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Dossier Editorial (Special Issue: Space Syntax)

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Space Syntax was developed at the University College London (UCL) in the late 1970s. It is best described as a research program that investigates the relation between human societies and space from a theoretical perspective based on the structure of inhabited space in its diverse forms: buildings, settlements, cities, and landscapes. The word "syntax" establishes a bridge between the dual motivations of Space Syntax; namely describing the built space and its occupancy and understanding how these patterns enable us to recognize and construct society and culture. The fundamental statement of Space Syntax suggests that it is possible to break buildings or built spaces down into their spatial components so as to analyse the interrelationships of these components and to yield information about pattern of space which is meaningful and functionally relevant. Over 40 years, Space Syntax has been applied with success for various purposes ranging from the master planning of entire cities to revealing the imprint of culture in domestic settings.

Today, Space Syntax is adopted and further developed in hundreds of universities and educational institutions as well as professional practices worldwide. Built on quantitative analysis and geospatial computer technology, Space Syntax provides a set of theories and methods for the analysis of spatial configurations of all kinds and at all scales. The Space Syntax approach was conceived to help architects, planners and urban designers to simulate the likely impacts of their designs on people who occupy and move around in these spaces whether they are buildings or urban settlements. Since then, it has been adopted around the world in a variety of research areas and practical applications including archaeology, criminology, information technology, urban and human geography, anthropology and cognitive science.

1

An impressive contribution comes from *Mark David Major, Raya M. Atour and Heba O. Tannous* by their work titled "Organized Complexity of the Urban Object" which covers a substantial amount of theoretical ground of the logic of space syntax concisely, including definitions of resilience in the field, the resilient nature of space syntax as a method, and the essential components of theoretical thinking to arise from the space syntax research program over the last forty years. On this basis, the paper offered a new hypothesis about laws of spatial conservation and optimization at work in the built environment by using the already established theories and works within space syntax literature. The hypothesis of conservation-optimization which defines the conceptual framework for the progressive and regressive practice of urban planning in settlements is also discussed. This theoretical discussion is illustrated by demonstrating the resilience or replication of previous space syntax findings, and by drawing on new research about the history, spatial structure, and neighbourhood logic of Metropolitan Doha. The original visuals from Doha effectively support and exemplify the previous theories/concepts of Space syntax.

2.

In their article titled "Association between Home Layout Connectivity and Cognitive Ability in Community Dwelling Older Adults: Implication for Occupational Therapy" *Sonit Bafna, Kinsuk K. Maitra, Yoonjeong Lim, Mansi Shah, Yi-An Chen* reports a quantitative study of the relationship between a characteristic of the physical home environment and the cognitive ability of adults. The authors believe that the specific aspects of the physical environment that matter and the extent to which they remain less understood underline that physical environment has long been recognized within occupational therapy as a key factor contributing to residents' functional abilities. The authors put forward a study that examines the relationship between the elderly life and space, which is becoming increasingly important today. The focus is on correlation between the syntactic data, which provides an objective interpretation of the space and the cognitive data on how the space is perceived. In this context, the study has a potential to fill an important gap in the literature.

3.

Another fascinating article comes from *Frederico de Hollanda* with his work titled Brasilia: Super blocks in Perspective explains the superblock experience of Brazilian cities from the viewpoint of an expert who discusses the experience with reference to a virtuous circle of design process. Systematic comparisons are made between

the traditional superblocks that are strictly defined by planning codes and the design of the superblocks considering current urban lifestyles which are proposed by the author. An interesting comparison is made with the previous experiences of Lucio Costa's superblock design and the design for the SQN-109 through Space Syntax concept and principles.

4.

In his article titled "Relative rhythms, Urban Oases, and Spatial Resilience - Exploring Syntaxes of Seclusion, Solitude, and Tranquility", *Daniel Koch* investigates the spaces of everyday life in cities and adopts a multifaceted view of the concept of "resilience" and builds on existing knowledge about the relations that link configurational structures of space with emergent collective behaviour patterns. The fieldwork draws on Lefebvre's "rhythmanalysis" and makes use of his own experiences as a participant in urban life, addressing both events and everyday situations and the ways in which our understanding of spaces unfolds over time. The author supported his argument through recourse of repeated studies of Stockholm that have consistently demonstrated a strong correlation between movement flows at the observation locations and the syntactic properties of those locations. Although discussed in macro scale, this work of Daniel Koch that puts a new emphasis on resilience in minor fragments, can be accepted as a new and inspiring shift in resilience theory.

5.

The fascinating piece of work comes from *Luísa Cannas da Silva and Teresa Valsassina Heitor* with their article entitled, "To Integrate or not to Integrate? A matter of Choice for Universities" which argues that universities are key elements in generating and enabling dynamic synergies, promoting the presence of students, academics, and learning spaces in urban contexts. Thus an analytical framework for university campuses within urban fabrics, is investigated by understanding the different types of urban insertion and connections established with local and regional players, and exploring the dichotomy between closeness centrality and betweenness centrality, as variables that can be used to balance the tension between integration and privacy which affects university campuses and academic communities. Syntactic analysis is used to provide deeper information and clarification on the university location and accessibility within the urban fabrics of Simon Fraser University in Burnaby, Canada; Aalto University in Espoo, Finland; MIT in Cambridge, MA, USA; and Yale University, in New Haven, USA, which host the similar functions. Space syntax has proven a valuable tool to provide insights into key aspects, such as the need to enhance visibility and improve integration, according to the Universities' strategic plans and positioning goals. Considering the analyses conducted and the purpose of the study; this article provides an original contribution to the literature of Space Syntax.

6.

In their article titled "Linking Space Syntax and Cluster Analysis to Design and Plan Temporary Housing Neighbourhoods: A Taxonomy of Sites in Norcia"; *Pezzica and Cutini* aims to uncover formal analogies between different TH (Temporary Housing) sites' layouts by linking Space Syntax and Clustering analysis within an unsupervised machine-learning pipeline, which can consider a virtually unlimited number of configurational qualities and how they vary across different scales. Linking Space Syntax and Machine Learning will increase possibilities for analysis automation, replicability, and flexibility, and can assist understanding of how local people perceive and interact within the spaces of the transitional city, and in particular its TH sites. The potential benefits of the proposal are illustrated through its application to the study of 20 TH sites built in Norcia after the 2016-2017 Central Italy earthquakes. The authors believe that their study will be a tool for administrations and professionals to develop audit proposals for temporary settlements to enhance their resilience after the disasters.

7.

In his article titled "Transformation of Urban Form in Shkodër during the Ottoman Period" *Ermal Shpuza* presents an attempt to reconstruct the historical urban form of Shkodër, which is the cultural cradle of Albenia, during the last five centuries. The study employs the space syntax analysis of Shkodër's street network to shed light on the processes of urban transformation while the city changed from an important Venetian stronghold in northwest Albania to the prosperous centre of an Ottoman province. The work which covers Shkodër's unique urban form and transformative processes quantitatively through Space Syntax will shed light on the studies on historical preservation and urban design and will contribute towards comparative and historical urban studies in the region and beyond.

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8.

The interesting article titled "Investigating Morphological Changes of a Capital City: The Case of Ankara" comes from *Melike Boz Günay and Ayşe Sema Kubat*. The authors contribute to this special issue by examining a unique capital city from Turkey which carries the effects of the historical planning periods on its urban structure from past to present. This study demonstrates Ankara's morphological changing process through Space Syntax since the declaration of the Turkish Republic. By analyzing historical maps belonging to six different periods that played a critical role in the historical development of Ankara, the paper puts the differentiation of the symbolic and monumental city axis of the capital city in today from a quantitative perspective. This research emphasizes the importance of morphological evaluation in light of the Space Syntax approach by focusing on a particular capital city.

9.

The extent of the art in the urban space calls for morphological research to test the perceptual performance of the artwork in terms of the characteristics of the physical fabric in which the murals locate. *Cansu Demir and Olgu Çalışkan* in their paper titled "Mural as Public Art in Urban Fabric: A Spatial Analysis in The Case of Yeldeğirmeni, Istanbul" conducts a spatial analysis focusing on network integration, visibility, and townscape characteristics of the neighbourhood fabric. The findings of the analysis are correlated with the level of recognition of the murals by the public to reveal the conditional relationship between the spatial morphology and the perception capacity of the murals as public art. Their work suggests a framework for morphological analysis that involves both configurational and townscape characteristics of the urban form in relation to the location and spatial setting of the murals in urban fabric. For that purpose, Yeldeğirmeni, a neighbourhood from the Asian side of İstanbul, has been selected for the analysis. Following a brief information about the site, the findings of Space Syntax, visibility and townscape analysis are presented. Via the matrix involving the results of analyses, eventually, the key morphological aspects to ensure the perception capacity of the murals are discussed.

This approach is aimed at architects, urban planners and urban designers and this dossier investigates the "Space Syntax" concept through nine articles and reviewed by a number of most known referees from Turkey. As a guest editor of this special issue on SPACE SYNTAX, I would like to express my deepest gratitude and sincere thanks to the referees of this special issue; *Ayşe Özbil Torun, Dalya Hazar, Demet Yeşiltepe, Emrah Şıkoğlu, Eren Kürkçüoğlu, Fitnat Çimşit Koş, Hasan Serdar Kaya, Kerem Koramaz, Kıvanç Ertugay, Mehmet Emin Şalgamcıoğlu, Meisam Soleimani, Müge Özkan Özbek, Nevset Gül Çanakçıoğlu, Nevter Zafer Cömert, Özlem Özer, Tolga Ünlü, Yasemin İnce Güney and Yener Baş.*

My hope is that the articles provided in this issue of DRArch will bring the field of research on technology, design and planning a little further ahead and will give you novel thoughts and insights. In this regard I want to express my deepest appreciation to the experts who served as authors of the articles. I would like to thank Mehmet Topçu and Havva Alkan Bala, the editors of DRArch journals, with whom I have been working productive and gracious collaborations for most of my recent journal works, and the editorial team of this issue. To conclude, I can proudly say that the articles published in this special issue of DRArch on "SPACE SYNTAX" address not only the state-of-art in the field, but also the most recent methods and implementation tools.

Best regards...

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DRArch's objectives are:

- to question how future building technologies are revolutionizing architectural design, city planning, urban design, landscape design, industrial design, interior design and education,

- to catalyze the processes that lean on interdisciplinary and collaborative design thinking, creating a resilient thinking culture,

- to improve the quality of built environment through encouraging greater sharing of academicians, analysts and specialists to share their experience and answer for issues in various areas, which distributes top-level work,

- to discover role of the designers and design disciplines -architecture, city planning, urban design, landscape design, industrial design, interior design, education and art in creating building and urban resilience,

- to retrofit the existing urban fabric to produce resilience appears and to support making and using technology within the building arts,

- to discuss academic issue about the digital life and its built-up environments, internet of space, digital in architecture, digital data in design, digital fabrication, software development in architecture, photogrammetry software, information technology in architecture, Archi-Walks, virtual design, cyber space, experiences through simulations, 3D technology in design, robotic construction, digital fabrication, parametric design and architecture, Building Information Management (BIM), extraterrestrial architecture, , artificial intelligence (AI) systems, Energy efficiency in buildings, digitization of human, the digitization of the construction, manufacturing, collaborative design, design integration, the accessibility of mobile devices and sensors, augmented reality apps, and GPS, emerging materials, new constructions techniques,

-to express new technology in architecture and planning for parametric urban design, real estate development and design, parametric smart planning (PSP), more human-centered products, sustainable development, sustainable cities, smart cities, vertical cities, urban morphology, urban aesthetics and townscape, urban structure and form, urban transformation, local and regional identity, design control and guidance, property development, practice and implementation.

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Research Article
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Organized complexity of the urban object

Mark David Major*[a]
Raya M. Atour [b]
Heba O. Tannous[c]

Abstract

Over a half-century, space syntax has proven resilient as a theory and method for describing and analyzing the built environment from dwellings and complex buildings to cities. The paper briefly discusses resilience as a concept in the built environment and the foundations of space syntax itself. We summarize the body of the theoretical thinking in space syntax – laws of the urban object, generic function, principles of centrality and linearity, the design method of spatio-formal processes, and laws of spatial emergence-convergence – before offering a new hypothesis about laws of spatial conservation and spatial optimization at work in the built environment. The latter builds on Conroy-Dalton's (2001) ideas about angularity and the conservation of linearity in movement. Both could provide an essential bridge with Carvalho and Penn's (2004) concept of self-similarity in settlements, which relates to Batty and Longley's (1994) notions of fractal cities. We argue the hypothesis of conservation-optimization defines the conceptual framework for the progressive and regressive practice of urban planning in settlements. We illustrate this theoretical discussion by demonstrating the resilience or replication of previous space syntax findings, and by drawing on new research about the history, spatial structure, and neighborhood logic of Metropolitan Doha.

Keywords: cities, resilience, scientific method, space syntax, urban

1. Introduction

The most accepted definition of 'resilience' in the disciplines of the built environment too often promotes the subject as the sole, exclusive purview of specialists, especially the urban planning field. Davoudi (2012) defines this narrow definition as engineering resilience or the ability of a system to return to a steady-state or equilibrium after a significant disturbance, usually because of a natural or human-made disaster, whereby system means a city, economy, or usually both. The basis for Holling's (1973, 1986) original definition was "the faster the system bounces back, the more resilient it is (with an) emphasis on return time" (Davoudi, 2012; 300). However, common sense tells us that resilient or resilience must have more expansive and inclusive terms if we do not want to introduce troubling ethical and moral paradoxes for professionals into the practice of architecture and town planning (Major & Al-Nabet, 2018). A more inclusive definition should include both design and planning, but also techniques based on scientific method: observation, hypothesis, data collection, testing and refinement, and theory. Classic scientific method is an

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approach that assigns great value to resilience through replicating results and, in the absence of the former, repudiating theories. Resilient method leads to sustainable design, offering adaptability for technological evolutions and a source of inspiration for the places where we live, work, and play. At its core, it means understanding the present and past to design and build a more beautiful and livable future for this planet's natural and human-made environments.

For a half-century, space syntax has been a resilient set of objective techniques for representing and measuring architectural and urban space using topological measures based on principia of network science (Benedikt, 1979; Hillier and Hanson, 1984; Hillier et al., 1987a-b; Hillier, 1989; Hillier et al., 1993; Penn et al., 1998; Turner et al., 2001; van Nes & Yamu, 2021). Today, space syntax is an international research program of academics and practitioners composing hundreds, even thousands of people, in more than forty countries worldwide, especially in Europe, South America, and Southeast Asia. Space syntax began with Bill Hillier, Julienne Hanson, John Peponis, Alan Penn, and many others, who were thinking, researching, testing, and refining their ideas about the built environment in the 1970s and 1980s at The Bartlett at University College London. The philosophy of space syntax relies on two clear ideas for investigating the spatial networks of architectural and urban space: scientific method and recognition that our built environment is both a product of society and an influence on society (Hillier and Hanson, 1984; Hillier, 1996; Hanson, 1998; Major, 2018). Although the latter recognition might open doors to deterministic dilemmas and many philosophical dialogues on the influence of which on which, the scientific method keeps space syntax research fixed in a manner that prevents it from falling into direct logical fallacies. Space syntax relies on the probable behavior of aggregate populations in space, not determinism.

Hillier and Hanson (1984) stake their ground from the opening words of The Social Logic of Space. They quote French archaeologist Andre Leroi-Gourhan (1964) “Le fait humain par excellence st peut-etre moins la creation de l’outil que la domestication du temps et de l’espace, c’est-a-dire la creation d’un temps et d’une espace humaine (The human fact par excellence is perhaps less the creation of the tool than the domestication of time and space, that is to say the creation of a human time and space)” (Hillier & Hanson, 1984; v). In the early 1940s, Leroi-Gourhan (1943 & 1945) hypothesized the concept of technical tendencies, which are universal technical dynamics operating independently of ethnic groups that are nonetheless the only forms realized through these tendencies. He argues this realized form is a technical fact. He developed this idea into a general theory about the relation between the technical as universal tendency and the ethnic as differentiated specific. We can detect the origins of Hillier and Hanson’s ideas about architecture and urban space in Leroi-Gourhan’s theories about the difference between technical universalities and ethnic specifications.

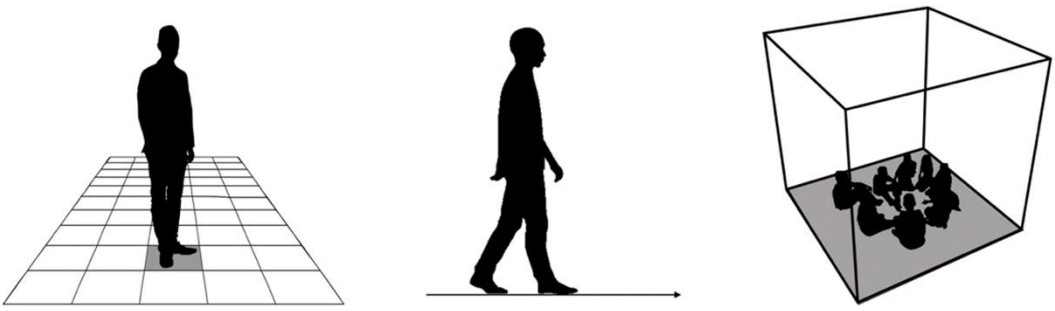

Figure 1 Representations of (left to right) a point, line, and convex space in space syntax (Source: Tannous et al., 2021).

The paper briefly demonstrates the resilience of the space syntax technique with a review of critical concepts, methodological grounding, and theoretical findings, emphasizing one of the most resilient objects in human history: the city. We layer this review with various well-established and new representations and research findings, respectively. Many focus on the Middle East and, specifically, the city of Doha in the State of Qatar. A comparison of design methods in ortho-radial

grids from the highly geometric, regular grids in the United States to the more deformed grid layouts of the Middle East serves as an essential baseline for this review. This grounding in space syntax is necessary before introducing a new hypothesis about laws of spatial conservation and optimization at work in the urban grid of cities, which can provide an additional layer to many Hillierian concepts about form and function in urban space.

Technique and Method

Space syntax representations are often plan-based, using easily understood constraints of the built environment for the most general human uses such as movement, occupation, and visibility. Such constraints are essential because we are forward-facing, bipedal creatures bound by gravity everywhere on the surface of this Earth (Hillier, 1996; Major, 2018) (Figure 1). A point in space is the most straightforward notion of building a geometry with only position and no size. The number of points in any space will be infinite without a resolution. Defining the bounds of space and 'size' for all points resolve this issue, such as using the average standing area of a normal human being (0.28m2) (Turner et al., 2001). Movement tends to be linear, so the axial line or line of sight and access (e.g., axis) represents an idealization. A line is a set of points having no width or depth, only a length. The matrix of longest and most strategic (i.e., fewest) axial lines completely covering all spaces of an urban environment as defined by its built surfaces (walls or facades) is the axial map (Hillier and Hanson, 1984). The axial map is the most common reference to a 'space syntax model' for forecasting movement flows in the urban environment with usually 60%-80% accuracy (Hillier et al., 1993; Penn et al., 1998). The occupation of space tends to be convex, where everyone can see and be seen by everyone else, such as a group of people gathered in a circle or a room. Convexity is 'the quality or state of being convex' (Source: Oxford English Dictionary). All points are visible to all other points in a convex space. The convex map composes all convex spaces in a built environment, which tends to be more helpful for building analysis (Hillier et al., 1987; Hillier, 1996; Hanson, 1998). The potential for seeing and moving is a visual field, all visible and accessible space from which we might see or move as defined from a point or set of points such as a point, axial line, or convex space (Benedikt, 1979) (Figure 2). A visibility map is the matrix of all visual fields from a gridded set of points to all others in a built environment (Turner et al., 2001). Space syntax uses combinations of these simple descriptions — point, line, space, field — to create sophisticated representations of the built environment.

Figure 2 Visual fields (in dark grey) from (left to right) a point, line, and convex space (in light grey) in the layout of Souq Waqif in Doha, Qatar (Source: Authors/Tannous et al., 2021).[1]

Space syntax researchers measure the matrices of these representations – point, line, convex space, visual field - using topological graph theory to quantify the configurational relationship of each to all others and vice versa or within a set range. Configuration is a network system where local changes have global effects across that system to varying degrees, dependent on system size

[1] Plan elements in the large open plaza towards the lower-left represent impediments to movement but not visibility, i.e., a typical human being sees over the top of these elements.

relative to the significance of the change itself (Hillier, 1996). We can illustrate the basics of configuration using a simple example from Hillier (1996) (Figure 3). We can understand the basics of measuring configuration using topological graph theory where two objects labeled A and B similarly relate until introducing a third object named C, such as the surface of the Earth. All three objects vary configurational relationships based on connection or permeability in the justified graph where we represent the object as a node and their relation as a line. We can measure such a relationship for various parameters based on mean depth within – borrowing a phrase Baudrillard (1968) popularized - the system of objects. The key is that configurational measures offer a scientific basis to implicate or dismiss the designed spatial network as a factor for social, functional, or cultural inputs or outputs.

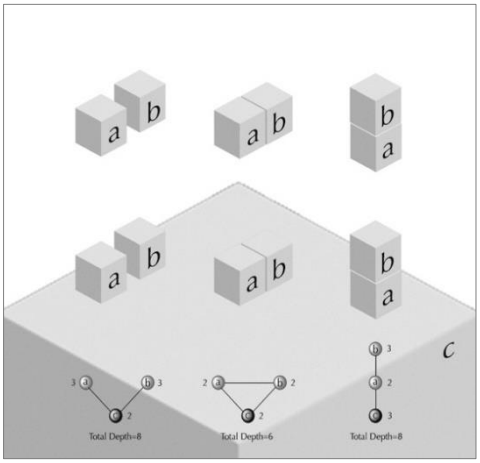

Figure 3 The basics of configuration (Source: Tannous et al., 2021 and Major, 2018 after Hillier, 1996).

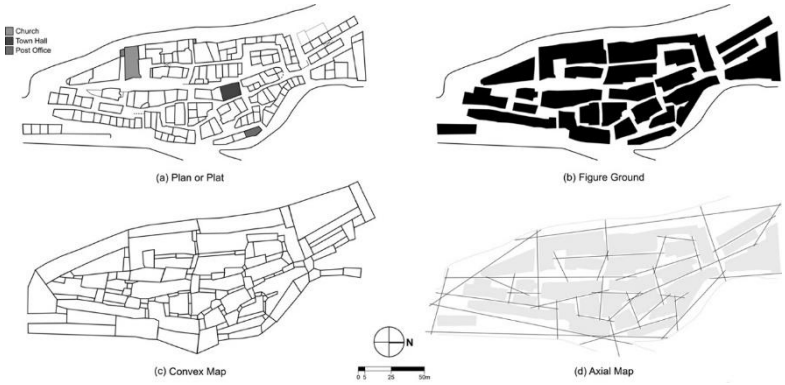

Figure 4 Space syntax modeling of the layout of Gassin in the Var region of France circa 1980 based on the (a) plan/plat, (b) figure-ground with defined bound, blocks in black, and space in white, (c) convex map, and (d) axial map (Source: Tannous et al., 2021 after Hillier and Hanson, 1984).

Urban analysis in space syntax usually relies on drawing an axial map of the open space structure based on a plan to analyze its spatial configuration (Hillier and Hanson, 1984; Hillier, 1989) (Figure 4). The best results usually require a plan or plat accurately depicting all building footprints in a settlement. We can also represent the open spaces using the fewest and fattest set of convex spaces as defined by the facades of the built environment necessary to encompass the entire settlement in the convex map. We might double-check the one-dimensional mapping of the axial map for connecting all two-dimensional representations of convex spaces by overlaying one map on top of the other. Most people skip this stage unless they research the design or use of specific convex spaces in a settlement such as a public plaza or square. They immediately draw the most extended and fewest axes to pass through and encompass the open space structure of the entire settlement to create an axial map. Best practice usually suggests beginning with the most extended lines, then the shortest lines, and concluding with lines of intermediate length connecting between

the two extremes of length.2 Using a figure-ground representation with all built forms in black often assists this process. Once the axial map is complete, computer software processes the map to analyze the system of relations between the lines. Hiller and Hanson (1984) argue the relation of all representations in any system is measured based on two essential properties: symmetry and asymmetry/distribution and non-distribution. It means the degree to which spaces compose shallow rings of circulation or deep sequences of trees in the underlying topological graph.

Laws of the Urban Object

Hillier and Hanson (1984) understood that others might misconstrue space syntax as an esoteric technique without general principles applicable to the built environment worldwide. They set about deriving general principles of space based on their research findings, colleagues, and students at UCL, especially settlements (Hillier & Hanson, 1984; Hillier, 1989, 1996, 1999a-b, 2002; Hillier & Vaughan, 2007). Such principles must apply to the design and planning of the built environment based on – but thriving in the explicit absence of – space syntax technique (Major & Donegan, 2020). It is impossible to summarize the knowledge base of findings deriving from space syntax in a single paper. A recent textbook about space syntax in urban design even falls short of comprehensive for brevity's sake (van Nes & Yamu, 2021). Nonetheless, these general principles have been helpful and resilient. Papers on hundreds of research topics from many reputable institutions globally support them and the application of space syntax in successful, real-world projects over the last 30 years, beginning with the Foster & Partners' King Cross masterplan in 1988 (Major, 2018).

Hillier (1989) argued three general laws govern the urban object. First, Type 1 laws govern its generation. Second, Type 2 laws govern its effect on urban function and vice versa. Finally, Type 3 laws govern its influence on society in generating a distinctive spatial culture. We can view Type 2 laws (practical and socioeconomic function) as the critical mediator between Type 1 (technical tendencies of form and space) and Type 3 (ethnic or cultural specifications) laws (Major, 2018). A city is never only one thing but a dynamic synthesis of all three, which gives rise to what is allocentric ('common to all') and egocentric ('unique to each') about settlements (Carvalho & Penn, 2004). Hillier's (1989 and 1996) most critical theoretical breakthroughs based on space syntax involve Type 1 laws giving shape to and being shaped by Type 2 and Type 3 laws. His ideas about the urban object appear to directly build on Lefebvre's (1974) ground-breaking argument regarding cities and space production. Lefebvre (1974) argued that space is a product of complex 'social structures' – physical, social, and mental spaces – as types, respectively, relating to Hillier's (1989) later three laws of the urban object (Salama & Wiedmann, 2013).

