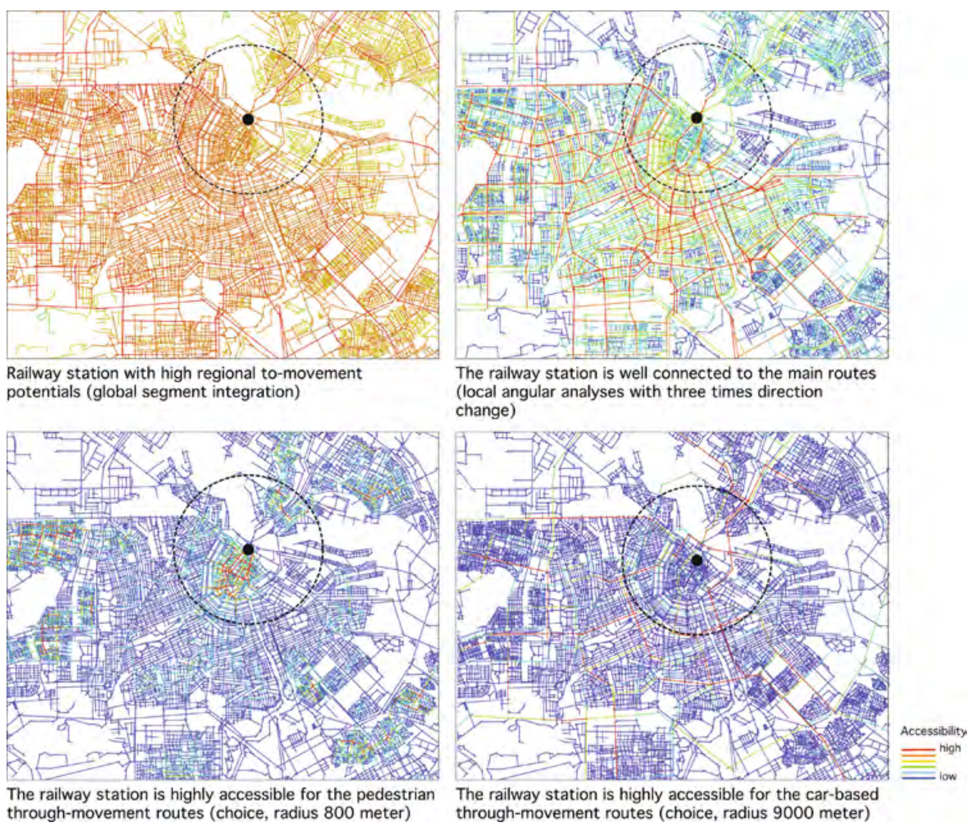

Fig. 7.26 Accessibility profile for the Amsterdam train station. The train station is locally well connected and regionally well connected