It includes what Hillier (1996) defined as "generic function, by which means the spatial implications of the most fundamental aspects of human use of space, that is the fact of occupation and the fact of movement" (5–6). Hillier (1996) detailed this concept specifically for buildings, but Major (2018) argues that generic function is just as applicable for settlements, if not more so. In The Syntax of City Space, Major (2018) discusses how topographical conditions generate previous arrangements in space, making some locations better suited for human settlement than others. Site selection is the first conscious act of design in town planning. It rarely occurs in an intellectual vacuum, if ever (Major, 2018). In settlements, generic function means movement and the fundamental human requirements of occupation, e.g., water, food, and shelter. We do not need to build to move. We need to move to build and occupy a space. Water, food, and shelter are basic requirements to sustain our occupation of a space on the surface of the Earth (Major, 2018).

Hillier (1996) outlined other concepts with broad applicability for the built environment, i.e., the principle of centrality and axiality. The principle of centrality is the most internally integrating or

[2] If the researcher does not use the auto-generation functionality of space syntax software. Auto-generation still requires careful review and correction of the axial map.

accessible shape is a circle. Hillier (1996) refers to this principle as the Law of Compactness. The principle of axiality is the most externally integrating or accessible shape is a line. We can refer to this as the Law of Linearity, though Hiller never explicitly does so (Hillier, 1996; 267-69; Major, 2018) (Figure 5). The most recognized form of these laws at work in buildings are room and corridors, respectively. In settlements, it is blocks and streets (Figure 6). As Jacobs (1961) observed, elongated urban blocks deter activity and walkability, whereas smaller ones promote the opposite, primarily blocks square-ish shape adhering to Hillier's (1996) Law of Compactness (Major, 2018; Major & Al-Nabet, 2018).

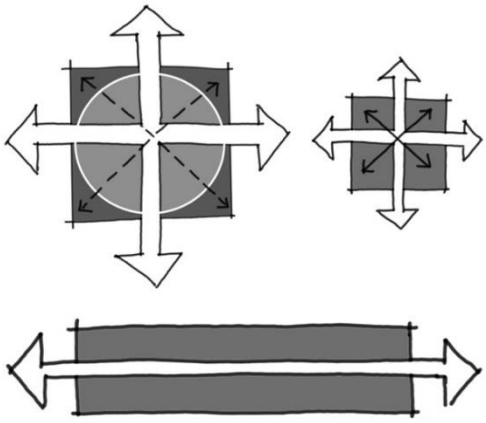

Figure 5 (top) Sketches illustrating in simple terms the principle of centrality or Law of Compactness and (bottom) the principle of axiality or Law of Linearity (Source: Authors, original skteches by Heba O. Tannous).

Figure 6 Figure-ground representations of one (1) square kilometer (km^2) area of urban fabric oriented north to a set scale in: (top, left to right) Alexandria, Egypt; Amman, Jordan; Beirut, Lebanon; Cairo, Egypt; Casablanca, Morroco; Damascus, Syria; Doha, Qatar; and (bottom, left to right) Dubai, UAE; Istanbul, Turkey; Jeddah, Saudia Arabia; Jerusalem; Kuwait City, Kuwait; Muscat, Oman; Riyadh, Saudi Arabia (Images: Authors/ARCT 210/DAUP-CENG-QU).

Finally, Hillier (1996) argued that cities adhere to laws of spatial emergence and convergence. By emergence, Hillier (1996) means predictable "global spatial effects" arising from purely "local physical moves" in the design of the urban grid (5). What we design has predictable effects on the spatial network of settlements. It must: otherwise, what is the point of hiring built environment professions? By convergence, Hillier (1996) means "processes whose rules… converge on particular global types which may vary in detail but at least some of whose most general properties will be invariant." It means effects on urban spatial networks are more similar than different in settlements, usually converging on the ortho-radial grid type worldwide to one degree to another (245) (Figure 7). Major (2013 and 2018) identifies the design methods characterizing these purely 'local physical moves' resulting in readily predictable spatio-formal processes (Major et al., 2019). These spatio-formal processes are expansion, block manipulation (upsizing and subdividing), deformation, extension, marginal separation by linear segregation, and discrete separation by linear segregation. The last is a common consequence of suburban sprawl, especially in the American experience (Figure 8). Major (2013 and 2018) argues these processes are allocentric, arising from Type 1 laws shaping urban form. They vary in egocentric terms from settlement to

settlement and region to region over time only for metric scale and geometrical articulation as mediated by Type 2 (socioeconomic) and Type 3 (cultural) laws of the urban object (Major et al., 2019). However, geometric order has the benefit of making the process effect of these formal design methods on urban space readily apparent to the naked eye (Major, 2013 and 2018).

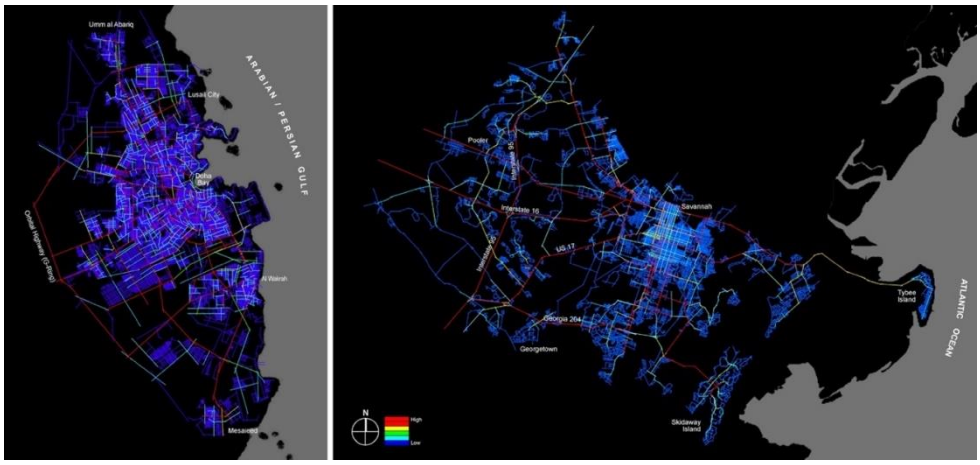

Figure 7 Global choice in the axial map of (left) Metropolitan Doha, Qatar in 2020 and (right) Metropolitan Savannah/Chatham County, Georgia USA in 2019 (Images: QUCG-CENG-20/21-1/Major, 2020). Note: Not set to common scale.

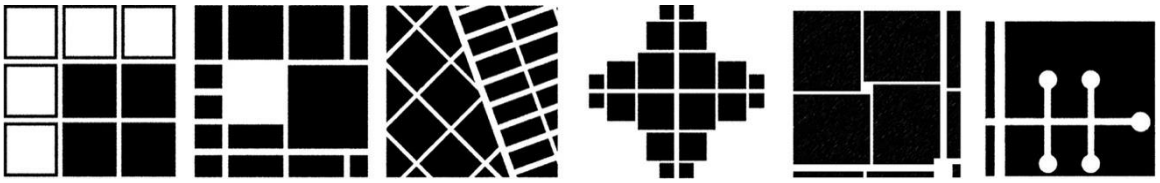

Figure 8 Representations of the most common design methods with predictable spatio-formal process effects in shaping the urban pattern: (from left to right) expansion, block manipulation, deformation, extension, marginal separation, and discrete separation (Source: Major, 2013, 2018 and Major et al., 2019).

Laws of Spatial Conservation and Optimization

There is a demonstrative resilience to Hillier and Hanson's (1984) thinking about the urban object through the replication of results by numerous practitioners and scholars using space syntax theory in settlements across the world; too many to briefly recount here (van Nes & Yamu, 2021).

In the case of Doha, the replication of results includes a well-defined, deformed wheel spatial structure connecting from the Old Doha to the expanding urban edges of the city, identification of a local area effect in the second-order measure of Synergy (global vs. local integration) for all internal routes of Souq Waqif ('standing market') in the oldest historic area of the city, and evidence of urban centrality at work in the composition of the urban spatial network to effectively maintain the shallowness of Souq Waqif within this emergent spatial structure over time. For example, Souq Waqif encompasses only 0.19 km2 excluding the perimeter streets, but the catchment contour map within three directional changes is 22 km2, extending 2-4 kilometers (km) to the west, southwest, and south. Using Hillier's (1999b) terminology, the 'spikey potato' catchment contour map of Souq Waqif represents a 116-to-1 ratio compared to its actual size. It occurs all in a manner previously described by Hillier, Hanson, and many others found in other cities worldwide (Hillier & Hanson, 1984; Hillier, 1996 and 1999a-b; Major, 2018) (Figure 9 and 10).

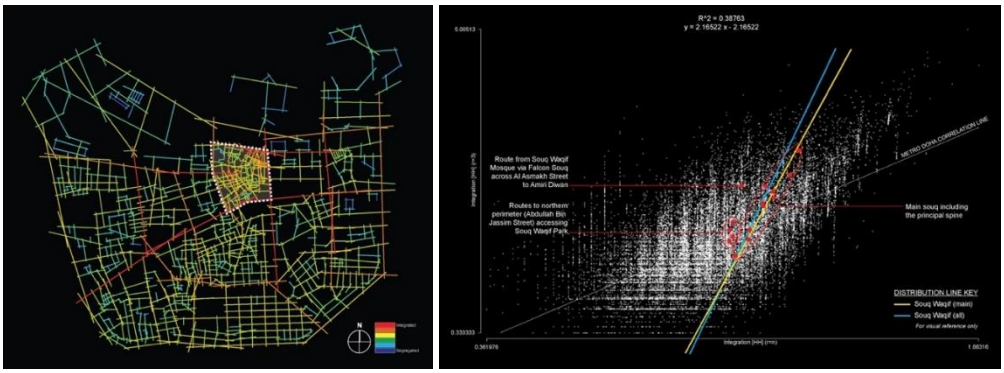

Figure 9 (left) Space syntax model of the pattern of local integration (r=3) within the C-Ring Road in Doha in 2020 and (right) Local Area Effect for the principal routes of Souq Waqif (outlined in white in the axial map to the left and below) for Synergy (global v. local integration) within the urban spatial network of Metropolitan Doha (Source: QUCG-CENG-20/21-1/UREP25-002-5-001).

Figure 10 Urban centrality of Souq Waqif (outlined in dotted white) represented in the catchment contour map on all routes, represented as axial lines, within three changes of direction from the principal routes excluding the perimeter streets (Source: QUCG-CENG-20/21-1/UREP25-002-5-001).

Despite the resilient nature of space syntax, there still appears to be a theoretical gap in our thinking. It lies below the urban whole – emergence-convergence, foreground and background networks – and even below the urban pattern itself, i.e., Laws of Compactness and Linearity, spatio-formal processes (Hillier, 1996; Hillier and Vaughn, 2007; Major, 2018). It deals with individual and collective actions in shaping and regulating the built environment. The former intimately ties to the generative effects of Hillier and Hanson's (1984) restricted random process following simple aggregation rules. The latter relates fundamentally to the emergence of town and urban planning as a distinct discipline and profession. Because of this, we hypothesize there is a need to introduce two additional laws of the urban object in the space syntax lexicon to address this perceived gap.

Figure 11 (left) Restricted random aggregation in giving rise to the early urban form of Doha, Qatar in 1947 and the (right) Sub-Saharan settlement of Ghadames, Libya in 2013 (Source: Embassy of Qatar in Bangkok, Thailand/Steinmetz, 2013).

First, there is substantial historical evidence for a law of spatial conservation at work in the built environment. The law of spatial conservation pertains to the replication of local design moves. People will tend to replicate formal order ad infinitum in pursuit of their spatial strategies to conserve topo-metric characteristics in the absence of intervention. Hillier and Hanson's (1984) restricted random process – as Major (2018) describes it, restricted random aggregation – in settlements is a prominent feature of the law of spatial conservation (Figure 11).

A law of spatial conservation would provide a framework to explain why restricted random aggregation persists in some settlements for so long until some require extensive remedial top-down planning corrections such as Haussmann's introduction of boulevards in Paris in the late 19th century or elsewhere in the world (Karimi, 1998). It helps to explain Americans' extensive use of geometric order concepts in urban form, arising out of European Renaissance planning principles, for more than 350 years if we date from the founding of St. Augustine, Florida, in 1565 until the Euclid decision in 1926 (Major, 2018).[3] It also illustrates Americans' persistence in building suburban sprawl for economic and regulatory reasons in the post-WW2 period, despite well-known problems that sprawl generates for the public health of individuals and communities (Katz et al., 1993; Major, 2018) (Figure 12).

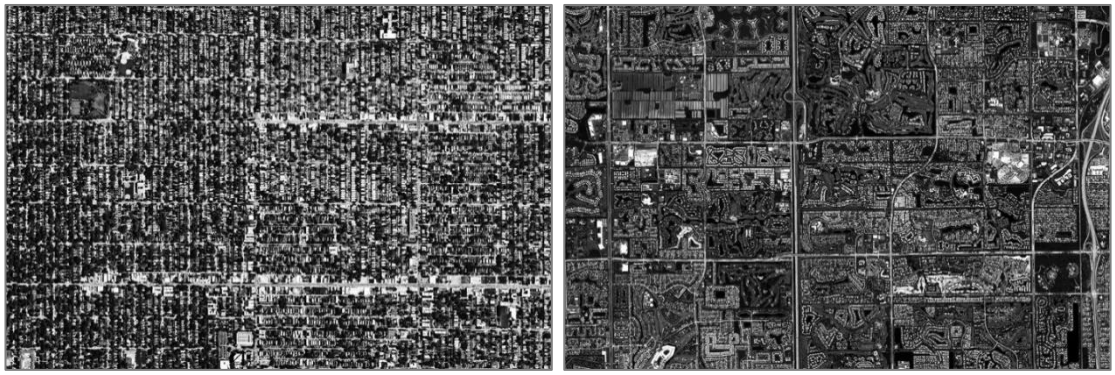

Figure 12 (left) The expansive orthogonal grid in the western suburbs of Chicago, Illinois USA in 2020 and the (right) proliferation of suburban sprawl in Boca Raton, Florida USA in 2019 (Source: Google Earth).

People will 'design along to get along' without intervention. The law of spatial conservation is the basis for town planning as a progressive endeavor or intervention where changing behavior is the goal for the good of society. In this sense, progressive means "happening or developing gradually or in stages," derived from the verb progredi from pro- meaning 'forward' plus gradi meaning 'to walk," which contributes to the Latin progressus meaning 'an advance' (Source: Oxford English Dictionary). It can be an actual or perceived good where subsequent events prove it either right or wrong over the long term. For example, Modernism manifestly represents a progressive movement in architecture and urban planning, even if subsequent events demonstrate critical flaws in Modernist planning principles (Jacobs, 1961). New Urbanism and its allies such as the Smart Growth Movement only represent the latest progressive attempt to address the underlying law of spatial conservation in changing individual and collective behavior of the good of society (Katz, 1993).

There is also evidence for a law of spatial optimization in the built environment. It indicates that people's use of space will tend to deviate marginally from local formal order to maximize most efficiently the topo-metric characteristics if allowed. It explicitly builds on Conroy-Dalton's (2001) ideas about angular choice and conservation of linearity in movement, namely that "people tend to conserve linearity through their routes with minimal angle deviation" (47.11). The most obvious evidence for this law at work in the urban environment is desire lines or paths, which we find

[3] Village of Euclid, Ohio v. Ambler Realty Co. (1926) was a landmark US Supreme Court decision establishing zoning a valid exercise of police power under the US Constitution.

worldwide. (Figure 13). It is an eroded path due to foot traffic, representing the shortest or most easily navigable route from one place to another in preference to – or the absence of – a designated alternative. The width and severity of erosion indicate foot traffic levels (Source: Wikipedia/Merriam-Webster Dictionary).

Figure 13 (left) Desire line cutting through the grass at the southern corner of the intersection of Ahmed Bin Ali Street and Mohammed Bin Thani Street near Hamad Medical City in 2019 and (right) remediation and attempt to deter use of a desire line by laying large landscaping stones in Medina Centrale at The Pearl-Qatar in 2018 in Doha, Qatar (Source: Authors).

Figure 14 (right) All unprogrammed street crossings (in blue) of perimeter streets and movement patterns (in yellow) of a typical two hundred (200) people from the perimeter streets and underground infrastructure during the first 10 minutes of their visit or until they reached their initial destination, whichever came first,[4] Doha and (left) public agency introduction of a double-row of fencing with landscaping to prevent unprogrammed street crossings (primarily women with children) from Souq Waqif (on the right) to Souq Waqif Park (on the left) later in 2020 (Source: UREP25-002-5-001).

The law of spatial optimization means 'people move along to get there easily.' It is the basis for design and planning as regressive control where controlling behavior is deemed necessary – or perceived as necessary, whether right or wrong over the long term – to protect society. The purpose of such control is to restrict people's ability to maximize their efficient use of space. It falls under the purview of public agencies' regulatory power to protect public safety. However, since the mid-20th century, it has often been a thinly veiled disguise to keep vehicular traffic flows moving quickly and smoothly at the expense of human-scale urban design. Other examples of regulatory attempts to control spatial optimization are erecting fences down the middle of the road and threatened enforcement of draconian 'jaywalking' laws to compel people to use designated crosswalks instead of crossing streets where it is most convenient (Figure 14). In contrast, advocates of contemporary planning concepts such as Shared Space implicitly seek to capitalize on the potentials of the law of spatial optimization. They promote human-scale urban design for pedestrians while explicitly seeking to retard vehicular speeds and impacts of the private automobile on the public realm of our cities.

[4] Compiled during three months of fieldwork in Winter 2020-21 at Souq Waqif.

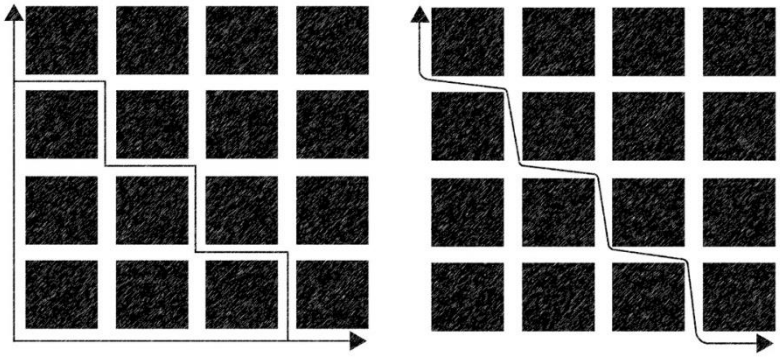

Figure 15 Orthogonal grid showing (left) two journeys from corner to the opposite corner of the layout with an equal trip distance of 950 feet (289.5 meters) via either the perimeter streets or cutting across the grid to approximate a diagonal and (right) a single journey with a trip distance of a little over 800 feet (~244 meters) by approximating a diagonal through space of each street segment (Source: Authors)

Geometry, Fractals, and Self-Similarity

Spatial conservation and optimization are opposite sides of the same coin, which could co-exist under a broader umbrella of a law of spatial conservation since conservation occurs in spatio-formal and use terms. However, we distinguish between form and use (or function) in our definition to clarify and illustrate the different potentials of each. Nonetheless, form does not follow function nor vice versa. Form and function merely are.

We can conduct a thought experiment utilizing Hillier's Laws of Compactness and Linearity to demonstrate first, why people optimize their movement across space to diagonalize the urban grid and second, how this might play a role in giving shape to both the urban object and people's use of space. For this purpose, we utilize a simple orthogonal layout composed of lots one-eighth (1/8) of an acre in size measuring 55 x 100 feet or fifty-five hundred (5,500) square feet (SF) where the street widths are fifty-five feet. In metric terms, it means the lots are marginally larger than 500 square meters (m^2), measuring about 16.75 x 30.5 meters, where the street widths are also 16.75 m. The overall size of the layout is 1030 x 950 feet (314 x 290 meters) with a land area of ~980,000 SF (~91,000 m2), or about 22.5 acres, excluding the perimeter streets.

Now, imagine two journeys available in the same layout from corner to the opposite corner as more or less represented in the least line axial map (Figure 15, left). The basis of the first journey is the most efficient trip from origin to destination. Efficiency in this sense means the most optimal, feasible route utilizing the fewest changes of direction. In this case, one change of direction using the perimeter streets. The basis of the second journey approximates a diagonal from origin to destination. In this case, the most optimal approximation for a diagonal across the layout requires a minimal seven changes of direction. The approximate length of both journeys is nine hundred and fifty feet (289.5 m).[5] Based on the least line axial structure, approximating a diagonal across the layout is seven times less efficient in terms of direction changes than using the perimeter streets for covering the same distance.

At least, this is what Minkowski's (1910) Taxicab or Manhattan geometry would tell us (Conroy, 2001). Taxicab or Manhattan geometry is an absolute coordinate system devising a new metric where the distance between two points is the difference ('as the crow flies') of their Cartesian coordinates. The latter name (Manhattan geometry or distance) alludes to the gridded layout of streets on the island of Manhattan, which causes the shortest path of a car between two intersections in the borough to possess a length equivalent to the intersections' distance in taxicab geometry. Perhaps it is telling that the rise of the use of Manhattan distance in town planning and

[5] The distance for the route approximating a diagonal across this layout is actually approximately twenty-five (~25) feet or 7.5 m longer due to centrally locating the journey in the space of each street segment.

urban transportation coincides with the rise of the private automobile and regulatory enforcement of street sections, which confine pedestrians to the edges of streets.

However, pedestrians move across the urban grid every day while in movement from here to there everywhere in the world. The reason is quite simple; people utilize any feasible opportunities to do the same within the space of the street segment itself to converse distance and optimize their use of space. The most efficient journey conserving distance in movement through this layout transverses segments at about a 15º angle with the cardinal directions, or right and left turns occurring at 105º rather than a 90º angle. In effect, the pedestrian reads the spatial structure in terms of visual integration for the closest approximation of a diagonal at the global and local scale of the journey, i.e., across the grid and within the street space itself, respectively. The distance of this journey is a little over eight hundred (800) feet. Even though approximating a diagonal still involves seven directional changes, the journey is twenty percent (20%) more efficient in conserving distance than using the perimeter streets.

The most efficient journeys from all spatial locations to all others in the layout tend to pass through the center and radiate outward from there to the edges (Hillier, 1996; Major, 2018). The larger the block, then the less acute is the available angle for pedestrians to transverse a street segment on a diagonal, therefore the amount of distance conserved is corresponding less. It seems important. Jacobs (1961) argues smaller blocks are better for pedestrian activity and Whyte (1988) concurs with her assessment, “the tight grid and short blocks may be rigid but that pattern maximizes pedestrian activity” (337). It appears more accurate to say that compactness rather than smallness is better for pedestrian activity.

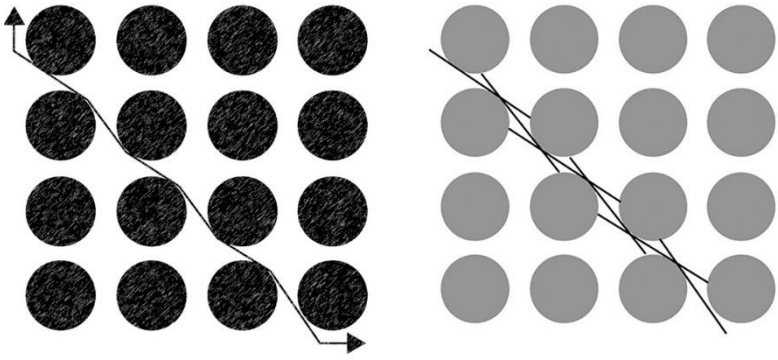

Figure 16 – Orthogonal grid showing experiment (left) optimizing a journey across the grid using circular-shaped blocks and (right) the axial structure of such a trip (Source: Authors).

Another simple experiment demonstrates this when we replace the square-shaped blocks in the layout with circular ones, i.e., the most internally integrating shape according to Hillier (1996), providing a minimum perimeter *surface area* for each urban block (Figure 16, left).6 The apex of the *circumference* defines the most optimal visual lines of sight in the layout. For a journey from one corner to the opposite across the layout, it is possible to approximate a diagonal from origin to destination more closely. Seven direction changes are still required, but they are more gradual than within 15º of a right angle. The most efficient journey to conserve distance transverses at a 35º angle through each street segment with a trip distance of seven hundred twenty-five (775) feet or 236 meters. Using circular blocks makes the journey ten percent (+10%) more efficient for conserving distance than the layout with square-shaped blocks and thirty percent (+30%) more efficient than utilizing perimeter streets with only one change of direction. Of course, circular blocks are not practical in terms of the most optimal use of the land for lot subdivision. The potential for

[6] Triangular-shaped blocks provide a minimal perimeter surface but defined within the same bounds, it would also lose a significant amount of buildable area. A layout based on triangular-shaped blocks would be diagonal streets in one dimension and straight streets in the other as well as for the perimeter streets if bound remains in the the shape of a rectangle.

greater efficiency in terms of movement by using circular blocks sacrifices other efficiencies afforded by rectangular blocks, i.e., surveying, vertical construction, etc.

The least line axial structure illustrates this journey (Figure 16, right). It is not an accident that it begins to approximate the typical structure of principal streets in a deformed grid layout, i.e., within a 15º angle of a direct continuation according to Hillier (1999a) but 20º in the case of this layout. North London provides a perfect example of how the law of spatial optimization can find its way into shaping urban form (Figure 17). A comparison of three radial trips out of central London to the northwest edges of the city – sequence of Camden Road/Chalk Farm Road/Belsize Park Road/ Haverstock Hill/Hampstead High Street/Heath Street, Finchley Road, and Edgeware Road – suggest spatial optimization at work as axial lines get longer and straighter with overall size over time. Many short axial lines (~15, dependent on where we begin the journey) compose the first radial route. A moderate number (~9, again depending on where we start) form the second. Only a few axial lines (~4) compose the last, i.e., Edgeware Road. However, all three perform the same functional role in the emergent spatial structure of Greater London. Taxicab or Manhattan distance also begins to better approximate actual Cartesian distances with the more significant formal order and *vice versa.*

Figure 17 – Satellite view from 5 km showing the compositional relationship of the (from left to right) Edgeware Road, Finchley Road, and Health Street/Hampstead High Street/Haverstock Hill/Belize Park Road/Chalk Farm Road eventually to Camden High Street in north London, United Kingdom in 2021 (Source: Authors/Google Earth).

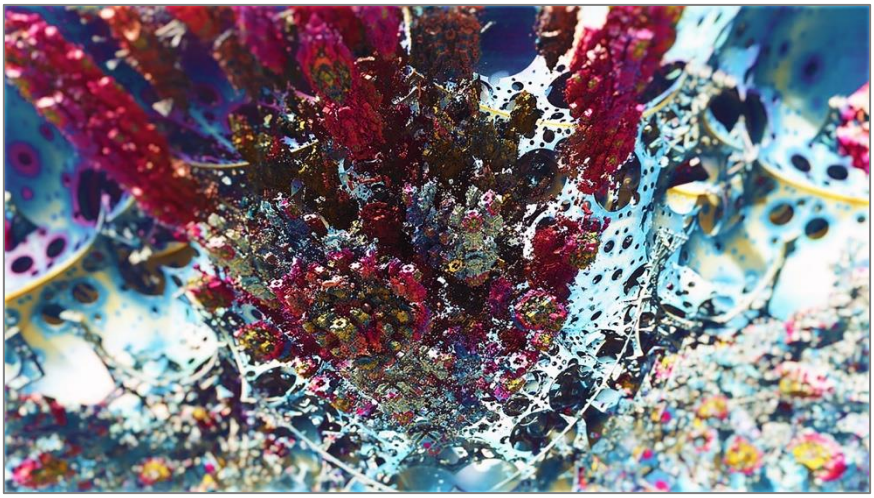

Figure 18 – Fractal city (Source: Pixabay).

Spatial conservation and optimization seem to offer a firmer theoretical foundation linking space syntax theory with the work of Batty (2005) and others about the fractal nature of cities (Batty & Longley, 1984). They argue that all cities have a fractal dimension (Figure 18). Fractals are infinitely complex patterns that are self-similar across different scales, created by repeating a straightforward process over and over in an ongoing feedback loop such as Hillier and Hanson's (1984) restricted random aggregation (Major, 2018). However, a law of spatial conservation as an aspect of people designing along to get along in their spatio-formal strategies also describes the fractal generation of urban form. It incorporates repetitive processes using only a few rules, some articulated in ethnic-specific terms, such as additional rules about the placement of front doors and windows overlooking yards in the experience of Islamic settlements (Tannous, 2020; Major & Tannous, 2020; Khan et al., 2021; Tannous et al., 2021). The fractal dimension is an aspect of self-similarity characterizing all settlements across different scales. It tends to persist even as the scale of the urban pattern upsizes during the evolution of city growth (Batty and Longley, 1994; Carvalho and Penn, 2004; Shpuza, 2014). It is unsurprising. Due to the human genotype, all cities are principally composed of blocks and streets as the material realization of Hillier's principles of centrality and linearity in the urban pattern. Spatial conservation and optimization are fundamental aspects of each in formal and spatial terms. Two sides of the same coin spent in giving shape to and our everyday use of the urban object.

The implications are many. Recognition of the resilience of local design moves in bottom-up processes in a law of spatial conservation might indicate a greater need for empathy about the instrumental power of the self-generating mechanisms of the urban object. In some cases, this might mean professionals allowing time before intervening, so such mechanisms to evolve into a state of maturity. On the other hand, minimal angle deviation to converse linearity in movement through built space is a well-established principle of space syntax and its measurement toolkit. Embedding this principle within a general law of spatial optimization might allow professionals a better framework for capitalizing on these spatial potentials in design and planning. Space syntax consultants already do this to a large degree in crafting the form and function of the built environment in real-world projects. However, articulating a law of spatial optimization on such terms removes the issue from the purview of design intuition – even ones based on space syntax – to practical application about what people want to do in their built environments if allowed. It might also bring into doubt the wisdom of road centerline mapping since it favors separated road sections and promotes mechanized travel by default, like the coordinate concept of Manhattan distance itself. Such a re-think might be necessary if we want to truly achieve human-centered design in this cultural milieu, which values other 'things' above that of the people living in our built environments.

Conclusion

We attempted to cover a substantial amount of theoretical ground concisely, including definitions of resilience in the field, the resilient nature of space syntax as a method, and the essential components of theoretical thinking to arise from the space syntax research program over the last forty years. On this basis, the paper offered a new hypothesis about laws of spatial conservation and optimization at work in the built environment. We argued the former provides an essential link to Batty and Longely's (1994) notions of fractal cities based on Carvalho and Penn's (2004) concept of self-similarity in settlements. The latter explicitly builds on Conroy-Dalton's (2001) ideas about angularity and conservation of linearity in movement. Both provide the conceptual framework for the progressive and regressive nature of town planning as a discipline worldwide today. We briefly illustrated evidence for our arguments based on replication of previous space syntax findings in the urban spatial network of Metropolitan Doha. We also presented new research findings drawing on the history, spatial structure, neighborhood logic, and pattern movement patterns in that city. The paper concluded by arguing that conservation-optimization provides a critical 'glue' to unify several concepts floating within and surrounding space syntax and town planning.

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Acknowledgements

The title of this paper is an explicit reference to Jacobs' (1961) famous phrase that cities happen to be problems in organized complexity in the Final Chapter of The Death and Life of Great American Cities (New York: Penguin Books).

Figure-ground representations of one km^2 in Muscat, Oman and Doha, Qatar by Heba O. Tannous as part of her MUPD Thesis (Tannous, 2020). Authors modified the figure-ground representations in Figure 6 originally by undergraduate students on the ARCT 210 course in the Department of Architecture and Urban Planning, College of Engineering at Qatar University in Fall 2017, 2018, and 2021 including: Najla Al-Mohannadi (Alexandria, Egypt); Alya Al-Marri (Amman, Jordan); Shams A. Allawi and Fatima K. Al-Hayder (Beirut, Lebanon); Farsana Abdulla Aravassery (Cairo, Egypt); Saaeda Al-Bader (Casablanca, Morocco); Hawra A. Moosawi and Marwa A. Elaradi (Damascus, Syria); Fatima Al-Jaeri (Dubai, UAE); Aisha Alahbabi (Istanbul, Turkey); Reem Taher and Hanan Alemadi (Jeddah, Saudi Arabia); Dhabya Al-Naimi (Jerusalem); Maryam Al-Subaey and Aljazi Al-Marri (Kuwait City, Kuwait); and, Maryam Mohammed (Riyadh, Saudi Arabia).

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Resume

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Association between home layout connectivity and cognitive ability in community dwelling older adults: Implication for occupational therapy

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Abstract

Physical environment has long been recognized within occupational therapy as a key factor contributing to residents' functional abilities. However, the specific aspects of the physical environment that matter and the extent to which they do so remain less understood. This paper reports a quantitative study of the relationship between a characteristic of the physical home environment—the degree of interconnectedness of its rooms—and the cognitive ability of adults. Working with demographic, health, and home layout data collected from a sample of community-dwelling older adults in Atlanta, Georgia (N=72, Mage=69.5), we found that the cognitive functioning determined by the Montreal Cognitive Assessment (MoCA) score was significantly associated with the average connectivity and mean depth of the homes while controlling participants' age and education. Regression analysis suggested home connectivity independently explained a little more than 4% of the variance in the MoCA scores. The results further revealed that the relationship may be better modeled using non-linear models, and that the increase in the numbers of circulation rings as average room connectivity rises may be partly, but not entirely, responsible for its association with cognitive ability. The study points to directions for further work, including causal modeling, based on recommendations that could be developed for homes to support older adults' abilities to continue to reside in their own homes as they grow older.

Keywords: aging in place, cognitive functioning, home connectivity

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1. Introduction

The role of environment in its many forms, including the physical characteristics of space, is a central concept in occupational therapy research, theory development, and practice. Kielhofner in his Model of Human Occupation (Kielhofner et al., 2008) as well as Law in her Murriel Lecture (Law, 1991) discussed the role of space or physical built environment (BE) in facilitating optimal occupational performance. But can the effects of the environment be shown to be systematic enough for its role in occupational therapy to be practical and effective? And if such systematic effects are found, can they be associated with specific features of the environment?

This question has recent begun to receive some attention from researchers in public health, focusing particularly spatial layouts of residential neighborhoods. Over the last two decades, several studies reported significant associations between features of neighborhood BE with depression (Domènech-Abella et al., 2020; Pan et al., 2021), physical activity (Bonaccorsi et al., 2020; Cleland et al., 2019; Yu et al., 2021), obesity, hypertension, and diabetes (Chandrabose et al., 2019). Importantly, these are also established risk factors for dementia and/or Alzheimer's disease (AD) in older adults (Livingston et al., 2017; Roe et al., 2020). Recent research on BE and health is beginning to find empirical evidence for an association between the layout of BE characteristics and the cognitive health of older adult residents. For example, a 2015 study on neighborhood connectivity and integration demonstrated a significant relationship between physical neighborhood characteristics and continued cognitive performance (Watts et al., 2015). In 2019, Besser et al. showed that the association between BE and cognition could be moderated by apolipoprotein E (APOE) genotype, a genetic risk factor for AD, thereby establishing a gene-environment interaction (Besser et al., 2019). These studies proceed from the assumption that the layout of streets can create significant differences of affordances to neighborhood services and markets, walkable areas, and security between individual homes. The differential affordances can lead to differences in cognitive behaviors and explain the observed association between BE layout parameters and cognitive health. Decline in cognitive health is a key predictor of dementia and AD (Livingston et al., 2017).

It is possible to argue that the association between BE and cognition is not just due to overt behavioral consequences of differential opportunities of affordance but due to latent cognitive factors as well. For example, a recent survey of research on designing facilities for individuals suffering from dementia reports a few empirical studies exploring the idea that building configuration or layout may influence residents' orientation, wandering habits as well as social interactions (Day, 2002). There is however lack of explicit theory as a result of which intriguing empirical findings are left unexplained (Day, 2002: 380).

One basis for a possible theory is the fact that people do not rely merely on immediate perceptual information or affordances from the environment in order to negotiate it, but also construct and invoke cognitive maps of environments as part of their plans, strategies, and schemas for conducting everyday activities (Downs, 1973; Gati & Tversky, 1984; Tversky, 2003; Tversky & Hemenway, 1984). The cognitive map that we normally use to learn and navigate the layout of space is constructed by firing in the hippocampal place cells in response to signals from the sensory-motor cortex and visuo-spatial cortex (O'Keefe, 1978). Visuo-spatial memory is therefore especially implicated in this ability. Any loss of functionality in visuo-spatial memory will impact both the ability to form new cognitive maps and to navigate using existing maps. The evidence came from the observation of severe deterioration of wayfinding performance when the participants were distracted with tasks that interfered with visuo-spatial cognition (Hund, 2016). Some layouts, then, may be easy for older adults to map cognitively and to negotiate, but other layouts may be not.

The relationship between the cognitive complexity of layouts and behavior competency must exist at the level of the individual home as well. People construct cognitive maps of their homes as much as they do so at the neighborhood level. A person, theoretically, uses these maps to locate

household and personal items, keep track of others in their homes, keep themselves oriented, and order their lives through the day. The cognitive maps of the layout of the home are particularly relevant in the case of older adults, who are likely to spend a considerable amount of their time in their own homes and performing various activities of daily living. Older adults whose cognitive abilities (memory and visuo-spatial cognition) suffer may find it difficult to construct cognitive maps of their environments, and thus their ability to engage in the occupational performances of their activities of daily living (ADLs).

If the layout induced cognitive challenges are not matched to their abilities, older adults tend to respond with maladapted behavior. For example, reducing the levels of their occupational activities, exhibiting learned helplessness, or showing negative affect. An idea that is well-entrenched in environmental studies of aging in the form of competence-environmental press model first developed by Nahemow and Lawton (1974).

Characteristics of layouts and cognitive ability

One way to manage the mismatch between competence and press that comes with aging is to reduce the environmental press to match the lowered competence level. For example, layouts can be simplified, all areas of the home put on a single floor, and ways found to reduce visual clutter in the home. A useful study in this context is by Marquardt et al. (2011), who found that residents in institutional homes with lower convexity scored higher on scores for ADLs. Convexity was constructed as a measure on a ratio scale that combined the amount of fragmentation into convex spaces and the proportion of spaces assigned specific labels, in which low convexity could be interpreted as a setting that had fewer but proportionally more labeled spaces. They surmised that low convexity would make the layout as a whole easier to memorize and so facilitate participation in ADLs.

But another way is to create layouts that may offer just the right amount of challenge and act as an enabler for behavioral adaptations that may even improve mental health. After all, certain basic activities of living have to be conducted no matter what, and when compelled to do so in environments that are challenging, but not to the extent that they prevent the activities from being conducted, inhabitants of these environments may continue to engage in the necessary activity. Engaging in challenging mental activity would then lead to improvement in their cognitive ability, and the home layout may then be thought of as an active ingredient of therapeutic practice, playing a passive role but more actively helping their residents stave off cognitive decline that comes with age. Nahemow and Lawton (1974: 29-30) themselves suggested this line of thinking, demarcating “a zone of maximum performance potential” with slightly challenging environmental press, in which adaptation would take on positive effects (Figure 1).

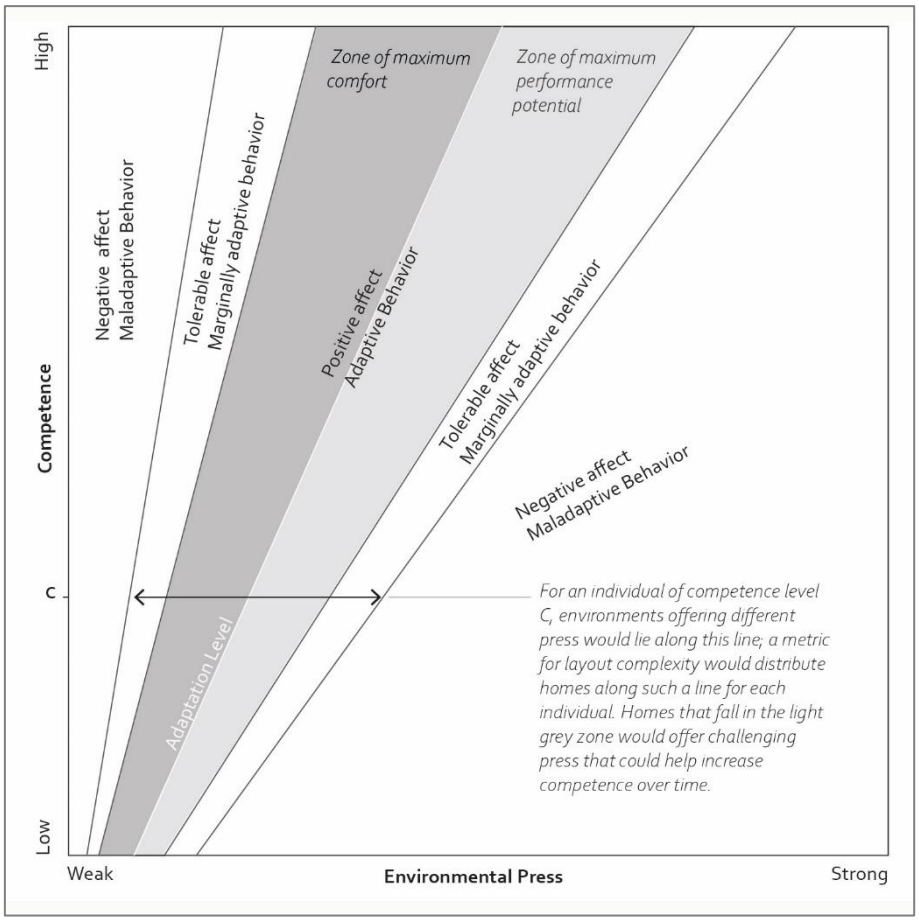

Figure 1 The press-competence model describing the types of adaptive behavior and affect individuals exhibit under varying conditions of environmental press and personal competence. Drawing after Nahemow and Lawton (1974).

There is a biological basis for this argument (termed "the enriched environments hypothesis" in neuroscience literature) that cognitively challenging environments can lead to improvement in cognitive function. However, the current evidence supporting it comes largely from animal models (Cao et al., 2017; Fischer, 2016; Leggio et al., 2005). If such an effect can be demonstrated in humans as well, it leads to the possibility of treating the home as a potential therapeutic aid or intervention tool. Early results are encouraging (Leggio et al., 2005), but reviews of this work routinely raise two kinds of questions that would need answering in order to devise effective treatments:

1) It is still not clear what exactly constitutes an enriched environment in the case of humans (Kühn et al., 2017);

2) there is lack of theory on the basis of which treatments may be standardized (Ball et al., 2019; Hertzog et al., 2008).

It is clear that the second of these questions depends on the knowledge required for the first. Once some key properties of an enriched environment are understood, experiments could be devised for developing the right level of complexity to create enriching environments and devising standards for treatment.

Metrics for environmental complexity

Our study is intended to address the first question. More specifically, the question that motivates our research is whether the complexity of layout can play a role in creating environmental enrichment and, if so, what properties of layout could capture this enrichment. Space syntax offers several indices to capture various characteristics of layouts derived from different kinds of discretization schemes (Bafna, 2003; Hillier, 1984; Peponis, 1997; Turner et al.,

2001)[1] .The one that we favor in this case is a type of partitioning scheme known as the "boundary map", a very early analytical strategy (Hillier, 1984) that has gone out of favor in recent work (but see Bafna, 2001). It is created simply by dividing the entire space of the home into discrete spaces (rooms) using two rules: 1) there should exist a clear, sharp, and unambiguous transition between two spaces, 2) the rooms so formed should have a distinct identity, established either through a label or through specific elements of furnishing. Doorways (with or without doors) are typical of such transitions, but there are other instances where a sharp threshold demarcates one room off from another—a nook or alcove, off a larger room, or a change of ceiling height between two spaces. The standard procedure, which we follow, is to treat the partitioned space as a graph in which nodes and sometimes edges can be assigned numeric indices that depend upon their positions within the graph.

In adopting the boundary map, we drop the typical requirement that the rooms formed by partitioning be convex spaces. Defining both consistent (that is, unique) and efficient convex partitions has been shown to be a problem without a solution in all cases (Peponis, 1997), and if efficiency is sacrificed in order to ensure consistency, the resulting scheme produces spaces that do not have a straightforward interpretation in terms of categories of rooms through which residents conceive of their homes.

This procedure generates a partition that has several features to recommend it:

1. It creates graphs that can be interpreted in a straightforward manner: edges as sharp transitions, either as doorways, or as thresholds, between distinct rooms, nodes as rooms that can be described in terms of categories that form a part of residents' conceptions of their homes.
2. The graphs, therefore, have a *realist* character; they represent not something accidentally created in the process of shaping a building, as often happens in the case of convex mapping schemes, but an organization that can conform closely to the residents' cognitive maps of the spatial organization of their homes.
3. Most importantly, this approach gives us a way to create indices that are easily computed, with measurement errors easily checked and corrected.

The metric that we think would capture the cognitive complexity of the layout most efficiently is the average room connectivity. Computed as the average number of links associated with each node in the boundary graph of the home, roughly as the number of doors per room in the house, it can be taken directly as a measure of the degree of interconnectedness of the rooms of the layout. If more doors are opened in the rooms of a house without increasing the number of rooms, then it follows that the extra doors will create internal circuits or rings, that is, alternate pathways between rooms. A house with a greater number of internal doors per room would offer greater variety for movement trajectories or movement options within it and encourage a more active lifestyle. It would, however, require a greater cognitive effort in the organization and execution of activities of daily living—in the selection of routes through the home by comparing expected effort, for instance, or in keeping track of other members of the household as they move around, or even in making mental maps of the house. On the other hand, this effort cannot become prohibitively great if the house is to maintain a sense of livability. Average room connectivity is therefore a good measure of layout complexity: it is simple to compute; it can be directly associated with design guidelines; and, within the range of normal houses, it is likely to vary from a value that is associated

[1] Space syntax is an analytical approach to the description of built space that seeks to capture the sociologically relevant aspects of the space of buildings and settlements. Those readers who are unfamiliar with space syntax will be able to find an accessible introduction in Bafna (2003); those seeking a more in-depth explanation of its theoretical ideas that motivated it should consult Hillier and Hanson (1984). Peponis and Wineman (2002) review the different questions in environment and behavior studies to which space syntax had contributed, and so give a fairly comprehensive sense of its successes and challenges.

with very little cognitive effort, to one that is associated with just enough challenge to lead to positive adaptations of the kind proposed by Nahemow and Lawton (1974).

2. Methods

Design and participants

This study is a cross-sectional design. Data were collected in three successive phases over 3 years. Seventy-one adults living within the greater Atlanta GA area participated in the study. These participants were recruited via convenience sampling, consisting of fliers, and word-of-mouth. Inclusion criteria were: (1) having an of age 60 or older, (2) living in their own home, (3) having no known cognitive impairments, and (4) having the desire to stay in their own home. Exclusion criteria included current orthopedic or neurological issues that prevented independent living. Any participants who lacked adequate vision or were non-ambulatory were also excluded from this study.

Variables

Demographic Variables: Age, gender, education, and income of all participants were collected. As a comparison, the same measures of US population estimates were also collected from U.S. Census Bureau data.

Variable characterizing cognitive ability: The Montreal Cognitive Assessment (MoCA) is an assessment that can be used to screen for cognitive impairment as well as to assess cognitive ability and track cognitive changes over time (Koski et al., 2009). The MoCA has excellent internal consistency (alpha = 0.83), excellent test-retest reliability (r = 0.92), and excellent concurrent validity (r = 0.87) (Nasreddine et al., 2005). At a cutoff score of 26, the MoCA has a very high sensitivity of detecting mild cognitive impairment (90%) and Alzheimer's disease (100%), with a somewhat lower specificity of 87% (Nasreddine et al., 2005). Lower than expected scores on MoCA may therefore indicate reduced cognitive ability but not cognitive impairment as such.

Variables characterizing home layouts: Space syntactical metrics were used directly to create variables characterizing different aspects of home layouts. Home layouts were recorded by observers trained to draw maps of homes on-site and to record measurements of room-sizes. These hand-drawn maps were then translated into diagrams in a generic CAD-format (.dxf) that recorded individual rooms as polygons connected by centerlines that represented doors between them. Depthmap version 10.14.00b (Copyright: University College London, Alasdair Turner, Eva Friedrich, 2010-11), was used to compute syntactical metrics.

Syntactical metrics are graph measures that are computed either for each node (that is, for each room in the house), or for the entire house. Our study took the entire house as a unit of measurement, and metrics that are computed at room level were aggregated and averaged to produce house-level metrics. The main variable of interest, as described in the previous section, was average room connectivity—this is computed simply as the mean number of links per node that occur in the graph of the home. Two other syntactical metrics also featured as explanatory variables in some of our models, but only as possible co-variates in our explorations to achieve proper specifications of our models. One of these was the number of nodes (the number of rooms obtained after partitioning the layout of the house), and the other, the average mean depth of all the nodes (the mean of all shortest paths between all non-identical pairs of nodes of the graph representing a house).

Analytical approach:

Our general analytical approach was to test different models for explaining variations in MoCA scores, with a particular focus on average room connectivity as a predictor. We began by examining

each of the variables of interest for potential problems or to identify distinctive or unusual values. MoCA scores were compared to published normative data to see if our sample had any unusual characteristics. Of the explanatory variables, both demographic variables and the syntactical indices were also compared to available public data in order in order to get a sense of the representativeness of our sample. Correlations between explanatory variables were examined to give us some information about how to set up multiple regression models that we would eventually use. After this preliminary work, we constructed a series of simple regressions to check how each of our proposed predictors performed individually and then finally constructed several multiple regression models testing different assumptions about both nature of the relationship between the outcome and explanatory variables—whether it was best taken to be linear or non-linear—and whether the specific characteristics of the outcome variable called for particular types of modeling approaches. Throughout our approach focused on exploration of data and discovery rather than on proving or disproving specific hypotheses.

The analyses and data-transformations were performed using a number of libraries available for the R programming language, using Rstudio as the IDE (R Core Team [2020]. *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria).The results reported here used the base library of R as well as libraries *ARM* [Andrew Gelman and Yu-Sung Su, 2020, *Data Analysis Using Regression and Multilevel/Hierarchical Models*, (R package version 1.11-2)], *CAR* [John Fox and Sanford Weisberg, 2019, *An R Companion to Applied Regression*, *Third Edition* (Thousand Oaks CA: Sage)], *Betareg* [Achim Zeileis, Francisco Cribari-Neto, et al. 2021, Betareg: Beta Regression (R package version 3.1-4)], and *Splines2* [Wang W, Yan J, 2021, Splines2: Regression Spline Functions and Classes (R package version 0.4.5)]. Graphics were all produced using the base R package.

3. Results

Preliminaries

Our sample included data from 71 individuals, of which 26 were men and 45 women. All were, by sampling design, older adults ranging in age from 60 to 92 years, distributed around a mean of 69.5 years (with a standard deviation of 8.8 years). As Table 1 shows, the level of education in our sample was relatively high. Only 2 individuals reported education level without a high school diploma, and 38 individuals (53%) reported having obtained a bachelor's degree or higher. In comparison, 54% of adults older than 65, residing in Atlanta, have a bachelor's degree (U.S. Census Bureau, 2019b). The income distribution in our sample (Table 1), with a median income category of ($50,000 to $74,000) also conformed quite closely to that of the city of Atlanta population (median income = 65,385; U.S. Census Bureau, 2019a).