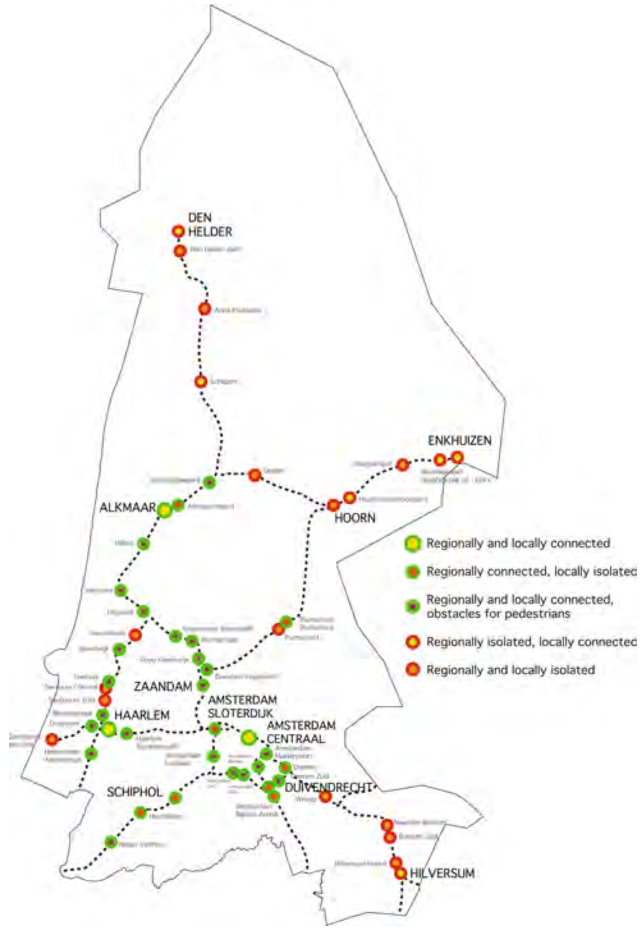

Fig. 7.27 The accessibility profile derived from space syntax analysis for North Holland

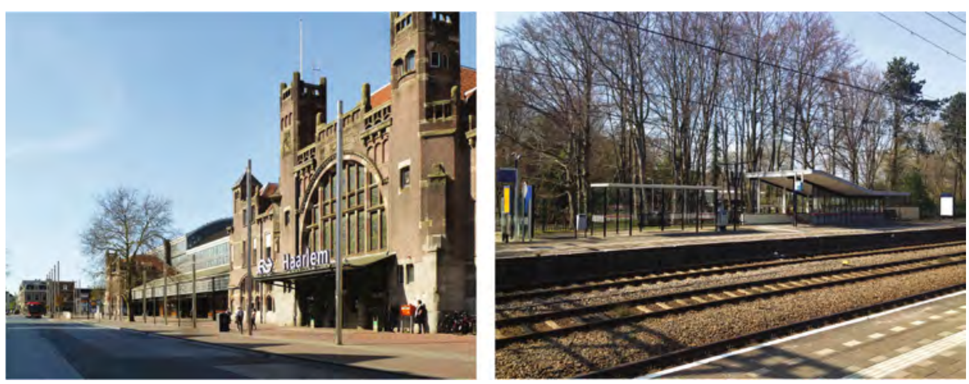

Fig. 7.28 Haarlem station, which is regionally and locally well connected (left), and Sandpoort Noord station, a poorly connected train station with only a ticket machine (right)

The recommendations made were partly implemented in the overall strategic plan of the province. Due to the financial crisis in the Netherlands from 2008 to 2016, the strategic plan for the province was put on hold.

In many large-scale projects, space syntax is mostly used in making diagnoses and recommendations. So far, implementation on a larger scale has not yet been carried out. The time perspective is much longer than in smaller urban renewal projects such as Trafalgar Square. However, the fact that stakeholders have started to show interest in the use of space syntax is at least a first step towards implementation.

7.5 Conclusion

Applying space syntax in urban planning and design has some pitfalls to be aware of, and there is often little awareness of space syntax's theoretical and methodological limitations. Moreover, how space syntax is applied in a project depends on the problem under scrutiny. Not all types of problems can be analysed and interpreted by applying space syntax. For example, issues related to place identity, built form, and meaning cannot be interpreted using space syntax analysis. Space syntax is often applied in practice with the applicant having superficial knowledge about its theory and method, and it is then wrongly applied due to the lack of knowledge and skills. Also, a lack of awareness of its limitations or possibilities often contributes to an incorrect interpretation of space syntax results. The most common misapplications and fallacies are as follows:

(1) Application of the wrong radius/radii

The use of the wrong radius /radii can give misleading recommendations. Therefore, it is important to check the spatial analyses with various radii up to the socio-economic data in the baseline study. The radius that corresponds with the existing situation is the one you have to use for testing out the various improvement strategies.

(2) Resolution of the axial map

The resolution of the axial and segment map depends on the scale level of the investigations. Upgrading urban squares requires a higher axial map resolution than regional strategic plans because every pedestrian path needs to be represented carefully in the urban squares projects. If no axial map of the whole city exists, drawing an axial map of the neighbourhood can be sufficient for small-scale urban projects. However, sometimes one new connection can affect the whole city, for example, the Millennium Bridge in London.