Table 1 Characteristics of the study sample, compared with national demographic characteristics (US Census Bureau, 2019a and 2019b)

		Sample Data			Population Estimates (US)	
		N (%)	Mean (SD)	Range	%	Mean
Age			69.5 (8.8)	60-92		NA
Gender	Male	26 (37%)			46%	
	Female	45 (63%)			54%	
Education	No High School	2 (2%)			12.43%	
	High School	31 (43%)			48.39%	
	College Degree	38 (53%)			39.17%	

Income	Less than $20,000	7 (9%)			12 %
	$20,000 to $34,999	10 (14%)			11.3 %
	$35,000 to $49,999	11 (16%)			9.8 %
	$50,000 to $74,999	12 (17%)			15.4 %
	$75,000 to $99,999	6 (9%)			11 %
	Over $100,000	25 (35%)			29.1 %
Av. Room Connectivity			1.99 (1.7)	1.61-2.36	NA
Av. Mean Depth			3.10 (0.71)	1.87-4.82	NA
MoCA30 Score			25.27 (3.46)	15-30	26 (2.3)

The MoCA scores of our sample had a mean of 25.3, with a standard deviation of 3.5 points. Thirty-three individuals (46%) scored below the standard cut-off value of 26 that is used to identify individuals with possible cognitive impairment. In a study to gather normative data, Rosetti et al. (Rossetti et al., 2011) obtained a much lower mean value of 23.4 (sd = 4.0) from a sample of 2356 individuals. However, the sample included individuals between 18 and 85 years, who were not screened for any diagnosed cognitive impairment. Another normative study (Borland et al. 2017) with a more comparable sample of 758 adults with an age range (65-85 years) to our sample, which also excluded any individual with severe cognitive impairment, had a mean score of 26 (sd = 2.3), with 37.3% reporting scores below 26, reports data that conform quite well with our sample. Our sample, in short, did not exhibit any unusual characteristics with respect to the MoCA scores.

The average connectivity scores of the homes of the individuals in our sample ranged from 1.61 to 2.36. The range appears very small but is actually well within expected limits. It can be interpreted somewhat roughly as the average number of doorways per room of the house. Given contemporary privacy norms, most rooms in a typical single-family house will have one doorway, a few may have two, and very few other spaces, such as hallways, corridors, or lobbies have more than three doorways opening into them. The number of spaces (all distinct and separable spaces in the home that can accommodate at least one person conducting some daily activity) in these homes ranged from 6 to 27, showing that there was a fairly good degree of variation in the size of the homes in our sample.

Models

A simple OLS regression of MoCA scores on the average connectivity of the individuals' homes showed that the connectivity was able to explain 5% of their variation ($p = 0.039$; df = 1 & 69). The corresponding coefficient was 5.09 MoCA score units, with a standard error of 2.42. MoCA scores have been found to be quite susceptible to age and education in most normative studies; there is more equivocal evidence about the role of gender in determining them. We checked with this with a series of simple OLS regressions, with each of these variables taken as independent regressors. Age was found to predict about 23% of the variation in MoCA scores ($p = 1.17 \times 10^{-5}$; df = 1 & 69). Education (taken as an ordinal variable with three levels) was found to predict 9% of the variation ($p = 0.004$, df = 1 & 69). It is conventional to treat education as a categorical variable, but our sample data showed a consistent and linear increase in the MoCA scores between all three categories taken in order, thus supporting the case for treating it as a single regressor on an ordinal scale. Gender accounted for just about 1% of the variation in scores without reaching significance ($p = 0.83$, df = 1 & 69). Income level was also found to be a potential predictor of MoCA scores, explaining nearly 12% of the variation ($p = 0.002$, df = 1 & 69), but income level is correlated with education in our sample (as it should be), and when the model was adjusted for age and education, the effect of income disappeared (coefficient = 0.29, s.e. = 0.21, $p = 0.17$).

Learning from these exploratory models, we decided to adjust for both age and education, but not for gender or income, in modeling MoCA scores by average connectivity. An OLS regression model (see Figure 2) with three predictors—age, education, and average connectivity—produced $R^2 = 0.34$, ($p = 7.28 \times 10^{-7}$, df = 3 & 67). All three predictors reached the set significance level of 0.5 (see Appendix 1a for details of the model). The estimation of the coefficient associated with average connectivity reduced slightly (4.61, in comparison with 5.09 from the regression with average connectivity as the sole regressor), but it came with a gain in efficiency (s.e. = 2.08, in comparison to 2.42 in the simple OLS regression). A comparison model of the MoCA scores with only age and education level as predictors, produced an $R^2 = 0.31$ ($p = 1.53 \times 10^{-6}$, df = 2 and 68). This means that average connectivity was able to account for an additional 3% of the overall variation in the MoCA scores.

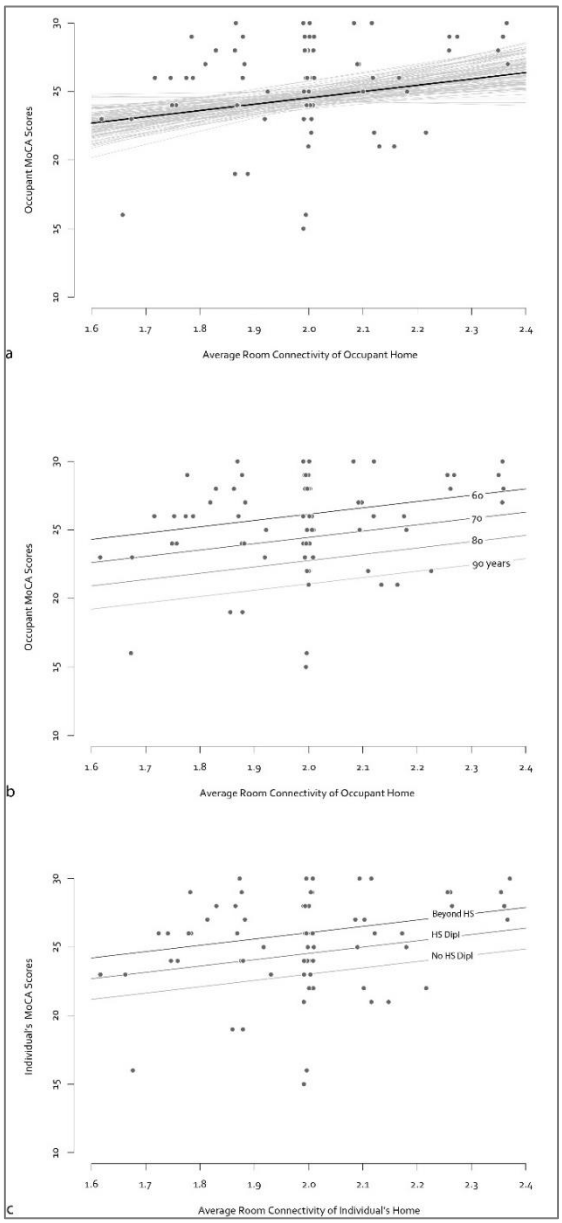

Figure 2 Estimated MoCA scores expected from given the average room connectivity values of their homes, plotted over actual values. The estimates are derived from the multiple linear regression model reported in Table 2. **2a** shows the line of best fit for 65 years old individuals educated up to high school; grey lines, representing other possible fits that might explain the given data, indicate the uncertainty of the estimates. **2b** shows estimated best fit lines for selected ages for a high school educated individual, and **2c** shows estimated best fit lines for each of the three levels of educational categories for a median aged individuals from the study sample. Note that in all diagrams, observed values are jittered along the x-axis to reveal overlapped datapoints, and so may not match each other precisely.

Basic diagnostic plots (Figure 3) of the regression model with age, education and average connectivity as predictors did not reveal any serious concerns. As the plots show, very slight heteroscedasticity as well as a slight departure from normality (hinting towards a negative skewness) in the residuals at the extreme range. Both these points reflect the truncated character of the MoCA scale at the upper end—the fact that MoCA scores of our sample cluster near the top, but cannot go past the highest score of 30. The observations are not a severe threat to the validity of the model for our data, but we discuss one possible way to address them in the section below for the more general case. There are no points with unusually high leverage.

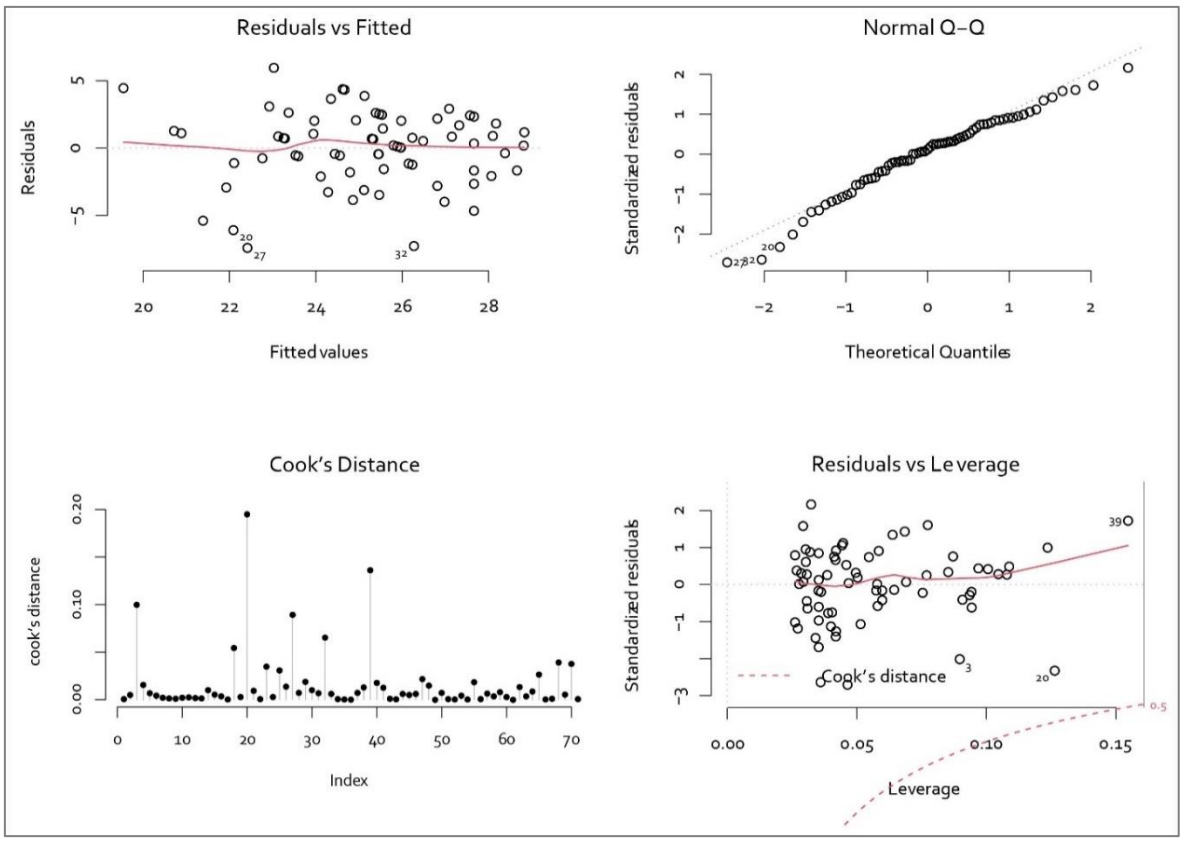

Figure 3 Diagnostic plots for the model presented in Appendix, Table 2.

Cognitive ability as a non-linear function of connectivity

It is reasonable to question whether the assumption that the relationship between the outcome variable and our main predictor can be expressed as a simple linear function. MoCA scores are constrained to lie between 0 and 30, and a large majority of healthy adults are expected to score near the higher end. In fact, the actual distribution of the scores that we modeled is only moderately skewed (skewness = -0.85); the residuals from our model still retain some skewness (-0.51), as our diagnostic plots (Figure 3) show. A somewhat related worry is the possible presence of heteroscedasticity as a result of the truncation of scores. To ameliorate this worry, we also tested a beta-regression model, rescaling MoCA scores as fractions of the maximum values, and modeling it as a beta distributed variable that ranges between 0 and 1 (Appendix 1b). The AIC value of –149.6 of the beta regression model is much lower as compared to AIC of –131.0 for an ordinary linear regression model of MoCA scores on the same scale, so it does offer improved efficiency. But within the range of connectivity values normally obtained in residences, the parameter estimates themselves close enough to the linear model to make the simpler linear model acceptable (Figure 4a; Appendix 1b).

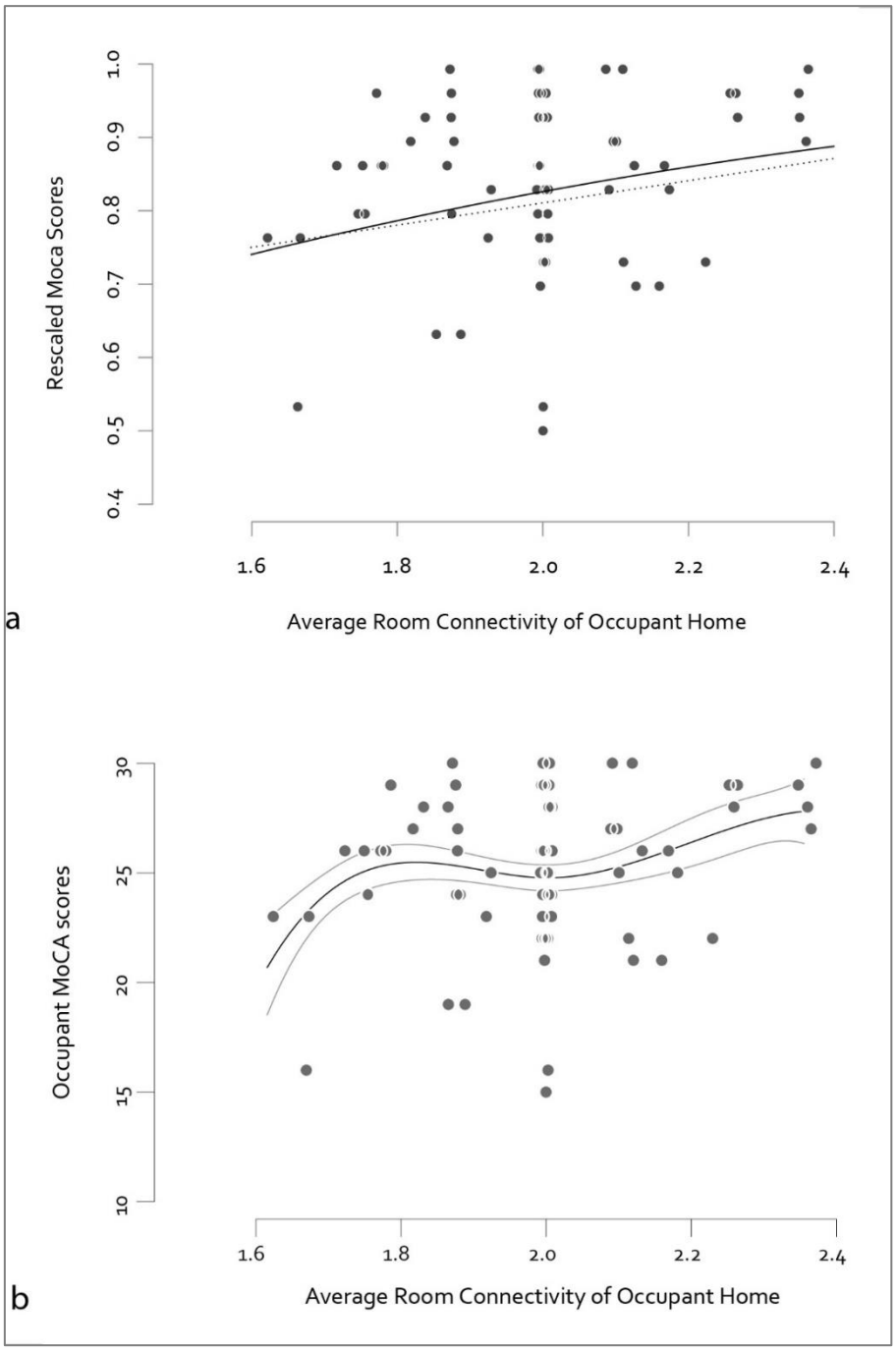

Figure 4 Models exploring non-linear associations between MoCA scores and Average room connectivity **4a** compares two fit curves; the dotted curve is the best fit line obtained for 70 years old individuals educated up to high school from a generalized linear model with gaussian distribution and identity link (in essence, an ordinary least squares multiple regression model); the solid curve is the best fit line from a beta regression model for individuals with the same characteristics (details in Appendix, Table 3); MoCA scores for both fits were rescaled to lie between 0 and 1. **4b** shows the pattern of association between MoCA scores of individuals and the average connectivity of their homes revealed by spline regression. The modeled curve shown here is a constructed using a b-spline basis (polynomials of degree = 3; df = 4), showing variation in MoCA scores predicted by average connectivity for a median aged individuals from the study sample with a high school education.

But there are other more substantive reasons to consider possibilities of non-linear relationship between connectivity and MoCA scores. Looking more closely at the scattergram in Figure 3, we can that a straight line may not best capture the change in MoCA scores as connectivity changes. In particular, there seems to be a less clear indication of a consistent positive association between the two for homes with average room connectivity below 2. This could be just a characteristic of our

sample, but there are reasonable theoretical grounds to believe that the pattern is general. From Euler's well-known theorem for polygons, we know that connectivity values greater than 2 can only arise if there are rings in the graphs, that is, if more than one paths exist between some pairs of nodes (Bafna et al., 2019). Below this threshold of 2, the drop in connectivity values is entirely a function of the number of rooms in the home; above this threshold, the connectivity depends upon a combination of the number of rooms and the number of circuits. We tested the hypothesis of non-linear relationship by modeling MoCA scores on our three predictors using a b-spline of 3 degrees for the relationship with average room connectivity, with 4 degrees of freedom. The estimated model produces an R^2 value of 0.36 ($F = 7.46$, $Df = 6$ and 64, $p = 4.3 \times 10^{-6}$), explaining 2% more of the variation, as compared to the model with a linear relationship (Figure 4b). To see if this increase in the explained proportion of variance is entirely due to average connectivity, we first modeled the MoCA scores with age and education as predictors, and then modeled the residuals from this fit, using only average connectivity as a predictor; the R2 value obtained was 0.06, which was 0.02 more than the proportion of variance explained by average connectivity alone in the OLS model. There are clear indications, therefore, that the relationship that exists between average connectivity and MoCA scores is not linear; however, a much larger sample and a stronger theory are required for exploring this relationship further.

4. Discussion

We must caution any enthusiastic readers against the inference that our findings offer empirical proof that layout can influence cognitive ability. Studies of this kind, based on observational data collected from the field, are only designed to test the extent to which the data are consistent with some hypothesized stochastic model that describes the posited relationship between predictor and outcome variables. The limited sample size of our study, which reflects the considerable resource costs needed to collect layout data on homes, also calls for caution in inference. But matters are somewhat ameliorated by the fact that our sample seems to be fairly representative of the US population in its demographic character (Table 1), giving us some confidence in the estimates generated from it.

Keeping these limitations in mind, we can make three reasonable inferences from the findings. The first, is that our data are consistent with the assumption that the relationship between features of home layout and their elderly residents' cognitive ability has a systematic component. Second, assuming that our sample data are representative, we can form at least a provisional judgment about the size of the associative effect we ought to expect. In our data, the average amount of difference in scores predicted over a standard deviation of interconnectivity found in houses—about one unit on the MoCA scale—was of the same order as that predicted by a decade of difference in ages. But the non-deterministic component—the between-subjects variance about the expected difference—is still relatively high; average room connectivity accounts for 4% of the variation in cognitive ability that is not accounted for by other factors. Third, our data clearly indicate that increase in cognitive ability is closely associated with increased occurrence of rings in traversal routes around the home, but that the increase of rings alone cannot account for the predicted difference in cognitive ability; it is possible that along with the increase in rings there is also an increase in perceived complexity of the home as the degree of interconnectivity increases, since larger homes with more rings also increase the difficulty of forming hierarchical conceptions of layouts.

If the results of study hold in further study, and if the substantive size of effects is judged to be therapeutically useful, our study offers support for a different approach into designing domestic environments for the elderly. Rather than designing home environments to only to reduce the environmental press, the design of environments may be utilized as a way to actively promote their health. As we had discussed in the introduction, the idea of devising a day-to-day living environment that offers the right level of cognitive challenges that lead to improved cognitive ability, or forestalls cognitive decline that comes with age, has been in the air since the 1970s. A key stumbling-block

has been the lack of ability to define what features of the environment can offer the right kind of enrichment for humans. Our findings lead towards the idea that the interconnected of layouts may be a basic feature of enriched environments.

Naturally, more work is needed to confirm these findings, to ensure that the associations they capture are consistent, and to establish reliable effect sizes, so that practical decisions about health outcomes may be made. The thrust of such work, if it develops, ought to be towards developing and clarifying the underlying theory rather than just seeking to establish more precise empirical associations with increasingly complex models.

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Resume

Dr. Bafna studies the principles that shape the built environment and govern its relationship with social, cultural, and imaginative life. He has published empirical studies on the impact of space on human behavior, cognition, social organization, and health, as well as critical studies of architectural works that explore topics in representation, aesthetics, and interpretation. As a member of the school of architecture faculty at Georgia Tech, he teaches courses in architectural theory, analysis and interpretation, and research methods. He is currently serving as the director of the PhD program in Architecture in the College of Design. Current projects include a book titled Imaginative Reasoning in the Shaping of Buildings.

Dr. Maitra is a Professor and the Chair and Professor of the Department of Occupational Therapy (OT) at Georgia State University, Atlanta, GA. He is an occupational therapist and a cognitive neuroscientist. Currently, he is working to understand the relationship between space cognition and the occupation of living in community-living older adults. He publishes in peer-reviewed national and international journals and regularly presents in national and international forums. Dr. Maitra received research support from federal agencies like the National Science Foundation (NSF) and the National Parkinson Foundation besides intramural fundings. He is a Fellow of the American Occupational Therapy Association, and he served as a Board of Trustees of the American Occupational Therapy Foundation for several years.

Dr. Lim is a pediatric occupational therapist at Let's Talk Therapy, Duluth, Georgia. She is also a lead clinical instructor and supervises fieldwork students from Occupational Therapy programs. Her clinical expertise is in strengths-based approach to autism and behavior and provides family-centered practice. Dr. Lim is a member of American Occupational Therapy Association.

Mansi is an architect and urban designer with 11 years of experience spanning practice, research, and teaching in India, the US, and Europe. She was mentored by Balkrishna Doshi – the 2018 Pritzker Laureate at his design laboratory in Ahmedabad, India from 2010-2014. Her research interests lie in understanding architecture's interaction with multiple disciplines such as psychology, linguistics, and anthropology. As a

visiting research scholar at Georgia Institute of Technology, she has been a part of several projects exploring the relationship between human behavior and the environment. She is currently a participant in a joint project between the architecture and psychology schools at Georgia Tech investigating the role of physical environments in post-pandemic work settings.

Yi-An Chen is an Assistant Professor in the Department of Occupational Therapy at Georgia State University (GSU). Chen's research interests mainly focus on upper extremity rehabilitation for people with neurological disorders (e.g., stroke and Parkinson's disease). She has been collaborating with experts and researchers from Georgia Tech and Emory University on several different projects, with the common goal to provide patient-centered training or design to allow better independent life of patients. Chen had her clinical training and earned a Master's degree in Occupational Therapy. She further pursued her Ph.D. in Biokinesiology at the University of Southern California, concentrating on neurorehabilitation. She completed her postdoc training at GSU Physical Therapy Department, focusing on telerehabilitation in stroke.

Appendix

Table 2 Summary details for ordinary least squares multiple regression model of MoCA with Age, Education (categorical) and Average Room Connectivity of Home as co-predictors

Call:
lm(formula = Moca30 ~ Age + Educ2_ord + Hs_connect, data = all_data)

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	24.09	4.97	4.85	0.00
Age	-0.17	0.04	-4.13	0.00
Educ2_ord	1.51	0.66	2.30	0.02
Hs Connect	4.61	2.08	2.21	0.03

Residual standard error: 2.8 on 67 degrees of freedom
Multiple R-squared: 0.37, Adjusted R-squared: 0.34
F-statistic: 13 on 3 and 67 DF, p-value: 7.3e-07

Table 3 Summary details of Beta Regression model of MoCA (rescaled) with Age, Education (categorical) and Average Room Connectivity of Home as co-predictors; the model for the estimation of means was specified with a logit link function; an intercept-only model with an identity link was specified for the estimation of the precision parameter

Call:
betareg(formula = Moca_beta_scl ~ Age + Educ2_ord + Hs_connect, data = all_data)

Coefficients (mean model with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	1.38	1.17	1.18	0.24
Age	-0.04	0.01	-4.55	0.00
Educ2_ord	0.32	0.15	2.10	0.04
Hs_connect	1.27	0.51	2.52	0.01

Phi coefficients (precision model with identity link):

	Estimate	Std. Error	z value	Pr(>|z|)
(phi)	13.52	2.28	5.92	0.00

Log-likelihood: 80 on 5 Df
Pseudo R-squared: 0.35
Number of iterations: 19 (BFGS) + 2 (Fisher scoring)

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Brasília: Superblocks in perspective

Frederico de Holanda*

Abstract

The design for the Superquadra Norte 109 [North Superblock 109] of the Brasília Pilot Plan, Brazil's Federal Capital, has started from a critical appraisal of the existent superblocks and makes a proposal that intends to: 1) establish clear relations of the block with the surroundings, stressing the importance of elements as the entrance for vehicles, the bus stop and the connections with the local shopping and the club, through the dimension and form of places, the localization of facilities, public lighting and vegetation; 2) improve internal legibility of the block, by creating places clearly defined by the buildings, to which entrance doors open; 3) create a street system in rings, not in a tree-like one, which are common in the existing superblocks, to improve internal circulation; 4) locate facilities internal to the superblock accessible to its entrance, by recognising (against what was predicted) that non-locals use them; 5) establish a continuous system of sidewalks that privileges the pedestrian, not the vehicle, as is traditional; 6) use vegetation and illumination to reinforce the identities of places in the superblock; 7) implement a configuration that explores a clear variation in forms, dimensions and uses, which favour the identity and orientability of the block; 8) configure open spaces and localise facilities of the superblock to favour co-presence and co-awareness among the inhabitants and between the latter and those passing by.

Keywords: Brasília, modern urbanism, superblocks, urban configuration, morphological performance, Space Syntax Theory.

1. Introduction

Brasília's "superblocks" are considered one of the main Lucio Costa's "inventions" in his "Pilot Plan" (henceforth "Plan") for the Brazilian Federal Capital (Costa, 1995). In four rows parallel to the Road Axis, the express road the cuts across the city form north to south, one of the two structural elements of the city (the other being the Monumental Axis, along which locate the main governmental buildings), they are the trademark of the residential fabric of his design for the city. Sixty odd years after the city's inauguration, what does the "superblock experience" tell us, by many considered as the dawn of a "new way of living in cities"? (Ferreira & Gorovitz, 2009).

As of its foundation, the University of Brasília has received a valuable asset in plots distributed along the Plan, to be administered and explored according to the institution's needs. This was the case with the superblock 109 in the North Wing of the city (henceforth in its Portuguese denomination "SQN-109"), unbuilt until 1985. In that year the University has asked some of the staff of the Faculty of Architecture to design the urbanistic project for four superblocks and I have carried out the one concerning the SQN-109.

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There are strict norms concerning such designs: apartment building heights limited to six stories over *pilotis*; occupation ratio of the block space by the housing plots of circa 20% of the total block area; compulsory facilities, as the Kindergarten and the Primary School, the newsstand, the administration, the playground and the multi-sports court; a single entrance for vehicles.

Nonetheless, even obeying such rules there is a wide range of morphological possibilities. Today, it is possible to assess the previous experience and hypothesise ways ahead to improve the blocks' configuration. The design that is presented in this paper illustrates one of such possibilities. However, before I embark on the discussion of the proposal itself, I discuss the theoretical framework considered.

2. Design as a conjecture-test process

Human practices – including the design and the production of places – constitute a *virtuous circle*, in Anthony Giddens' expression: we learn from our mistakes, from results which have been worse or better than those expected, we reconsider the precedents. Next time we will do different, in a continuous cultural evolution. Intervening in reality through design is like this: the virtuous circle in Figure 1 brings together Anthony Giddens and Bill Hillier, with reminiscences from Karl Popper, and represents design as a conjecture-test process (Giddens, 1984; Hillier, 1996; Popper, 2003 (1963)).

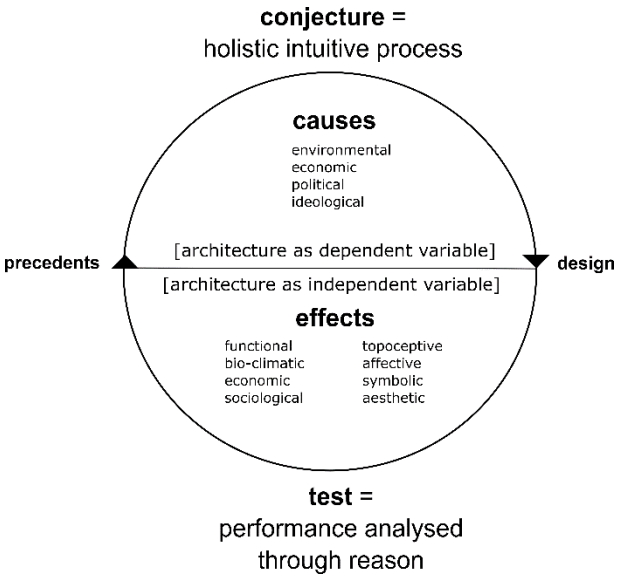

Figure 1 The *virtuous circle* of design as a conjecture-test process (inspired in Giddens, 1986, Hillier, 1996, and Popper, 1963). (Source: the Author)

The diagram re-takes the idea of causes and effects or architecture and inserts them in a continuous process. In other words, architecture, in the upper part of the circle, is considered a dependent variable, and, in its lower part, an independent variable. We design by considering precedents, even if they are constituted by unconscious, implicit, irreflexive knowledge. A task of scientific knowledge – systematic, conscious, reflexive – is to raise to the level of critical consciousness such savoir-faire, or, in Hillier's elegant formulation, switch from ideas we think with to ideas we think of (Hillier, 1996). When Lucio Costa designs his superblocks he submits in discursive knowledge the ideas he works with to formulate his proposal, i.e., ideology sensu lato (ideas in the broadest sense) as a determination of his design.

Here are the design principles of the superblocks he synthetically refers to: 1) a green belt; 2) cars in the centre, pedestrians in the periphery; 3) a single entrance for vehicles, avoiding through traffic; 4) "standard maximum height of, maybe, six stories over *pilotis*"; 5) "deep" schools, i.e., far from the vehicular entrance, presupposing they would be used only by locals; 6) "without

pavements of any sort, nor curbs" (Costa, 1995). How do such attributes satisfy or otherwise social expectations in relation to architecture, not any longer as ideas, but as the lived experience of the blocks along their six decades of existence?

Except for principle "6" all others have been implemented; they constitute the genotype – essence, structure – which underline the variety of the empirical examples materialised – phenotypes. (The concept of genotype is omnipresent in Space Syntax Theory – henceforth SST – initially proposed by Bill Hillier, Julienne Hanson and other colleagues at the Bartlett School of Architecture, University College London, and spread throughout research institutions worldwide, including Brazil (Hillier & Hanson, 1984)[1]. From the experience of the implemented superblocks I explore the lower half of Figure 1: how do they affect our expectations in relation to its architecture? How, considering the critical assessment of the existing ones, may we create new precedents to inform (*determine* – if you like) new designs?

In empirical reasonings as this one, in which real examples come to the fore, not pure concepts, the starting point – surely – are the actual realizations in time and space. The design of the SQN-109 has started, therefore, from the previous experience, but there is not here a wide examination of the many examples we have in Brasília; rather, I have chosen to focus on one of them (with little exceptions) – the South Superblock 308 (henceforth SQS-308) – which is acknowledged as the most well-succeeded one. In considering the best example, we can detect the genotypical problems, which, as such, are structural, and therefore happen even in less emblematic cases.

I critically comment on the SQS-308 attributes, and then move on to present the SQN-109 design and discuss how I have tried to avoid the identified problems. For the sake of conciseness, the attributes come to the fore, not the aspects of performance, as in the lower half of Figure 1, which I shall call the "eight-function model" (see below). The reason is simple: same attributes are related to different aspects of performance, and to focus primarily on the aspects would result in undesirable prolixity.

Finally, I present the SQN-109 project as a design conjecture (upper part of Figure 1) at which I arrive through a holistic and intuitive process, informed by precedents, which feed on the critical appraisal of existent reality (lower part of Figure 1), through an analytical decomposition of the eight aspects of performance. The analytical knowledge that has made this critique possible was cumulative, informed by research. The conjecture, no, as Hillier observes:

> The object of the architect's thought is a configuration, and a configuration is a whole entity, not an accumulation of parts. This of course is what we mean by a design conjecture. It is a configurational guess. It cannot be otherwise, since a configuration cannot be arrived at by an additive process. (…) A process of configurational conjecture cannot proceed other than non-discursively. It cannot therefore either follow a reasoned procedure, nor can it proceed additively from the bottom up. Design is by nature a holistic, intuitive procedure, and this conclusion follows from a reasoned analysis of the process of design (Hillier, 1996).

If the holistic conception is informed by intuition, its evaluation is informed by reason; if the former refers to a structured whole, the latter decomposes it into parts (or aspects, for that matter); in the evaluation process, software, analytical variables, measurements are applied. The design does not result from a single turn of the virtuous circle, but from as many turns as it proves necessary (or as many turns as time – or the client – allows for...), informed by the findings, as to performance, that tools and knowledge have made possible. At each finding, if a problem is diagnosed, our previous knowledge is enriched as to what to avoid and what to aim at, a new design conjecture is (intuitively) made, a new test is (reflectively) carried out – recurrently until the moment we feel no longer be able to advance in the design conjecture (limitations imposed by time, client, circumstances etc.) and at the state-of-the-art knowledge. It is impossible to estimate

[1] The founding book of the theory is HILLIER, Bill; HANSON, Julienne. *The social logic of space*. Cambridge: Cambridge University Press, 1984. In it for the first time are expressed in book form the axioms, methods and techniques of the theory, also known as the Theory of the Social Logic of Space.

a posteriori how many turns in the circle we have performed – even less so a priori how many we will perform next time...

3. The eight-function model

The idea of *aspects* or *dimensions of performance* in architecture can be traced to as back as Vitruvius and his trilogy, or "three-function model" (my terms): firmitas (solidity, i.e., the architecture will not fall apart), utilitas (the architecture will be convenient to use) and venustas (the architecture will please the eye). In the 1970's, through endeavours to strengthen *architecture as a discipline* (Hillier & Leaman, 1976), the classic essays by Bill Hillier and Adrian Leaman re-embark on the idea: in *How is design possible*?(Hillier & Leaman, 1974) they suggest a "four-function model" by which architecture implies four "modifiers" of the natural and the social environments in which it is inserted, another denomination for the same idea: the *behaviour modifier*, the *symbolic modifier*, the *climatic modifier* and the *resource modifier*. But if the aspects or dimensions are three, four, eight (as in Figure 1), or less, or more, it does not matter, the reasoning is the same, and it is in this route that we embark on here: we try to answer the questions of how does architecture affect our lives? or what type of social expectation is it able to satisfy? In the version I adopt since 2007 (F. d. Holanda, 2007; Holanda, 2010b) I summarise the aspects by means of questions:

> *Functional aspects*. Does the place satisfy the practical exigencies of daily life in terms of the type and the quantity of spaces required by the necessary activities, and their mutual relations?
>
> *Bio-climactic aspects*. Does the place provide adequate conditions of lighting, acoustics, air temperature, humidity, speed and quality?
>
> *Economic aspects*. Are maintenance costs compatible with the purchase power of the people concerned?
>
> *Sociological aspects*. Does the configuration of form-space (solids, voids and their relations) imply desirable ways of individuals and groups (social classes, genders, generations) deploying themselves in places and moving through them, and accordingly desirable conditions for encounters and avoidances and for the visibility of the other? Do the type, quantity and relative location of activities imply desirable patterns of utilization of places, in space and time?
>
> *Topoceptive aspects*.[2] Is the place visually legible, i.e., does it have a clear identity? Does the place offer good conditions for orientability?
>
> *Affective aspects*. Does the place have a clear, strong affective personality? How does it affect people's emotional state – e.g., vis-à-vis solemnity, grandeur, coldness, formality, intimacy, informality, simplicity etc.?
>
> *Symbolic aspects*. Is the place rich in architectural elements that remind us of other elements, on a larger scale than that of the place in question (e.g., a building representing the whole city), or of elements of diverse nature – values, ideas, history?
>
> *Aesthetic aspects*. Is the place beautiful, i.e., are there characteristics of a structured whole and qualities of simplicity/complexity, evenness/dominance, similarity/difference, that evoke qualities of clarity and originality, and in turn pregnancy, implying autonomous stimulation of the senses beyond practical matters? Is the place a work of art conveying a world view? Does its form-space express a philosophy?

4. General aspects

The SQS-308 was one of the first blocks implemented in Brasília (1959) (Figure 2). The superblocks are square in plan, measuring 250 x 250 m, a limit defined by the surrounding pedestrian walk, much used for jogging. Figure 3 shows the SQS-308, with its only entrance for vehicles, and its immediate surroundings, with the local shopping, the church, the Park School (which serve the neighbourhood of four superblocks and in which, in the educational system of

[2] *Topoceptive* is a neologism in KOHLSDORF, Maria E. *A Apreensão da Forma da Cidade*. Brasília: Editora Universidade de Brasília, 1996, later to appear in enlarged form in KOHLSDORF, Gunter; KOHLSDORF, Maria Elaine. *Ensaio sobre o desempenho morfológico dos lugares*. Brasília: FRBH, 2017. The neologism means *place perception* by the senses, mainly vision. Kohlsdorf is inspired by Kevin Lynch's work but goes much beyond it.

Brasília, cultural and sports activities take place) and the supermarket. Two other facilities outside the image complement the "borough", as Lucio Costa has expressed it: a club and a cinema.

Besides the schools, there are mandatory facilities within the superblock: playground, multi-sports court, and a newsstand. More recently a small building for the block administration has been included, as well as a taxi stop. Considering the limits of the surroundings pedestrian walk (250 x 250 m = 6,25 hectares), the occupation ratio by the residential buildings of circa 20% is responsible for the praised "bucolic" atmosphere of Brasília's superblocks.

Figure 2 SQS-308. Localization at the South Wing of the Pilot Plan. (Source: elaboration by the Author, on the basis of *Google Earth*.)

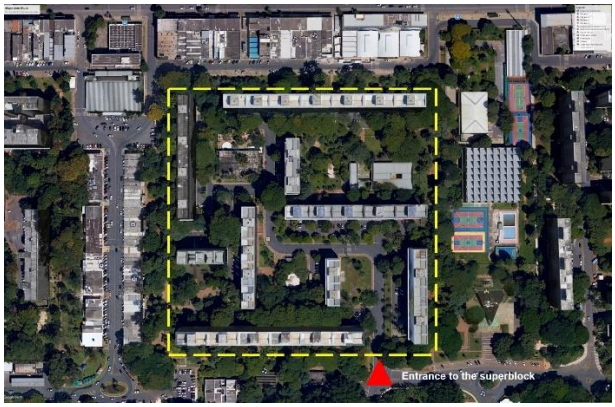

Figure 3 SQS-308. The superblock and its surroundings (local shopping, church, Park School, supermarket etc.). In yellow dashed lines, the location of the peripheral pathway, marking the 250 m *x* 250 m limits of the superblock. (Source: elaboration by the Author, on the basis of *Google Earth*.)

Figure 4 SQS-308. Two views of internal spaces of the block. (Source: the Author.)

Designed in 1985, the SQN-109 began its implementation in 1994. Figure 5 shows the location in the North Wing of the Pilot Plan, Figure 6 shows the design with the location of facilities, and Figure 7 the present stage of implementation, with its immediate surroundings. From the fifteen apartment buildings, ten are ready and inhabited. From the facilities, none has been built so far.

Figure 5 SQN-109. Localization at the North Wing of the Pilot Plan. (Source: elaboration by the Author, on the basis of *Google Earth*.)

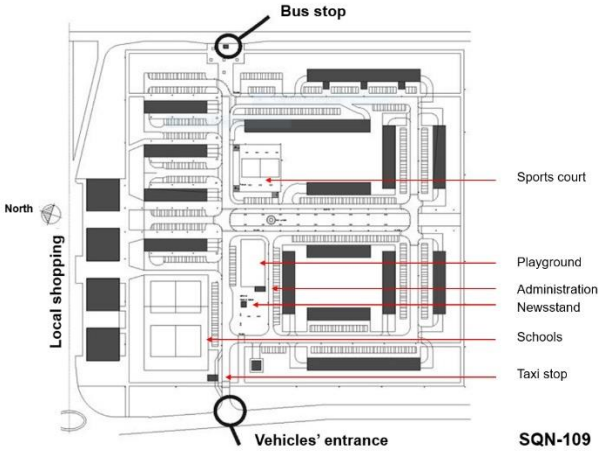

Figure 6. SQN-109. Overall design. (Source: the Author.)

Figure 7 SQN-109. Current state of implementation (2021). (Source: elaboration by the Author, on the basis of *Google Earth*.)

5. Entrance and street grid – vehicles and pedestrians

In previous blocks together with the only entrance we have a tree-like street system, with various implications: 1) *functionally*, it demands longer routes to service vehicles as mail, delivering goods and trash-collecting vans, forces one to drive twice along the same street segments, which has also *economic* implications in the performing of these services; 2) *topoceptively*, the similar street segments' length and the zigzagging of the route cause disorientation (Figure 8).

Figure 8 Labyrinthine and tree-like street system. (Source: elaboration by the Author, on the basis of *Google Earth*.)

In the SQN-109 I have kept the mandatory single entrance, but the street system is in rings, not tree-like (with few exceptions). There is a varied length of street segments, contributing to the topoceptive performance of the place concerning *orientability* (Figure 9): there is a reference to the classic Romans *cardus maximus* (north-south axis, which connects the interior of the block to the local shopping, to the north, and to the potential club, to the south) and the *decumanus maximus* (east-west, which leads to the bus stop, to the east, and to the entrance of the block, to the west); the two macro-elements, which do not exist in any previous superblocks, will confer a peculiar *identity* to the place, besides the *legibility* at the overall scale of the system.

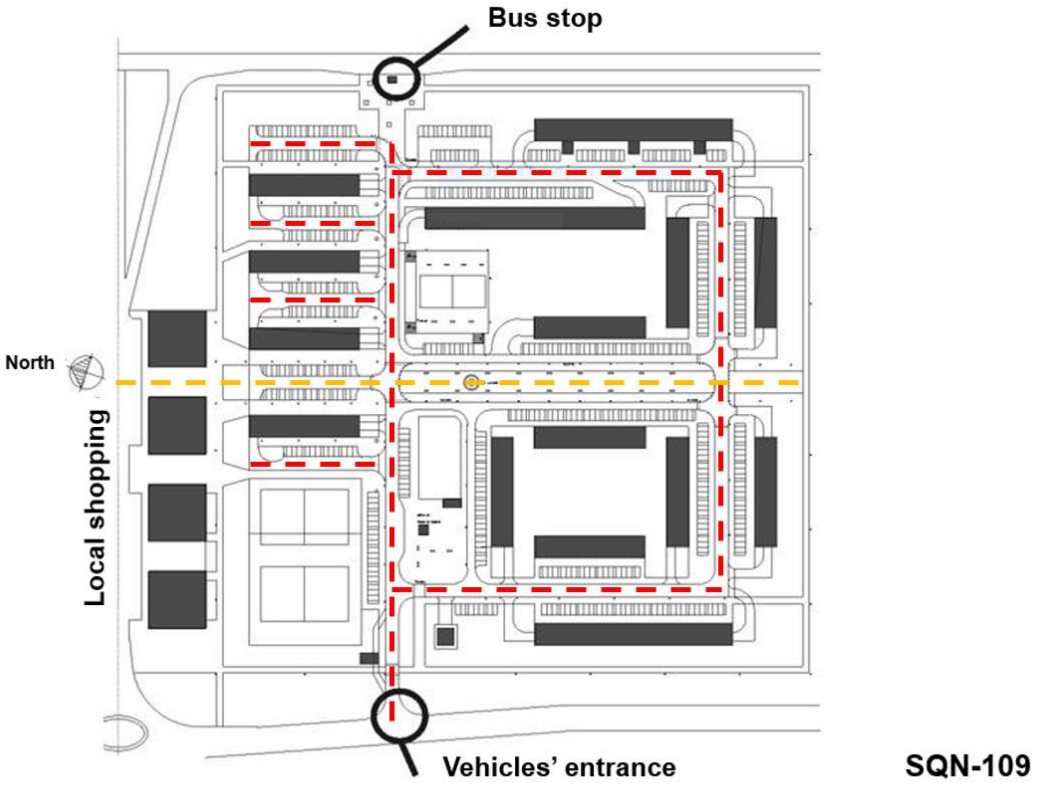

Figure 9 SQN-109. Circulation of vehicles and pedestrians. (Source: the Author.)

Topography has been ill-treated at the SQS-308, barriers have been created which perform badly *visually* and *functionally* (Figure 10). Path-walks are often blocked by walls and underground garage entrances. I tried also to avoid a frequent dichotomy found in other blocks (but not at the SQS-308), between arid spaces for circulation of vehicles and parking, and the beautifully gardened inner

spaces of the place (Figure 11, Figure 12). Often enough, the former are 20 m wide, which makes it difficult for trees to be planted. At the SQN-109, these spaces are 50% wider (30 m), and this will result in environments as the one we have experimented at the Darcy Ribeiro Campus, University of Brasília (Figure 13; compare this to Figure 11). *Bioclimatic* performance is improved, by the shade, and the affective performance as well (i.e., from the emotional point of view), due to the strengthening of the so much appreciated "bucolic atmosphere". Thus, there is not a strong separation between spaces for pedestrians and spaces for vehicles – with the corresponding blurring of differences between *mineral* and *vegetal*.

Figure 10 Ramparts and priority for vehicles in garage entrances. (Source: the Author.)

Figure 11 The arid space for vehicles circulation and parking. (Source: the Author.)

Figure 12 The bucolic space of the inner spaces. (Source: the Author.)

Figure 13 Street cross-section at the Darcy Ribeiro Campus, University of Brasília. (Source: the Author.)

On the other hand, at the SQS-308 vehicles zigzagging is mimicked in pedestrian routes, affecting *functional* and *topoceptive* performances. The celebrated permeability of the free continuous open space granted by the *pilotis* is more mythical than real: first, *pilotis* have progressively been occupied by the porter's apartment and by a room for collective parties of the inhabitants; second, the floor of the *pilotis* level often rises above surrounding ground level in order to let light in to the underground garages, and it is often accessed by stairs; third, routes are not spatially legible, i.e., they are not clearly sanctioned by a clear interplay of volumes and voids granted by the buildings. To go from the inner spaces of the block to the local shopping or to the bus stop navigating up and down stairs or going through a sequence of unimportant spaces is one thing; doing this along a spatial axis clearly defined by built volumes, as along our *cardus maximus*, is something else altogether (Figure 14).

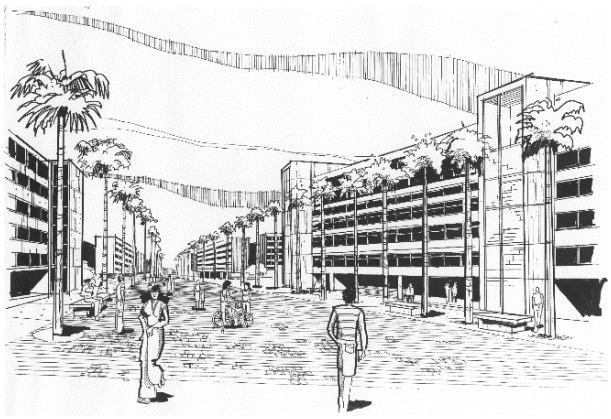

Figure 14 Sketch of the proposed *cardus maximus*, cutting across the superblock from north to south, leading to the local shopping. (Source: drawing kindly prepared by Eliel Américo da Silva for the Author.)

The two large axes signal the important relation with two magnets of the surroundings: the bus stop and the local shopping. Such a generous connection is denied in previous superblocks, volumes and spaces are thought in themselves, not in relation to the context, as at, for example, the SQS-109 (Figure 15, symmetrical to our project, but now in the South Wing of the Plan): two large buildings block the perception of the magnets from the inner spaces of the block.

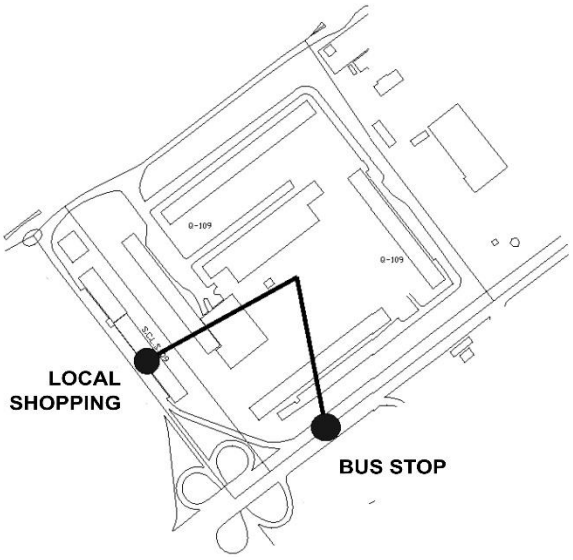

Figure 15 SQS-109. Denial of the clear relation with important magnets of the surroundings. (Source: the Author.)

Formalizations allowed by SST contribute to further characterise the introspective and labyrinthine configuration of the SQS-308, as compared to the SQN-109; this is done through the axial map (Figure 16) and its corresponding measures. The axiality is a technique from SST by which we capture the possibilities of movement, now concerning pedestrians, from all points to all others in the case under study; the result is systemic, the processing reveals the field of possibilities of movement by coloured lines, from the hottest (in red) to the coldest (in deep blue): the hotter the colour, the more accessible the line is to the system (it is easily reachable, in terms of less turns, from any other line in the system), and vice-versa, the colder the colour, more route inflexions we have to perform. In the abstraction performed here, I have considered only the built volumes as barriers, thus simplifying the phenomenon by ignoring 1) the permeabilities granted by the pilotis for the reasons above, and 2) the barriers formed by walls and ramparts, as of those of the SQS-308, Figure 10: I was interested in contrasting the possibilities of movement only through the macro-structure constituted by the buildings.

The result speaks loudly (Figure 16). First, at the SQS-308 there is no single example of a route (an axial line) that cuts across the whole block: one or both endpoints always end at a façade of a building inside the block; at the SQN-109, there are two bunches of lines which cut across the block along the cardus' and the decumanus' spaces, and there are other lines that do this in other positions. Second, the frequent blockages commented concerning vehicles repeat themselves as far as pedestrians are concerned in previous blocks, thus making the axial system of our SQN-109 much more integrated than the one of the SQS-308: this is revealed by the measure of integration from SST, of 8.03 in average for the SQN-109 and 3.77 for the SQS-308. In other words, besides being difficult to reach the surroundings, thus signalling the introspective character of the SQS-308, the internal spaces of the block are also separated among themselves by a much greater number of route inflections.