(3) Combination of space syntax analysis with other types of analyses

Often the knowledge of how to combine space syntax analyses with other types of analyses is lacking. Therefore, knowledge and skills for each applied method are essential. In this context, using GIS as a platform in combination with the results of the various methods needs to be done with care.

(4) Transfer of space syntax results to planning and design guidelines

Applying research results to practical planning and design guidelines is still a young field. Often, knowledge on how to translate space syntax analysis results to, for example, design guidelines and other generic rules are missing.

(5) Space syntax as a 'Do-It-Yourself' approach

Space syntax analyses are often perceived as a colourful analytical add-on in reports, without any knowledge on how to unlock their potential. This is followed by the assumption that applying space syntax does not require theoretical and methodological knowledge. The Do-It-Yourself approach is quite common, but this leads to shallow and misinterpreted space syntax results.

(6) Context dependency

Often, there is a lack of awareness that context-dependent issues such as built form and meaning cannot be analysed or 'predicted' with space syntax.

What space syntax can predict is the impact on pedestrian flow rates and the location of economic-related activities. In the longer term, space syntax can also predict property prices and rental values on the real estate market and the potentials for densification.

Therefore, training in how to use the space syntax method is recommended before applying space syntax in urban planning and design practice. Before using space syntax in urban design and planning, always analyse the present context (the baseline study) before experimenting with various alternative improvement proposals.

Interesting future work will be post evaluations of constructed projects where space syntax was applied in the consultation and design development phase. This will give new knowledge about the degree of the ‘predictive power’ of space syntax. This kind of evidence is essential to not only understand the degree of usefulness of space syntax in urban consultancy, but also to develop the space syntax method further.

7.6 Exercises

For the exercises, please use the software. Depthmap software and the “Depthmap manual for dummies” can be downloaded from www.spacesyntax.net and www.github.com.

Exercise 1
Use Google Maps to choose a deprived or new town neighbourhood. Imagine that the municipality wants to revitalise this area into a vibrant neighbourhood with street life. What would you advise? Develop two or three urban design options. Analyse the existing situation and your urban design options. You can choose from the space syntax pallet the analysis methods you find the most suitable for carrying out a spatial diagnosis and option testing. Explain your choices and interpret the space syntax results.

Exercise 2
Use Google Maps to download an orthogonal satellite image of the Harebakken area in Norway. Harebakken is a shopping centre in Arendal municipality and is located at the junction of the E18 highway and the local main road 410 that runs towards Arendal centre. The spatial layout of this area contributes to car-based accessibility and private car dependency. The level of walkability is very low. Harebakken is a development that is in contrast with the national Norwegian policies. Norwegian policies aim for densification of existing urban areas, while at the same time increasing active transportation such as walking and decreasing private car dependency. Develop strategies and urban design suggestions for what can be done to upgrade this area in line with Norwegian policies. Also, consider the local centre of Arendal in close proximity. What might a multi-functional local centre with vibrant street life and a high degree of walkability look like? How can it add to the existing historic core of the town Arendal without detracting from the walking potential (Fig. 7.29)?

Fig. 7.29 The Harebakken shopping centre in Arendal, Norway

Exercise 3

Choose in Google Maps a neighbourhood you know is not functioning well. Make a diagnosis using space syntax. Use the master planning and safe neighbourhood principles to describe and explain the problems of this neighbourhood. Explain how you would assess human behaviour and the socio-economic performance of the neighbourhood. Develop an urban design proposal. In the next step, analyse on a micro-level your urban design intervention with space syntax. Describe the results of your analyses.

7.7 Answers

Exercise 2

The advice here is to plan a new neighbourhood around the shopping mall with a well-connected street network, balanced streets, and with buildings with doors and windows faced towards streets on the ground floor level.

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