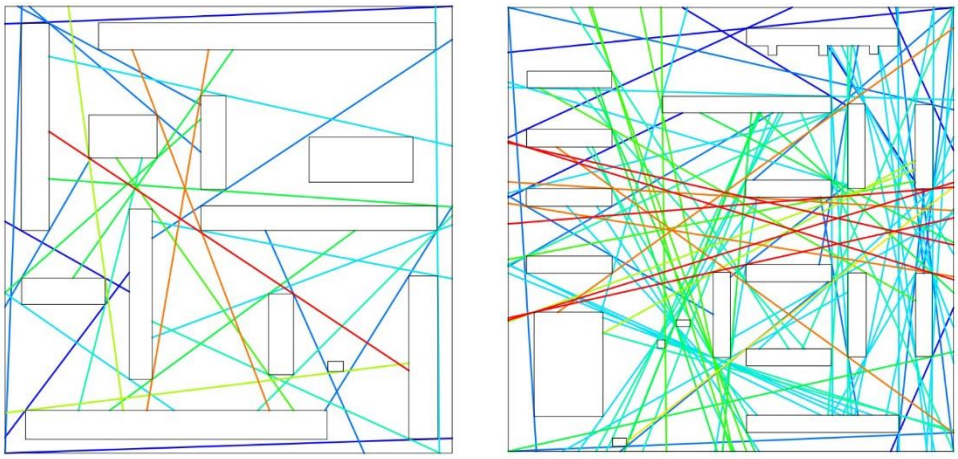

Figure 16 Axial maps of the SQS-308 (left) and of the SQN-109 (right). (Source: the Author.)

Finally, the north-south axial space, with very narrow traffic lanes (2,5 m wide) for the exclusive access to parking spaces, in both sides of a wide pedestrian lane 20 m wide, an axis that is furthermore decorated with palm trees and sculptural elements as a fountain, would be an unprecedented element in Brasília's superblocks. If the *symbolic* performance of a place depends on elements strong enough to represent the whole through the part – the definition proper of symbolism – the *cardus maximus* of the SQN-109 is our favourite candidate.

6. Localization of schools

The localization of schools deep at the block, presupposing that only children who live in the surroundings would use them proved wrong. This was a *functional* mistake resulting in a strong movement of cars through the block and a nuisance to the inhabitants. The mistake happens in *all* previous superblocks (Figure 17). In no city, this one included, the orthodox logic of the neighbourhood unit, by which the local facilities are used by… the locals, works. Choosing to which school parents take a kid results from a series of factors, not from the distance to the facility (this has also happened to our kids, while we were living at the North Wing, at another superblock): the quality of the school, the convenience of the location along the route to work of the parents, the fact that the school receives students who live in the satellite nuclei but who work in the Plan but *not* within the superblock etc. At the SQN-109 the schools locate close to the entrance (Figure 18). There is a *topoceptive* plus: as special buildings, they will contribute to strongly signal the access to the block for those passing by.

Figure 17 SQS-308. Localization of schools. (Source: elaboration by the Author, on the basis of Google *Earth*.)

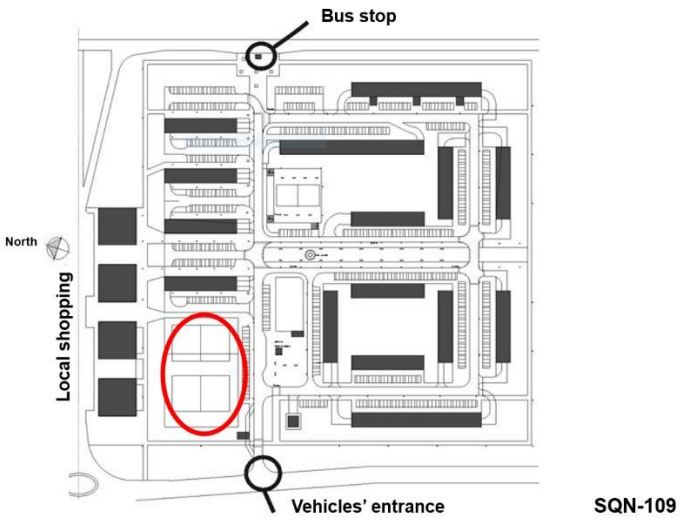

Figure 18 SQN-109. Localization of schools. (Source: the Author.)

7. The order of the open spaces

The order of the superblock open spaces can be examined in "gross-tunning" and in "fine-tunning" (note that the two superblocks have almost exactly the same occupation ratio of residential plots concerning the total superblock area: 21,5% for the SQS-308, 20,4% for the SQN-109).[3] In the case of "gross-tunning" analysis I consider only the spaces defined by the volumes of the apartment buildings, units which are represented synthetically by ellipsoids (Figure 19, Figure 20); they are *macro-morphological units*, perceived as if our stance would locate at a height immediately above the roof of the schools, which are single-storied (the strength of the spatial definition of the six-story buildings above the height of the schools justifies this unorthodoxy). At the SQS-308 and in other blocks in general, in this tunning, there is no clear differentiation among open space units – they have similar size and form (Figure 19). At the SQN-109 (Figure 20), on the contrary, there are four main types of spaces, of different sizes and forms, thus favouring topoception: 1) two large axial spaces – the *cardus* and the *decumanus* – which cut across the block (in red); 2) the axes of vehicles' access to the residential parking spaces (with variation in size, in yellow); 3) a somehow interior space of a secondary block inside the superblock, without vehicular access, thought for orchards and gardens implemented by the inhabitants, something which is actually already being done by the locals (in green).

[3] The reasoning is close to the one concerning the *convex analysis* from SST. But in the theory, space can be decomposed in one-dimensional units (the *axial lines*, as seen above), but also in two-dimensional units, and this in two ways. *Convex spaces* correspond intuitively to the notion of "place" at a small urban scale: there must be conditions of co-presence among the subjects who are inside them, and who may walk in straight lines among themselves (formally, in a convex space we can insert a convex polygon – i.e., one without *concavities*, the perimeter of which, therefore, cannot be crossed by a line in more than two points). However, here, the "gross-tunning" analysis disconsiders even low height buildings because, at a larger scale, it is useful to take into account spaces which are defined only by the six-stories apartment edifices. The "fine-tunning" analysis (see below) is closer to the convex analysis of SST, but again, there is an intuitive approximation aiming at the understanding of the non-specialist reader: the figures illustrate the argument, ellipsoids, not polygons, are enough to suggest these micro-morphological units.

Figure 19 SQS-308. Macro-morphological units of open spaces. (Source: elaboration by the Author, on the basis of *Google Earth*.)

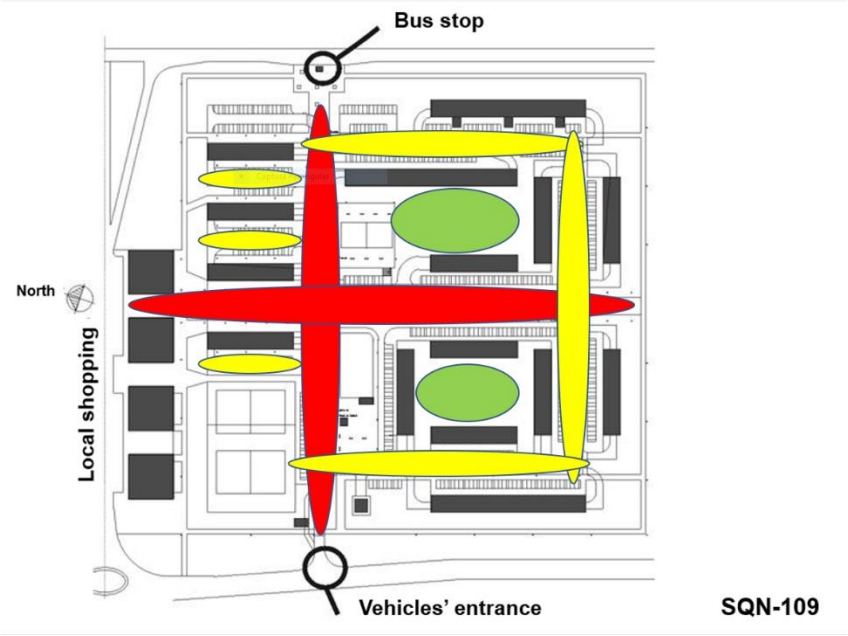

Figure 20 SQN-109. Macro-morphological units of open spaces. (Source: the Author.)

In "fine-tunning", now including the school buildings, the SQS-308 is, again, very fragmented, comparatively to the SQN-109. In the former (Figure 21), there is a proliferation of small spaces (12) defined always on one side by the lateral blind façades of buildings, as it was fashionable in classic modern edifices; in the latter (Figure 22), this type of spaces are half of those in number (6), and, more important, they are so small as to go practically unperceived. (If blind façades are common in the older buildings of the Pilot Plan (Figure 23, left), this fortunately does not happen so often anymore, as windows and verandas also open to these lateral façades, defining a more gentle open space configuration – the famous "eyes to the street" of Jane Jacobs' (Figure 23, right), (Jacobs, 1961)).

Figure 21 SQS-308. Spatial decomposition in "fine-tunning". Spaces defined by at least one blind façade (sometimes two) are marked in orange. (Source: elaboration by the Author, on the basis of *Google Earth*.)

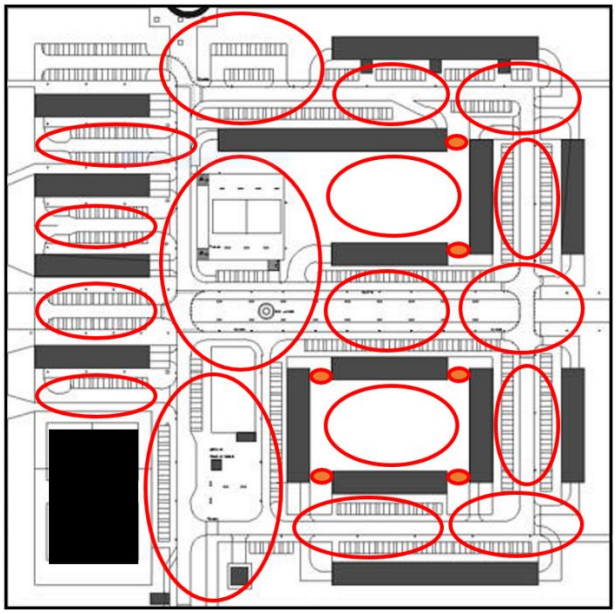

Figure 22 SQN-109. Spatial decomposition in "fine-tunning". Lateral façades, as in almost all recent buildings, are not blind. (Source: the Author.)

Figure 23 Blind façades of classic modern buildings from the 1960's (left, SQS-108) and more recent buildings without them, from the early 2000's (right, SQN-109). (Source: the Author.)

Finally, there is one more analytical category that adds information to this comparison: the *isovists*. The concept comes from Michael Benedikt, but has been incorporated within the procedures of SST:

> ... I cannot see *everything from where I am*. Once you become aware of the limited amount of space you can actually see, and then think of it from the outside as it were, as a volume or body of space with you embedded in it, then you can take the next step and determine its objective *size* and *shape*. More formally: the body of space visible to and from a point x is called the *isovist* at x. (...) Isovists belong to the world, "waiting" for eyes [original italics](Benedikt, 2020).

The software *Depthmap(Turner, 2004)*, constitutive of techniques from SST (Hillier, 1996), allows for the comparison of isovists from all points to all other points of a certain place: "points" here are the cells of a grid that is defined according to the size of the place under analysis and the processing capacity of the computer available – in the present case, I have defined a 2 x 2 m grid. Figure 24 compares the isovists of the two superblocks, now in "fine-tunning", in which all buildings, including the small newsstand are considered. Warmer colours represent cells which are mostly visible from all points of the place (this is called visual *integration Rn*); colder ones, the opposite. Note: 1) there are four areas in red of similar importance at SQS-308 (Figure 24, left); this repeats, at this level of fine-tunning, the idea of redundancy of information commented on above; 2) the points of view from the "hotspots" at SQS-308 do not connect important elements of the configuration: they are blocked by buildings or reach head on the fence of the school, to the right of the image. At the SQN-109 (Figure 24, right) the central space is clearly outstanding, revealing the importance of the two perpendicular axes and, more so, the point where they cross. Also, from this spot we see the most important magnets of the surroundings: the bus stop, the entrance to the block, the local shopping – there is a clear definition of a strong *focal point*, if Kevin Lynch's jargon is to be used, whereas at the SQS-308 we have somehow four weak ones (Lynch, 1960).

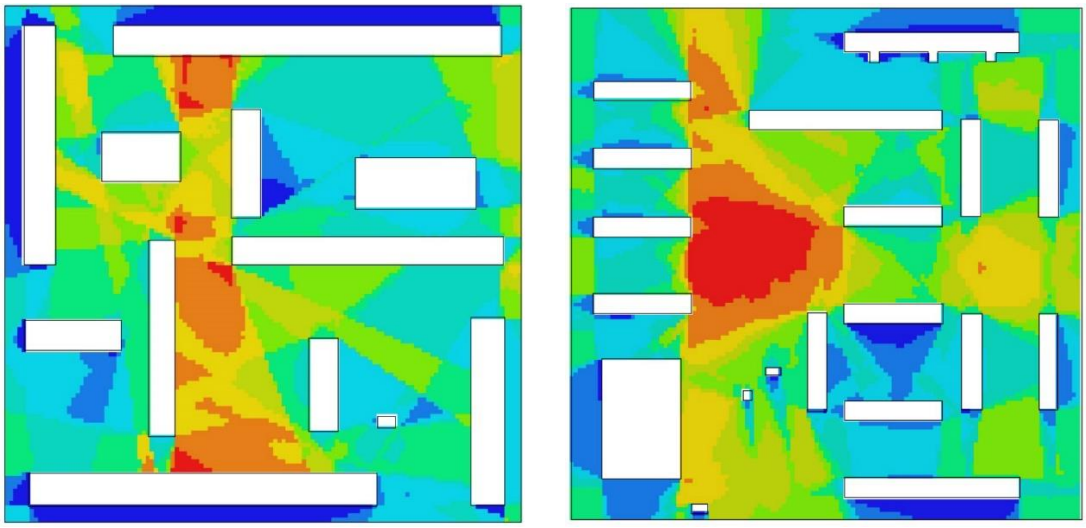

Figure 24 Isovists from all points to all others (*visual integration Rn*), from the SQS-308 (left) and from the SQN-109 (right). (Source: images kindly prepared by Valério de Medeiros for the Author.)

Furthermore, the two major elements differ. The *cardus maximus* (north-south), besides performing the functional role of connecting the block to the local shopping, is more bucolic, aiming at passive leisure, rest, sitting down in benches under the morning and the afternoon soft light, when the place is in shade. In the south-north direction (Figure 25, right), the distance in between volumes shrinks progressively, and, in the contrary, in the north-south direction (Figure 25, left), it broadens progressively, favouring different isovists' forms, depending on the direction of the regard, thus contributing to orientability (*topoception*). A comparison of the isovists taken from the peripheral pathway, in both directions – north-south and south-north – shows the difference in form of the perceived space. The *decumanus maximus* has a distinct character (see below).

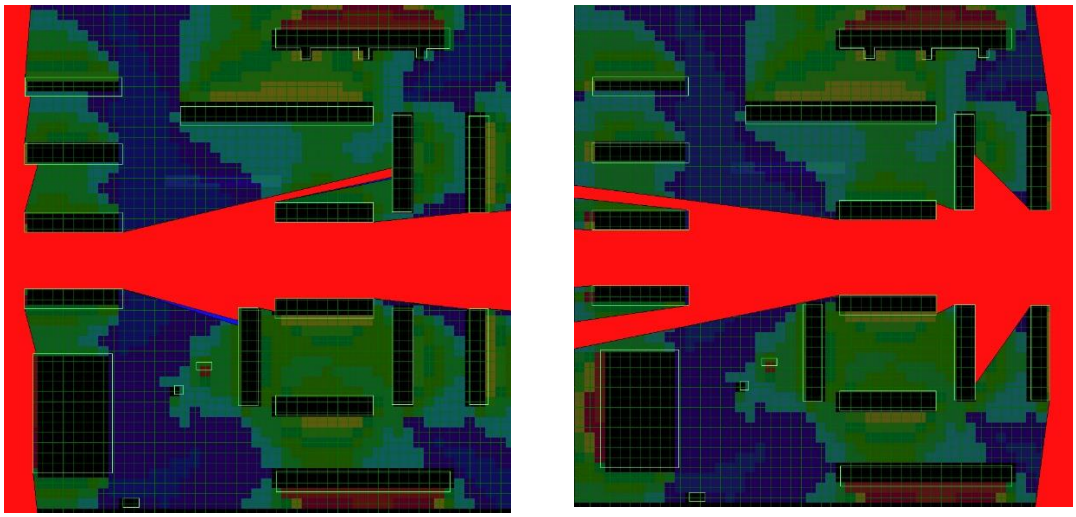

Figure 25 Isovists taken from the endpoints of the *cardus maximus*: north-south (left) and south-north (right). (Source: the Author.)

The exploration of laws of plastic composition, e.g., *similarity* x *difference*, and *common* x *special* (Kohlsdorf & Kohlsdorf, 2017), has been explored, more concerning the open space units than concerning the volumes (the latter are pre-determined). The two distinctive axial spaces, inspired by the classic Roman tradition, convey a good *aesthetic* performance, which, naturally enough, will depend on other aspects – e.g., if the precious landscape design by my colleague Vicente de Paulo Quintella Barcellos be implemented. Also in the aesthetic field, the philosophical worldview is rather *Apollonian* than *Dionysian* – e.g., the economy of means, the orthogonal fabric, the formation of a small number of orthogonal spatial units etc. Except orthogonality, all this contrasts with the SQS-308 configuration.

8. The distribution of facilities

At the SQS-308, facilities spread throughout the block, are invisible among themselves (Figure 26), and this results in the reciprocal invisibility of the varied subjects who use the place (or use the immediate surroundings): babies with nannies or parents, children, in the playground, adolescents and adults, at the sports court or at the pond or at the newsstand etc.

Figure 26 SQS-308. Localization of facilities. (Source: elaboration by the Author, on the basis of *Google Earth*.)

At the SQN-109 the *decumanus maximus* has an important *sociological* role – it is the space of greatest *urbanity* in the block (Figure 27). First, it allows *co-presence* and *co-awareness* – i.e., conditions of mutual accessibility and visibility – among different subjects who become mutually invisible, by *spatial configuration*, at the SQS-308; along the decumanus locate the main non-residential facilities that generate presence in public open spaces: the sports court, the playground,

the administration, the newsstand, the schools and the taxi stop. The plots for the two mandatory school units are contiguous (which never happens in other blocks) so that we can minimize the long blind walls of the isolated plots – fashionable in modern urbanism.

Moreover, the large axial space favours the interface between inhabitants and strangers, for it will be used by those who take buses, who step down from them at its eastern endpoint, and walk, *through the block*, along its *internal* pathways, to jobs located to the west of the place. This, again, is unprecedented: because of aspects already commented, major pedestrian flows happen along the peripheral pedestrian walks. The mutual accessibility and visibility among diverse social subjects enrich sociability by bringing together is same spaces inhabitants and people just passing through.

Topoceptive performance is added to the *sociological* one: the *decumanus* is the widest and longest space of the block, its configuration defined mostly by façades of the six-stories apartment buildings, but also by the single-storied schools, administration, newsstand, the bus stop and the taxi stop. The 360° degrees isovist from the point where the *cardus* and the *decumanus* cross – truly a "spatial explosion" – illustrates the importance of the two macro-elements of the superblock (Figure 28). Nothing similar occurs at the SQS-308. Figure 29 illustrates the whole superblock through a bird's-eye view perspective.

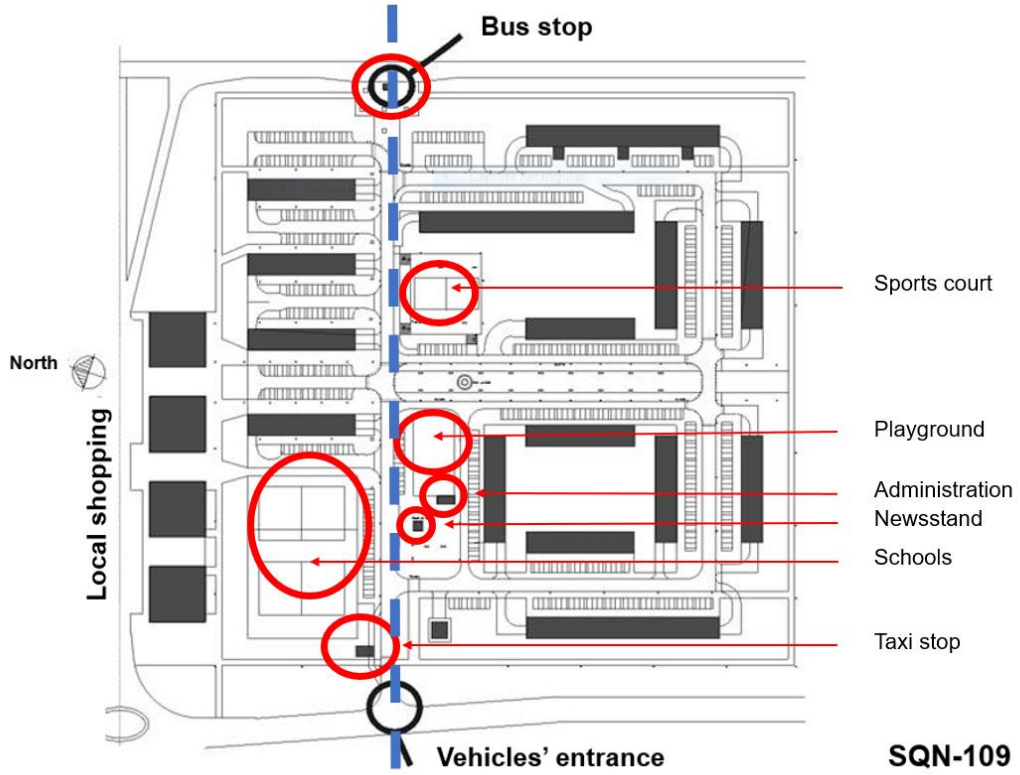

Figure 27 SQN-109. Facilities along the *decumanus maximus*. (Source: the Author.)

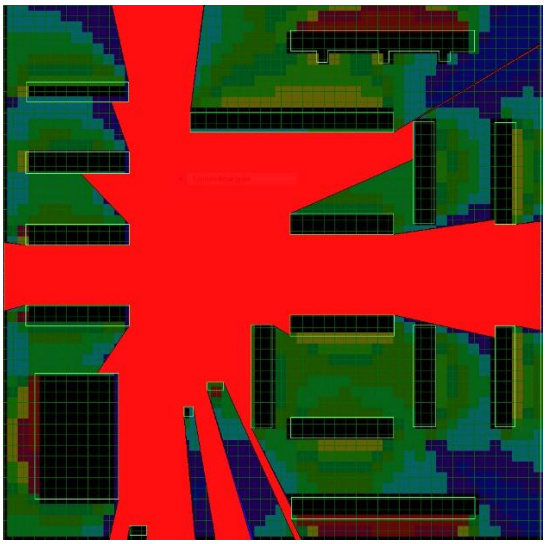

Figure 28 Isovist taken from the crossing of the *cardus maximus* with the *decumanus maximus* – "spatial explosion". (Source: the Author.)

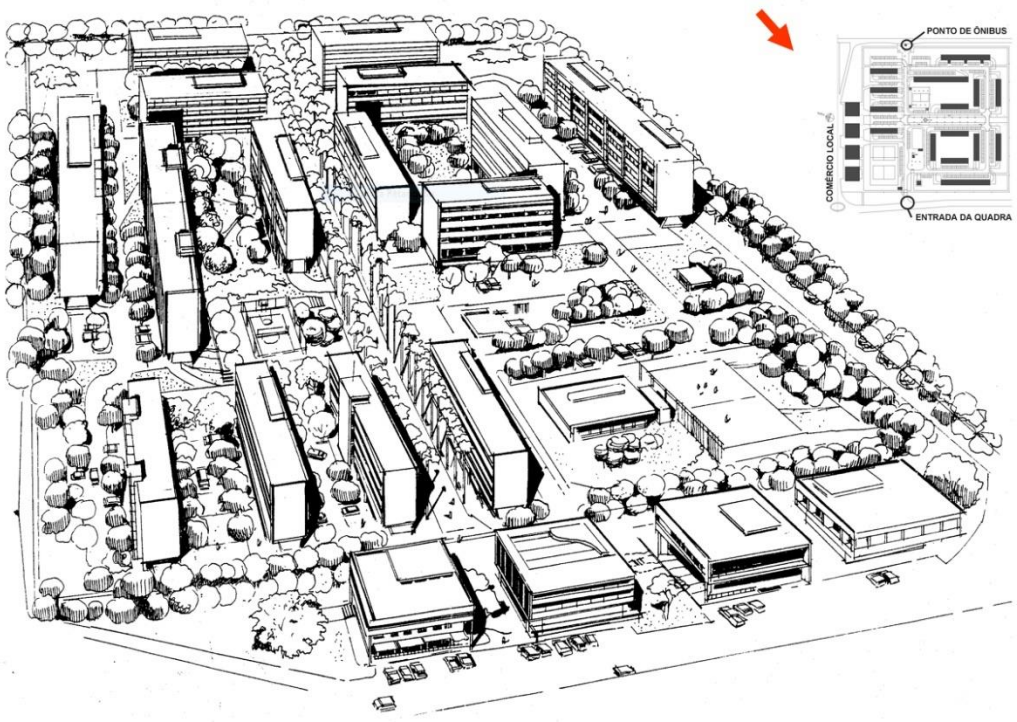

Figure 29. SQN-109. Bird's-eye view of the superblock. (Source: drawing kindly prepared by Eliel Américo da Silva for the Author.)

9. Use of public space

It is soon to evaluate how the design proposal for the SQN-109 will favour (or otherwise) the use of public space by inhabitants and strangers, due to the incompleteness of the block. However, despite being inhabited by high-middle classes (Figure 31), who would rather frequent closed, private spaces (Holanda, 2002), the use of public spaces in Brasília's superblocks dismantles the myth of "desertification", "loneliness", "sadness" of those who inhabit them, in this city so rich in myths – of demonization or sanctification, depending on the prejudices of their spokespersons:

> In Brasília, the outdoor city public of other Brazilian cities has all but disappeared. … Social life oscillates unremittingly between work and residence. … Hence, the overwhelming sense of monotony and sameness that Brasilienses experience in the city. (Holston, 1989, p. 153, 163, 312) (Holston, 1989).

Quite the contrary, such bombastic statements do not match empirical evidence: open spaces of the superblocks are used by all age groups, from babies through children and adults and elderly people, in various sorts of activities (Figure 30).

Figure 30 Use of public space in the superblocks by all age groups. (Source: the Author.)

The problem, then, is not how many but who use the place: it is the *economic performance* of the superblocks, highly valued by the market to the point of making them only accessible to higher income layers, thus resulting in their elitist appropriation. In contrast to main stream urban research, it is not simply localization that highly correlate with real estate prices, the *building types of domestic space* matters importantly: in same boroughs property values may vary immensely according to such types – i.e., their *local*, not *global* properties, as I have shown elsewhere(F. d. R. B. Holanda, 2007). Lucio Costa believed that simply the variation in size and finishing would imply adequate variation in prices which would suit all income layers (Costa, 1995). Wrong. The "superblock type" is expensive, a much greater typological variety would be needed so that a greater social diversity might happen here – as in Vila Planalto, a borough that dates from the initial stages of the building of the city, extremely central (1.500 m from the Square of the Three Powers, the governmental core), the social stratification of which is close to that of the city as a whole, in fact, housing *more poor people* and *less rich people*, proportionally, than the whole municipality (Figure 32)(Holanda, 2010a).

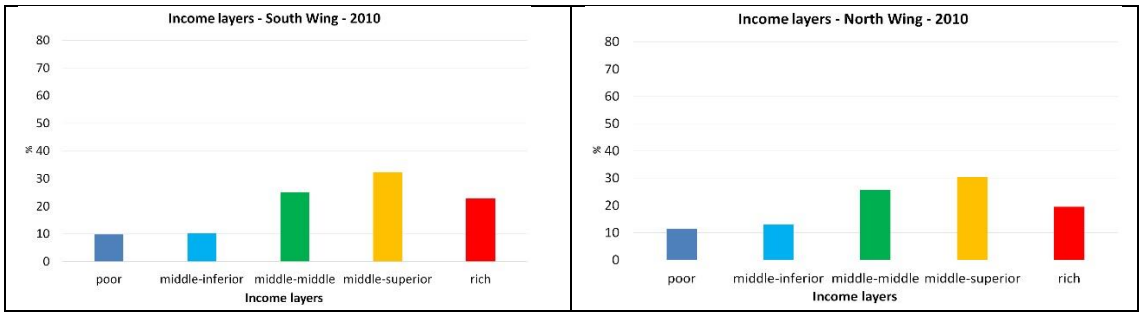

Figure 31 Income layers in the South Wing (left) and in the North Wing (right) or the Pilot Plan. (Source: IBGE, 2011.)

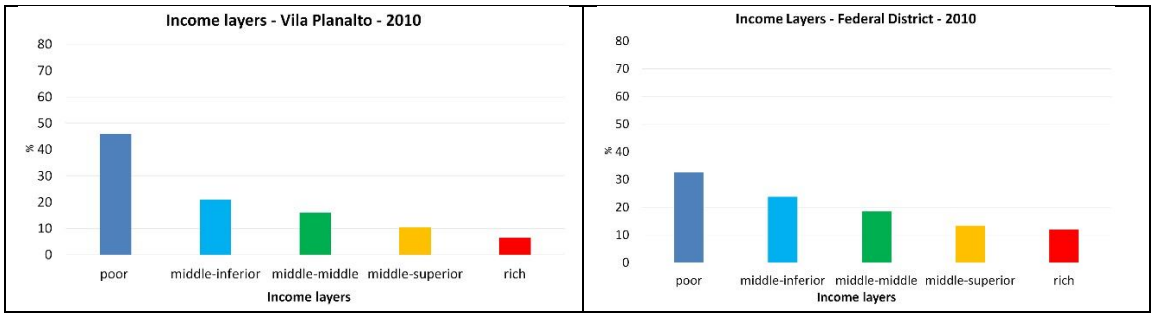

Figure 32 Income layers in Vila Planalto (left) and in Brasília as a whole (right). (Source: IBGE, 2011.)

10.Conclusion

Brasília's superblocks and the city of Brasília as a whole are well evaluated by all income layers, as a classic study by Machado and Magalhães has demonstrated, since back there in the 1980's (Machado & Magalhães, 1985). And it continues so, despite mythical discourses that demonize them – both the superblocks and the city. However, even strictly obeying the norms, and within the present legal limitations (an elitist configuration) we can do better. Figure 33 summarises the attributes of the previous experiences and the design for the SQN-109.

Brasília's superblocks	
Precedents	**Proposal**
• Weak differentiation of the units of open space • Labyrinthine, tree-like street schemes, with similar segment sizes, frequent rout inflections • Introverted facilities • Distinction vehicles x pedestrians • Distinction mineral x vegetal • Distinction inhabitant x stranger • Dispersed uses • etc...	• Strong differentiation of the units of open space • Ringy street schemes, varied street segment lengths, few route inflections • Extroverted facilities • Mixture vehicles x pedestrians • Mixture vegetal x mineral • Interaction inhabitant x stranger • Uses in synergy • etc...

Figure 33 Brasília's superblocks. Attributes of previous examples x attributes of the SQN-109 superblock. (Source: the Author.)

However, the performance of the SQN-109 awaits a more robust empirical test; it will take some time until we have the proposal implemented in its complete form, so that a more thorough evaluation can be made. At any rate, the "superblock type" houses a high-middle class stratus. Being one of the two only building types for domestic space proposed by Lucio Costa for the Pilot Plan (the second one were the "individual houses" by the lake, which were not the concern in this paper) (Costa, 1995), the superblocks are not an example to be followed if we wish socially diverse boroughs – the most telling example being, in Brasília, Vila Planalto. Even if the superblock may be "one of the most innovative and righteous contributions for multifamily housing schemes",[4] in the city as a whole, and in each of its boroughs in particular, in order to favour social diversity at the former and at the latter, not just superblocks should be built (as it became the urbanistic motto in the Capital), not even multifamily schemes only: to house everyone, the city, today, and each and every one of its boroughs have to be necessarily typologically much more varied than this – Vila Planalto, here, and Copacabana, in Rio de Janeiro (the borough has similar social strata as the city as a whole), are great examples to emulate (IBGE, 2011).

[4] *Idem*, p. 326.

Nonetheless, planning rules and the design of new boroughs insist on homogeneous neighbourhoods for the poor, or for the rich, or for the middle classes. There seems to be no way out within the State apparatus. A better and less unequal city will depend on the organization of Civil Society and its social movements to bring more social justice to the city (Harvey, 2012).

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Resume

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[Exceptional space], based in his PhD Thesis (Edunb, 2002); Arquitetura e Urbanidade [Architecture and Urbanity] (ed.) (ProEditores Associados Ltda., 2003; 2nd Edition, FRBH, 2011); Brasília: cidade moderna, cidade eternal [Brasilia: modern city, eternal city], granted the ENANPARQ 2012 National Prize (FAU UnB, 2010); the bilingual book – Portuguese and English – Oscar Niemeyer: de vidro e concreto / of glass and concrete (FRBH, 2011); Exceptional Space (e-book format, FRBH, 2011); Ordem e desordem: arquitetura e vida social [Order and disorder: architecture and social life] (ed.) (FRBH, 2012); 10 mandamentos da arquitetura [10 commandments of architecture] (FRBH, 2013). In 2010 he founded a press to publish books on architecture (FRBH). He coordinates the research group "Dimensões Morfológicas do Processo de Urbanização" [Morphological Dimensions of the Urbanisation Process], registered in CNPq's [Brazilian National Research Council] since 1986. Senior Research Fellow, CNPq. He belongs to scientific committees and editorial boards in Brazil and abroad. He is married to Rosa de Lima, has two children – Joana and Pedro – and two granddaughters – Irene and Carolina. More info in: em http://www.fredericodeholanda.com.br; //fredericoholanda.academia.edu;
https://www.youtube.com/channel/UC8GKmH2AMAxMS4elN0IHD7Q/videos

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Relative rhythms, urban oases, and spatial resilience / Exploring syntaxes of seclusion, solitude, and tranquility

Daniel Koch*

Abstract

This article engages with the role of what one might tentatively call "secondary" urban spaces, in that while they are public, they are not the most vibrant, populated, or active places. These are not the spaces envisioned in many project illustrations. They are not full of people and activity. They are however a crucial part of a wider texture of urban situations, and important to extending our understanding of seclusion, solitude, and tranquility beyond distant parks and recreation areas. My aim here is to understand the emergence of these spaces in-between; those that are close to the vibrant streets and are embedded in city centers, yet which offer a respite from the most bustling urbanity. These spaces, I will argue, more easily allow for the kinds of interactions that can lead to bridging and bonding with the unknown, in addition to the important everyday encounters that occur on central streets and squares. Using qualitative methods which build on Lefebvre's rhythmanalysis, the discussion will draw on observations of the syntactic properties that condition, enable, and characterize such spaces, and address a series of concepts, including capacity, insulation, sequencing, and interface. A better understanding of such places, it is argued, not only allows a richer set of tools for working with urban design and planning but offers possibilities for more resilient planning in terms of generating social relations, the emergence of communities, and for cities to manage and withstand extraordinary conditions.

Keywords: rhythm analysis, space syntax, resilience, urbanity, urban design

1. Introduction

A growing body of research has in recent years highlighted the importance of spaces for rest and pause in contemporary cities. In the field of urban design, "rest" is regularly raised in relation to green spaces, health challenges, and issues of stress and mental well-being (Anderson, Ruggeri, Steemers, & Huppert, 2016; Barthel & Kyttä, 2020; Engström & Gren, 2017; Park & Evans, 2016; Roe & McCay, 2021). Red threads that run through this existing scholarly work include an interest in improving accessibility to parks and recreational green spaces for individuals, recurring discussions of "urban versus rural" environments, and a common tendency to romanticize the periphery; amongst planners and architects, and in line with the UN Sustainability Goals, a greater

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number of vibrant, open (green), public spaces for social exchange is seen as central solutions in addressing the problem of rest in contemporary cities (United Nations, 2015). In the contemporary planning paradigm, open spaces within intense urban areas are thus celebrated for their "vibrancy," while larger green areas are valorized in terms of their scenic and functional qualities in relation to the intentional recreational activities that they are to support. While I acknowledge the importance of such spaces within urban environments, this paradigm risks reinforcing dichotomies (Samuelsson, 2021), treating public space as a homogeneous mass (Koch, 2021), and—ultimately—misunderstanding the concept of "rest."

In this article, I investigate the spaces of everyday life in cities that, while not the most bustling squares, streets, or parks, are often present and arguably necessary for urban life and resilience. In some ways, my argument continues Gustav Engström and Åsa Gren's advocacy of the need for slower rhythms and seclusion when incorporating qualitative green space in dense environments (Engström & Gren, 2017). The paper adopts a multifaceted view of the concept of *resilience* (Walker, Holling, Carpenter, & Kinzig, 2004) and builds on existing knowledge about the relations that link configurational structures of space with emergent collective behavioral patterns (Hillier & Hanson, 1984). The fieldwork draws on Lefebvre's *rhythmanalysis* (Lefebvre, 1996b, 2004) and makes use of my own experiences as a participant in urban life, addressing both events and everyday situations and the ways in which our understanding of spaces unfolds over time. Such broad knowledge is complemented by structured visits in two forms: specific, documented research visits (Figure 1) and visits conducted in the course of teaching.

Figure 1 A targeted visit/walk on October 30, 2021. The photographs are taken within 10 minutes (14.16-14.25), and demonstrate the radically shifting degrees of "vibrancy" in public spaces in Gamla Stan, Stockholm. The phogographed locations are Brända Tomten, Stortorget, Västerlånggatan and Gåstorget. The photograph of Västerlånggatan is taken from high vantage point in order to show how far the density of bodies extends along the street. The locations are shown on the map in Figure 2 Photographs by the author.

I will engage with a series of situations that I have chosen, aiming to qualitatively bring out the specific characteristics and atmospheres of their locations, to learn from particularities, and to avoid quasi-statistical tendencies. I acknowledge that the selection is limited to environments with a middle-class demographic—the areas they are embedded in have become increasingly gentrified in recent decades—and as such that one needs to be careful in generalizing from such particulars.

2. Rhythmanalysis and Configurative Analysis

Movements through the city are, by virtue of social and spatial modes of organization, unequally necessary in daily life: similarly, individual rhythms are polyrhythmic and may or may not follow emergent normative or collective rhythms (Amin, 2008; Koch & Sand, 2009). Rhythms therefore form externally recognizable patterns, through which we can better understand our cities (Koch, 2017; Netto, 2008). By identifying relations between built form and urban rhythms, in this paper I argue that configurational research offers possibilities to understand how the re-organization of space might affect rhythms, redistribute flows, and recharacterize individual spaces and spatial patterns.

There are clear challenges in combining the works of Henri Lefebvre with those of Hillier, Hanson, and others; not least because Lefebvre is often critical of the kind of statistical analysis that is prevalent in syntactic research. I do not claim to resolve this tension and acknowledge that bringing the theories together affects how both are to be understood. At the same time, Lefebvre is not wholly negative to structural analysis and quantitative research (Lefebvre, 1991). On the contrary, rhythmanalysis aims to combine the two:

> **"Rhythm** reunites **quantitative** aspects and elements, which mark time and distinguish moments in it – and **qualitative** aspects and elements, which link them together, found the unities and result from them" (Lefebvre, 2004, pp. 8-9).

Rhtyhmanalysis becomes a way of structuring the combination of disparate methods, but also of qualifying each, as well as their interrelation. I combine rhythmanalytic understanding with qualitative configurational discussions, bringing in knowledge from quantitative syntactic studies: I understand correlations to form a quantitative basis for a qualitative understanding of collective urban rhythms over time. From a rhythmanalytic perspective, syntax research can help us to better understand relations between linear and cyclical rhythms and the organization of urban architectural space. If rhythms in part are a result of "social organization manifesting itself" (Lefebvre, 1996a, p. 222), one can also find theoretical links to spatial configuration: in particular, I note that large parts of *The Social Logic of Space* address "the ways in which society materializes itself" (Hillier & Hanson, 1984) and John Peponis similarly describes "the pedagogical function of the city" (Peponis, 2017)—both can arguably be used to frame a relation between spatial configuration and spatial practice (Lefebvre, 1991).

There are challenges with Lefebvre's rhythmanalysis. Aside from the introductory comments on the Rue Rambuteau, the discussion remains largely abstract. For instance, in "Attempt at the Rhythmanalysis of Meditteranean Cities" (Lefebvre & Régulier, 2004), specificity and difference get lost amongst generalizations that, as Emily Reid-Musson points out, tend towards essentialism (Reid-Musson, 2018), entertains a series of contradictions, and leans into dualisms, including a "nostalgic and, at bottom, moralistic idea about modern time regarded as mechanic and unhealthy, as opposed to the ancient time seen as organic and curative" (Brighenti & Kärrholm, 2018).

While the participation of the researcher or analyst in rhythms—or what Brighenti and Kärrholm call the "immediately affective dimension" (Brighenti & Kärrholm, 2020, p. 159)—has become a dominant focus in continued work, rhythmanalysis builds on both observations from the "outside" and experiences from the "inside." As Lefebvre and Régulier put it, "Externality is necessary; and yet in order to grasp a rhythm one must have been grasped by it, have given or abandoned oneself 'inwardly' to the time that is rhythmed" (Lefebvre & Régulier, 2004, p. 88). As Claire Revol notes, this combination also makes rhythmanalysis qualitatively different from, for instance, phenomenological studies, since "the main concern of the rhythmanalyst is not to say that there are rhythms, that rhythms exist, but to analyse them and to find what they reveal about what they are supposed to link: time, space and energy" (Revol, 2019, p. 5). In light of this insight, I have employed a concrete and localized understanding in my work wherein *rhythm* acts as a method and

an analytic tool, precisely because the "localisation and materialisation of time through rhythm that makes the concept of rhythmanalysis interesting for analytical use" (Osman & Mulíček, 2017, p. 47).

In the fieldwork, I have used of a combination of targeted research efforts and knowledge gathered over time, combining the possibilities embedded in lived spatial practice with a critical use of specific actions to test the validity of routinized experience. This fieldwork further builds on Monica Sand's suggestions around walking (and getting lost) in the city as an analytic tool (Sand, 2011). The fieldwork has covered a wider variety of places for a wider purpose, but the situations discussed here were chosen because they are in line with regularly occurring rhythms on the sites in question and because in their specificity they highlight particular aspects of rhythms. In this sense, they act similarly to the "particulars" used by Paulina Pietro de la Fuente in her study of squares and rhythms of eating in Malmö (de la Fuente, 2015). In line with Lefebvre's intent, observations are central to the study; as Revol writes, "…observation has a special place in rhythmanalysis because it is integrated in the process of analysis as well as the definition of what is being analysed" (Revol, 2019, pp. 5-6).

2.1. Configurational understanding of Stockholm, and the use of open space for seclusion in the pandemic

I make use of existing research for the "external" observation; I support my argument through recourse of repeated studies of Stockholm that have consistently demonstrated a strong correlation between movement flows at the observation locations and the syntactic properties of those locations (Choi & Koch, 2015; Legeby, 2013; Marcus, 2000). The streets that I describe as "lively" in this study all belong to the "integration core" of Stockholm and of the various island neighborhoods in which they are situated (for those unfamiliar with the city, Stockholm is built in an archipelago setting, between the Lake Mälaren and the Baltic Sea). The configurational roles of these locations are pervasive; they are central at both local and global scales, and in terms of both closeness and betweenness centrality ("integration" and "choice"). They are furthermore important connectors between and across islands, extending via bridges to reach further into the urban fabric, and their vibrant characters contribute to the way in which their contexts are perceived as lively urban areas.

Here I note another important aspect that ties rhythmanalysis and syntactic analysis together: both modes of analysis primarily deal with relativity. Correlations between spatial configurations and behavioral data are almost exclusively relational. That is, *more central spaces* or *less central spaces* correlate to *more intense uses* or *less intense uses*. This article considers configurational analysis of space to uncover hierarchies of visibility and accessibility, and thereby identify the characteristics that make places *more central* or *less central*, easier to find or less easy to find, and more intensely used or less intensely used. As Lefebvre and Régulier put it:

> "Let us insist of the relativity of rhythms. They are not measured as the speed of a moving object on its trajectory is measured, beginning from a well-defined starting point (point zero) with a unit defined once and for all. A rhythm is only slow or fast in relation to other rhythms with which it finds itself associated in a more or less vast unity" (Lefebvre & Régulier, 2004, p. 89).

Similarly, rather than understanding seclusion, solitude, or tranquility as absolutes, I understand them as relative concepts: in a bustling central area, seclusion can be achieved in a fairly well-visited café, whereas in less vibrant environments, a sense of seclusion or solitude may require spaces where one can be more explicitly "alone." This is not to advocate total relativism; boundaries, contexts, and limitations (of material, social, cultural, and biological kinds) all exert influence in defining these relations.

Finally, while this study was initiated prior to the Covid-19 pandemic and engages with wider urban questions, the ways that it has been stress-tested within the urban fabric in the past year

offer additional relevant perspectives. As Sweden took a different path from other countries during the pandemic, focusing restrictions on physical distancing and citizen responsibility—including recommendations to work mostly from home (Ludvigsson, 2020)—many people made more intensive use of their local environment's public spaces (Bohman, Ryan, Stjernborg, & Nilsson, 2021). The pressure on parks, squares, and nature areas increased noticeably, and they became an important part of enabling degrees of socialization and recreation (Legeby & Koch, 2020) and personal well-being (Samuelsson, Barthel, Giusti, & Hartig, 2021). This included both "on-the-side" spaces and larger recreational areas in more peripheral locations, whereas some of the usually most intensely used locations were rather avoided. While these patterns have been confirmed by many different sources, from phone tracking to Twitter use, responses in a web-based PPGIS questionnaire also demonstrate the importance of "finding seclusion" *in public space*, preferably "close by" (Legeby & Koch, 2020).

3. Emplaced rhythms

3.1. Gamla Stan: Tyska Brunnsplan and Brända Tomten

Figure 2 Tyska Brunnsplan; distance to Järntorget is 137.5 m / 115.5 m / 5 turns; distance to Västerlånggatan is 147.75 m / 76 m / 2 turns / (107.8 m to intersection); distance to Stortorget is 162.5 m / 160.4 m / 2 turns; distance to the nearest subway station is 413 m / 295.5 m / 3-4 turns; distance to the Royal Castle is 284 m / 242.5 m / 3-4 turns (4 to entry, 3 to square). Brända Tomten: distance to Stortorget is 142 m / 115 m / 2 turns; distance to Järntorget is 305 m / 230 m / 5 turns; distance to Västerlånggatan is 157 m / 154 m / 2 turns; distance to the nearest subway is 368 m / 315 m / 4-5 turns; distance to the Royal Castle is 173.5 m / 131 m / 3-4 turns.

Tyska Brunnsplan, August 31, 2021, 14.05

As we resume our walk from Stortorget— which, after more than a year of Covid-19 restrictions, is full of people in the outdoor dining areas, moving across or lingering on the square, sitting on the stairs of the Nobel Museum, or participating in guided tours in the Old Town—we rather quickly find ourselves to be the only ones walking along Svartmangatan, a small street that is on the shortest path between the square we just left and the square we are aiming towards, Järntorget. We have walked here from the comparative quietness of Riddarholmen, passing the major tourist and commercial street Väseterlånggatan and making our way up to the Royal Castle, with its gathering of tourists. Now once again we are outside of the area of bustle that we entered into not so long ago. By Tyska Brunnsplan, we are mostly alone, save for two older people, who study us briefly as if trying to figure out who we are; I begin speaking to the students and they quickly lose interest. *Another group of tourists*, they seem to assume. We remain there for a few minutes, discussing how quickly we ended up outside of the lively atmosphere that most of the students associate with Gamla Stan. As one of the few squares with a large tree in this part of the city, we notice that we haven't seen any greenery for a while and that we have consistently been walking on various kinds of cobble or pavement. The streets that we have walked along have been narrow,

especially Västerlånggatan, which we only followed for a short distance before finding an alternative route, as the size of our group conflicted with other bodies moving along the street and attempts to keep the group together only made such conflicts worse. The sun is shining at an angle that highlights the tree and the fountain beneath it, and the absence of cars in the wheelchair-accessible parking bay suggests that this would be an ideal place to sit and read, or have a low-key conversation, or just rest for a bit. While that would be possible on Stortorget as well, the atmosphere here is drastically different: resting here would be a very different activity than resting there (Verschaffel, 2010). The square, however, doesn't offer any immediate opportunity to do so.

Brända Tomten, October 30, 2021, 14.15

Arriving from Järntorget this time, I pass through Tyska Brunnsplan, which is again empty of people. I am briefly frustrated by the fact that there are three cars parked in what last time was an excellent place to pause and continue down to another square we have often visited on study trips (although not in the walk described above). Brända Tomten is slightly larger than Järntorget, and along the western side of the mostly triangular square the café Under Kastanjen ("Under the Chestnut Tree") has an area for outdoor dining that is open—slightly less than half the seats are filled. The atmosphere is calm and quiet; aside from the al fresco diners, the square is largely empty when I arrive, and few people pass by. It is a bit colder, and the sun is a bit lower, than on my previous visit, but it is still a pleasant day and I remain there for a short while reading. People come and go. Most groups are small, and people appear to already know each other; they tend to be either heading for the café, towards Stortorget or to the nearby bus stop. Of those going to the café, it is easy to discern three categories of customer: tourists, who are guided to the place by smartphones or guidebooks; people who clearly know of the café and come straight to it; and "locals," who can be distinguished through snippets of overheard conversations. "Drop-in" customers—those that "discover" the café as they meander the streets—are rare. Those heading towards Stortorget come in small bursts, most likely from the bus stop. A few others also spend time here, and I notice how easy it is to follow the actions of almost any individual on the square—in fact, it is almost difficult not to. Those of us present here, not counting the café-goers, each exchange eye contact at least once, and in this single act of minimal interaction, we become co-aware. A change has been made, recently: the square used to be separated into public benches and outdoor dining, but the dining area has been rearranged to run along the whole length of the façade, which has meant removal of all public benches (Figure 3). As I am about to leave, a larger group begins to gather, so I stay to watch as the group slowly increases in numbers; some kind of guided tour is initiated, and they begin to split into different smaller groups. They do not interfere, the square is still calm and spacious, and it does not seem to inconvenience anyone that they gather here, like it would if they gathered on the more densely visited squares or in a more clearly territorialized place. They seem to be unusual enough to arouse curiosity, judging by overheard conversations, but not unusual enough to become an event. Once they disperse, I begin to sense that I too am growing into a curiosity, spending more time than the square's rhythm suggests, doing nothing but hanging around and watching. I leave and move across Stortorget to Västerlånggatan, crossing two thresholds of noticeably increased vibrancy—at the latter to the extent that even alone, I need to navigate the bustle of bodies so as to not be in the way, to find my way forward, and to not (too often) bump into anyone.

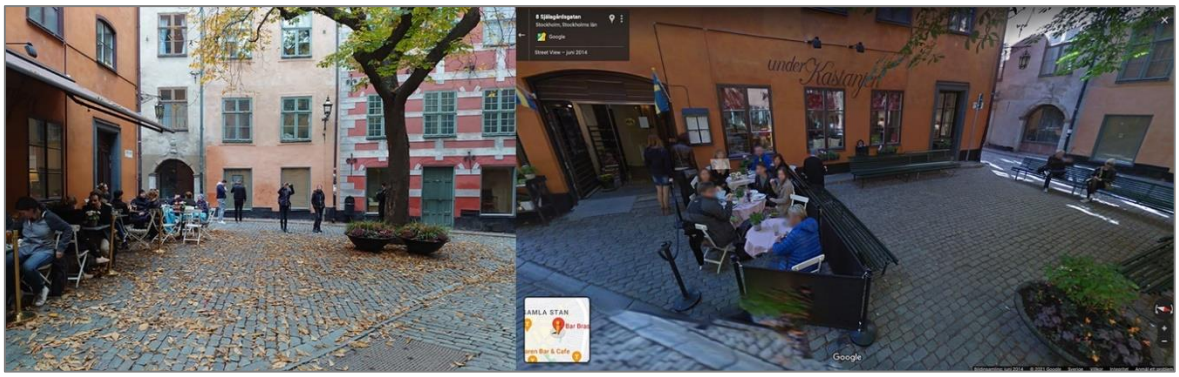

Figure 3 The outdoor dining area in a contemporary image (October 30, 2021) and the arrangement in 2014 (Google Streetview) showing the replacement of public benches by the outdoor serving of Under Kastanjen. Photograph by the Author and from Google (© Google 2014).

These episodes play out at two locations which I have visited the first week of the semester after summer for several years, as they are part of a study visit that we take our students on in their first week of the Masters' program in Sustainable Urban Planning and Design at KTH Royal Institute of Technology. The walk is arranged to include aspects of what this article is concerned with, highlighting the closeness in central Stockholm of radically different rhythms. Starting from the Gamla Stan subway station, the walk goes west to the waterfront of Lake Mälaren, continuing around Riddarholmen up to and through a section of Västerlånggatan, to the Roayal Palace, further to Stortorget and then past Tyska Brunnsplan and/or Brända Tomten to Österlånggatan, and on to where this street meets Västerlånggatan at Järntorget, from where we continue to Södermalm. Usually done in the morning, this year saw it was performed three times in the afternoon instead, as we needed a Covid-safe solution and decided to do stage the walk multiple times, in smaller groups. In preparing and performing these study walks, as well as other more extended observations, it has become clear that these kinds of squares exist in many places on the island; there are remarkably many, although the extent to which a given square is included in the tourist economy varies.

3.2. Skinnarviksparken, June 7, 2021, 17.45

Figure 4 Skinnarviksparken and surrounding context. The distance to Hornsgatan is 222 m / 205 m (211 m to intersection) / 2 turns (+1 for Hornsgatan direction); distance to nearest subway station is 190 m / 176 m / 3 turns (+1 to enter, -1 to reach the "side of the entrance building"); distance to Bysistorget is 513 m / 417 m / 4 turns (including entering Bysistorget, 5 turns shortest metric path); distance to Mariatorget is 1010 m / 816.5 m / 4 turns (including entering Mariatorget).

It is early evening in the summer. While there are Covid-19 restrictions in place, outdoor gatherings are allowed, following a reduction of restrictions that has been in place since June 1, 2021. One of our doctoral students has just defended her thesis and I join a small outdoor celebration. We are around twenty people, clustering in smaller groups around picnic blankets, close to one edge of the park. There is easily enough space to physically distance from other groups. In the warm summer evening, the environment offers a pleasant blend between a bit of quiet celebration and the occasional intense conversation or discussion, and louder congratulations from new arrivals. While at other times of the year, our chosen spot may be at its best in the morning or at midday, we have a fair amount of sunshine until quite late. Some other groups, mostly somewhat smaller than ours, have gathered on the other side of the pedestrian path, and especially on the other side of a small sets of bushes offering a light screen of vegetation between us and them. As the evening continues, there is a steady, but small, stream of pedestrians walking through the park. Some stop to sit on available benches, and the occasional pair or lone wanderer take a seat under a large tree or on the sunlit rock to have coffee, converse, or read. The café at the entrance of the park remains open for some of the time, but for the most part, their activity and those of other groups never collide, and at least today none of the groups seem to end up in competitive behavior in terms of music or activity, even as further groups turn up during the evening.

Skinnarviksparken is a mid-sized park by one of the main arteries of Södermalm in the center of Stockholm. It is also next to a subway station. The part of the park addressed here is the grass-covered section closest to the station. The park extends over a rather steep, mostly bush-covered slope, which is crisscrossed with steep pedestrian paths, and takes in the rocky hilltop of Skinnarviksberget, which is more remote. The part that we gather on is also most clearly integrated into pathway networks between the adjacent (predominantly housing) area, the subway, and busy street Hornsgatan. While the grass area tends to remain mostly calm, it is used throughout, and the rocky surfaces of the hilltop fluctuate more between emptiness and larger and noisier weekend evening parties, as its comparative remoteness allows for more noise without disturbing surroundings. For a number of years, I have been able to incorporate the park in my routines—my two weekly jogging rounds pass through it—allowing me to capture the rhythm and character of the park repeatedly over an extended period, in addition to more targeted observational visits.

Figure 5 Inhabitation of Skinnarviksparken on a sunny summer day, showing the emergent results of a spatial negotiation of the surface as well as the degree of occupation. Aerial photo by Stockholms Stad (© Stockholms Stad 2019).

While Skinnaviksparken is a well-visited park, it almost always has space for more people—be it in the period of most intense sunbathing or on late evenings on the weekend. In contrast, the nearby square Bysistorget and the “green” square of Mariatorget often feel significantly more “full”: they see more intense use, and they are also more directly linked to the central street network and Hornsgatan. Part of the park’s capacity comes from its subdivision by natural and artificial elements: walkways and bushes make for strong and clear boundaries, whereas topography allows for further negotiation of territory if needed—two grass slopes with a rocky

height in between can become one, two, or three territories quite easily, and throughout visits it is clear how the interplay between activity, the density of visits, and the environment interact in these territorial negotiations (Figure 5). This character and subsequent occupational patterns rhyme well with both Lars Marcus' discussion of capacity (Marcus, 2000) and with the findings in the Vienna park gender mainstreaming project (Irschik & Kail, 2013), showing that parks which are divided into sub-spaces see more diverse use both in terms of kind of activity and occupants. While this capacity seems to act in line with the principles laid out by Marcus—more spaces offer more opportunities for diversity—it does so with less clearly drawn boundaries, since literal subdivisions offer only a weak support in the territorial negotiations between actors and activities.

3.3. St. Axel Landquists Park, September 18, 2021, 13.40

Figure 6 St. Axel Landquist's Park and its surrounding context. The distance to Folkungagatan is 155.8 m / 122 m (130 m to intersection) / 2 turns (including entering the park); distance to Götgatan is 413.5 m / 406 m (408 to intersection) / 2-3 turns (including entering the park); distance to Nytorget 251.2 m / 212 m / 2 turns; distance to the subway is 503 m / 414.04 m / 3 turns (including entering the subway); distance to Medborgarplatsen is 671 m / 505 m / 4 turns.

This visit to St. Axel Landquist's Park is the first in a while, and I come here on a Saturday, together with a friend after a fairly long walk. It is mid-afternoon. We have decided to have an ice cream, as there is a small ice-cream stand that has opened here. It wasn't here a few years ago, when I had reason to pass by more often, and while we both like ice cream on a warm and sunny day, it irritates me that the stand is placed in the middle of the park, claiming central territory and privileging its own visibility instead of occupying a more peripheral space—even if the vast majority of the park remains open for public use. The stand, according to my friend who, living closeby, visits the park more often than I, does really well and the line for ice cream is sometimes long. Today, the queue is relatively short; while it is a pleasant day, the most intense sunshine of the Swedish summer is now over. Having bought our ice creams, we sit down for a bit and I inquire if it is usually difficult to find a place to sit. The answer is no, not really. Only sometimes. Still, the number of chairs is pretty small: just a few tables, with a few chairs each. Of course, on nice days, many choose to sit on the grass or on the public benches along the park's edges. The latter are also not full on this day, although we can't see all of them because the park is divided into sub-spaces by vegetation. The park meets the streets around it quite differently (Figure 7): in the north, it meets the building block directly, but a line of bushes clearly mark out the territory of the park. In other directions, the park is slightly higher than its surroundings, requiring one to take a few steps up or follow small ramps to enter. While directly connected to three streets, it is thereby also clearly demarcated as its "own" space. We sit for quite some time, discussing a variety of things, and I keep both conscious and sub-conscious track of the rhythm of the space, not the least whether it feels like we are blocking anyone else's use of the seats. During our time here, the seats never fill up, and there is always at least one table that is completely free.

Figure 7 St. Axel Landquist's Park. A view of one side of the park and height differences at the entry. October 30, 2021. Photographs by the author.

St. Axel Landquist's Park lies just south of Folkungagatan and not far from Götgatan, two of the busiest streets on the southernmost island of inner-city Stockholm. It is in the area that has become known as "SoFo", paraphrasing the SoHo area in London in an attempt to reflect its intensity of use and the presence of "local" commercial actors—or at least different sets of brands than those found on the high street. As the SoFo nomer emerged, the brands also became increasingly high-end, confirming a growing gentrification. A group of friends and I regularly used to have breakfast at a (now defunct) café near the park on Saturdays, and as such I used to pass through this place fairly often; I lived further away, and it was on a convenient path from the subway to the café. It has always stuck with me as something of a quasi-hidden oasis, partially due to its intentionally separated character. Its character as an oasis is further supported by fellow researchers' observational studies, which note how the small park remains less intensely used than the streets around it—and significantly less so than the square Nytorget, which is not far away (Choi, 2014; Choi & Koch, 2015; Legeby, 2013). As a walking path, its use seems to be primarily for what Choi calls "recreational" and "social" walking, characterized by slower pace, greater interaction with the walker's surroundings, and focus on relaxation. While I have visited the park less in recent years, its character seems to remain intact, even with the new the ice-cream stall. The stall, however, while ticking many of the identity boxes of Södermalm, wanders perilously close to what Sharon Zukin calls "pacification by cappuccino" (Zukin, 1995), and while being a local, conscious actor participates in a commercialization of public space however much it is appreciated by locals (Kärrholm, 2012).

4. Foreground Networks, Background Networks, and Characters of Social Interplay

The tendency for seldom-frequented streets and squares to exist within the dense centrality cores of networks is explained in syntax research by the observation that *choice* and *integration* both tend to correlate with *pedestrian flow*, the latter exponentially (Marcus, 2000, p. 113; Stavroulaki, Bolin, Berghauser Pont, Marcus, & Håkansson, 2019). My observations thus largely support previously documented statistical patterns but make tangible just how quickly intensity drops off: the places discussed here are between one and two blocks from some of Stockholm's most intensively visited locations. These patterns of centrality and movement flows have contributed to the theory of *foreground and background networks* (Hillier, 1999, 2009), which holds that networks can be conceptualized as "productive" or "reproductive" of social relations, that "difference" "meets" in the streets that bind the city together, and that local communities are built on the basis of that which is separated from them.

The sites discussed here ask for care and nuance in subjecting them to such a conceptualization. While not sites where differences meet as a result of the sheer density of flows through the city, they are not simply "local" either. Rather, they offer atmospheres for other kinds of interaction, or for breaks from the intensity of the high streets. Their qualities come specifically from being calm, quiet, slow, or otherwise less vibrant and intense than the central streets, while being *close* to those streets. As spaces that more easily accommodate more extended interaction, their closeness to larger urban arteries offers potentials of integration by both enabling and demanding interactions that are qualitatively *other*. Some of this follows easily recognizable patterns and depends on easily understandable processes relating to the spatial and bodily limits of interaction. As Ash Amin expresses it, "Clearly, how people behave in a noisy square in which pedestrians are constantly avoiding other bodies and objects will be very different from that in a smaller square laid out for café life and convivial mingling" (Amin, 2008, p. 9). Amin goes on to further note how, conversely, spaces with similar patterns tend to share common social traits—in both vibrant and empty spaces, rhythms cause resonances between people and between people and environment, whereby "These resonances of situated multiplicity condition social action in quite powerful ways" (Amin, 2008, p. 13).

In more sparsely populated environments, there are spatial, logical, and social reasons for a stronger awareness of one another and such environments can make deeper forms of interaction easier (Giddens, 1984). Conversely, the impossibility of meeting everyone's gaze in the bustling street allows eye-contact to be avoided and people to act as if others were objects. While the anonymity of the crowd can offer a sense of freedom from control (De Beauvoir, 1965), the correspondence between physical co-presence and co-awareness is complex and often decreases with increasing masses. Arguably, there are thresholds where differences between the more and less intense spaces grow stronger, such as when the spatiality and materiality of one's own and others' bodies make itself present in more direct and intrusive ways (Grosz, 1995). Such situations induce a constant need to zig-zag, wait, pause, circumvent, or shift sideways in order to get through or to let others pass, or to avoid directly bumping into or being bumped into by others. The necessity of acknowledging corporeality and bodily mass transforms others' bodies, making them tend towards larger, continuous masses—and clearly, while perhaps not leading to the recognition of one another as individuals, there is interaction going on as well as negotiations and enactments of norms of behavior.

Calmer situations do not, of course, necessarily lead to conversations between strangers. However, they do tend towards increased attention being paid to individual actions and characters, suggesting that such spaces may aid in developing a more concrete understanding of just what others are doing in the same space. In moments of rest, we may develop a somewhat better understanding of who others are, and why they are where they are, than that which is to be gleaned in a fleeting encounter on the sidewalk of a bustling street. More time is likely to be spent seeing or hearing one another in calmer spaces, and conversations—or music playing from headphones—

are more likely to be overheard. Low degrees of intensity may also witness stronger territorial effects (Brighenti & Kärrholm, 2018), as specific choices about ways of inhabiting a calm space lead to palpable socioterritorial negotiations regarding subsequent acts of (co-)inhabitation.

Complex effects of "co-awareness" are also at play in such exchanges. A mutual gaze demands that the other be recognized as a *subject* (Calefato, 2004), and in this it also demands the recognition of one's own subjectivity— "who are you, and who am I (to you)?" (Butler, 2005). The precise situations of co-presence that can lead to such exchanges are of course *intersectional*: they are culturally and historically dependent and can be heavily affected by class stratification and gendered differentiation (Vincent, Neal, & Iqbal, 2018). They are also not "inherently" positive since the questions raised in co-recognition or the situated sense of co-awareness can be highly exclusionary. If eye contact can trigger questions around belonging or the right to be somewhere, the answer may be a feeling that one should leave, generated even in the "fractions of a second … before conscious reflections set in" (Swanton, 2010). Even the smallest of interactions can thereby develop into exclusionary practices and rhythms (Reid-Musson, 2018). While these kinds of exclusion are not intrinsically linked to whether one is a local inhabitant or not, their effects increase in line with expanded possibilities of continuous territorial domination.

Secluded spaces are, however, also indirectly interactive: in as far as that they are places of pause and rest, they are also places of avoidance (Koch, 2016). Their character is partially defined by not being a vibrant street or square—they are relationally "other," the place of *fewer encounters* than their counterpart. This recalls Zukin's and Kosta's account of the "off-Broadway" location, which is always dependent on Broadway and offers potentials for cultural differentiation with various "off-foreground" locations adopting different characteristics. Of the places addressed in this paper, perhaps Brända Tomten most clearly tends towards Zukin and Kosta's discussion of an "off-broadway" identity: a place "for those who know" (Zukin & Kosta, 2004).

This *emergent territoriality*, which is negotiated in multifaceted ways, provides a further key to understanding how such sites work. Each site balances between personal, local, and global territoriality in its own particular way: if pulled further away from the foreground network, or further away from the decidedly shared public spaces of the city, such places may become local territory and thus subject to the effects of control and the limitations that such control brings (for better or worse). Similarly, if further integrated into the foreground, such places would not allow either local or temporal territoriality to claim them in ways that are necessary for some of the practices that today form their quality (see, e.g., Minoura, 2016). As spaces for "alterity," they can offer oases of possible temporary territorializations, emplacing "transpatial" community formations (Hillier & Hanson, 1984) in "the heart" of dense settlements. They are places of otherness, alterity, and difference in complex and nuanced ways that include but are not limited to their slower rhythms. By being less continuously dominated by bodies and their territorial claims, or by certain groups of people or activities (neither locally controlled nor globally dominated), they are one important form of "the more intimate spaces of the city in which diverse individuals contest and negotiate their position in society and urban civic culture" (Hewitt, 2016, p. 358). Here, closeness to the intense public spaces is crucial—it affects the territorial negotiations of the site. Secluded spaces are not visited enough to become cosmopolitan spaces, yet not quite segregated enough to form full-on local territories. This is a complexity that offers pockets for visitors from all over the city to meet in relative seclusion, for visitors and locals to encounter one another in a different atmosphere, yet still for locals to claim space. The possibility of otherness and difference is central for social resilience, just as it is important for a diverse and inclusive democratic society (Williams, 2011).

5. Interface, Capacity, Insulation, and Sequencing

While it is tempting to continue going deeper into the sociospatial situatedness of occupation, I will move on to the equally important matter of how these urban "pockets" or "fissures" (De Holanda, 2017) appear in the urban fabric as spatial configurations. What are the spatial conditions that such spaces share, which enable their existence as urban oases rather than as "vibrant, lively public spaces," "locally community spaces," or "distant' or 'peripheral' spaces of calm and respite.

The spaces explored in the observations all share a combination of closeness—in meters and configurative distance—and what Julienne Hanson has termed "insulation" (Hanson, 1998). For Hanson, *insulation* stands for the number of spaces in-between different rooms—for instance, between bedrooms and bathrooms or different bedrooms. Any space in-between "insulates" one space from another. The urban sites addressed earlier are invariably not directly adjacent to the most vibrant spaces: there is a minimum of one space in-between and they cannot be seen from the central arteries. This suggests that in urban fabrics, *configurative insulation* can be highly efficient—as Lars Marcus notes regarding another site on Södermallm, "Thus, a dramatic drop in integration is accomplished within an otherwise highly integrated area. This gives Bjursholmsplan a very special character, in that it is a rather segregated area, found just one or two steps from some of the most integrating lines of all on Södermalm" (Marcus, 2000, p. 126). However, while such spaces don't seem to need particularly much insulation, they are also dependent on not having *too much* as this would push them towards becoming "local" or "peripheral."

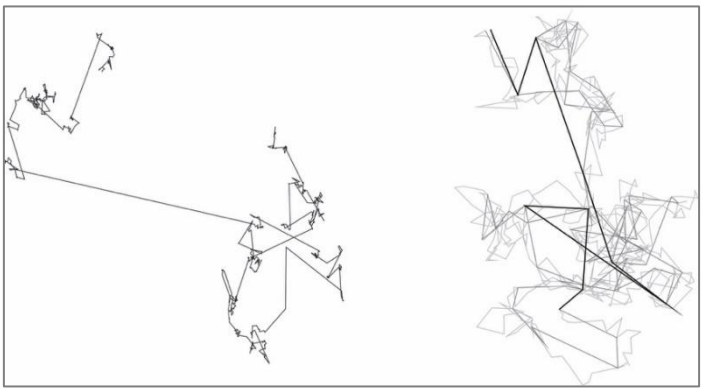

Figure 8 Lévy flight (left) and Brownian walk (right) search patterns; the Lévy flight is based on a mix of longer jumps between local searches, whereas the Brownian walk tend towards a more consistent distance. The figure of Brownian walk shows patterns from three different step lengths. Hillier's argument is that the foreground network in part operates by enabling 'local' searches in distant places—similar to how Lévy flight search patterns work—rather than forming a network of origins and destinations 'of its own'. Figures adapted from Wikimedia Commons, Public domain license.

The second characteristic that these *urban oases* share can be understood through recourse to another of Hanson's terms, "sequencing," which describes the way in which spaces are configured one after the another (Hanson, 1998). Linked to the way Sophia Psarra discusses *narrative* (Psarra, 2009), *sequencing* also invokes the structural narrative and textural character that results from always already being embedded in networks through proximity to other spaces and by means of the way in which most trips to such a space (at least for non-locals) entail making use of the foreground network. Foreground and background networks, according to Hillier, can in turn be understood in terms of "Brownian" and "Levy-flight" search strategies (Figure 8) (Hillier, 2016, pp. 208-209), wherein the latter demonstrates how the foreground network can *facilitate* long-distance movement, while origins, destinations, or continued activity may disperse more widely in local contexts. Such an understanding thereby challenges the habit of making overly *direct* links between the question of "who" moves on particular segments and the configurational value of that segment, while refining our understanding of how the systemic role of a given space relates to how and why people are likely to use the foreground network when navigating longer distances. In this view, Västerlånggatan act as a "corridor" for most movements to or through the area of Gamla Stan in Stockholm, whether their destinations are on it or not, but does not define where people are

headed. In this sense, arguably, the potentials of co-presence and experiencing difference that are engendered by vibrant places become at least partially integrated in the kind of places discussed here, as is the production of shared understandings of urbanity. However, the locations addressed in this paper are also sequenced on routes between other places; not being an "endpoint" seems to be important for upholding a potential blend of users as well as for being discovered by people. Such spaces are, as Alexander Ståhle expresses it, "in the way" (Ståhle, 2008). Departing from a simple reading of Ståhle's argument, it is important to understand that they are not, however, in "everyone's" way, and not for a (functionally) maximized number of visitors.

The third aspect the urban oases share is that they are part of what can be termed a "capacity system." For Lars Marcus, *spatial capacity* is the capacity of spatial configuration to carry difference, where this capacity is largely created by delimitations—for instance, two rooms can hold two different activities more easily than one room, etc. While this is usually translated to rooms in a building or, as in Marcus' own research, into plot subdivisions, I argue that the character of the squares and parks that I have observed largely comes from their multiplicity. While they hold some capacity internally—even if Brända Tomten has seen its capacity reduced by rearrangement of the outdoor serving—they form parts of a wider capacity together with other public spaces nearby. They are also relatively insulated relative to intensely used public squares (Bysistorget, Mariatorget, Järntorget, Stortorget, Nytorget, Björns Trädgård, and so on), and, for the parks, they are within walking distance to other, larger parks (Tantolunden, Högalidsparken, and Vitabergsparken). In this in-between, sets of squares and parks occupy a spectrum of positions creating bundles of off-site locations complementing the "vibrant" and the "peripheral." For most of them, one can find more stable or dynamic use of this in-between location for various activities, functions, or identities that deviate from main street culture. While one should be careful not to assume it is a perfect ecosystem, it is indeed an ecosystem where social (and functional) resilience in part comes from complementarity and degrees of interchangeability.

The fourth important shared factor lies in how the spatial interface of these observed spaces is structured to balance character and identity, occupying a space between decidedly local and visitor-dominated, which refines their capacity to contribute to the potential of offering different qualities of encounters and interactions between differences, and their potential to hold "alternate" atmospheres, activities and gatherings. An important factor here is the "integration interface," a measure of how the centrality of different scales overlaps, which provides statistical probabilities of people acting on different scales encountering one another, where the locally central streets of the discussed sites also have global importance (Hillier & Hanson, 1984; Legeby, 2013; Peponis, Ross, & Rashid, 1997). However, for these squares, I consider that *closeness* (which I define in a more colloquial sense as proximity between locations that offer a different social character) is as important, as well as how the interface between the different locations is structured in a concrete, architectural sense (Peponis et al., 2015). The sites are not strictly "segregated," but they are outside of the foreground network. They are locations that, as Peponis, Park, and Feng argue in relation to the spatial configuration of Gangnam in Seoul, Korea, "…allows the creation of local areas with distinct character, while enabling large scale metropolitan connectivity, by public transportation or privately used vehicles. It creates a variety of urban conditions in close proximity, thus setting the stage for a mixture of land uses or development densities and a pluralism of urban actors" (Peponis, Park, & Feng, 2016, p. 105). While Peponis et al. discuss a larger and more dense metropolitan area than my Stockholm examples, and whilst they target other kinds of diversity than I interrogate here, the argument is relevant. In the places studied in my fieldwork, there is a finely grained balance and differentiation, whereby not only how locally dominated they are varies, but also who seems to be visiting them, and from where. Amongst the examples that I present, the ostensibly most homogenous population and most "local" character is to be found in St. Axel Landquist's Park, which is also furthest away from subway stations and closest to the "vibrant" space of Folkungagatan, which in turn (at this point) is also the weakest global connector.

6. Discussion and Conclusions: Resiliences of Capacity and Difference

The kind of places studied here offer *resilience* in two important ways. These are both integrated and unrelated. First, these places are able to host changes in the use of urban space; second, these species have a capacity to carry difference in public space.[1]

The first aspect—capacity to host change—was clearly tested in the Covid-19 pandemic, wherein the extent to which urban textures were able to respond to restrictions and limitations depended on the closeness, plurality, and redundancy of open space (Legeby & Koch, 2020). In the pandemic, this capacity was seen in places where there was *more space* than can be "efficiently used" in daily life, where space was *distributed* so that it was close-by, and where that space was diverse in the sense that it catered for different needs in the new situation. Without reducing the importance of larger recreational areas (Samuelsson et al., 2021), it is thus important to understand the ways in which public spaces are distributed and integrated in an urban texture that allow such diversity. But this capacity is fundamentally based on such spaces *not* being constantly full of activity in the regular, daily urban life—the standard evaluation of the "attractiveness" or "success" of a place—since that would leave them little to no capacity to host the new activities emerging. This, furthermore, quite clearly demonstrates what holds true also without a pandemic: if all public space is vibrant and full of activity, there are few openings for acting *otherwise*.

"Off-foreground" can here be seen as a term for "accessible but calm." To return to the work of Engström and Gren that is brought up in the introduction to this paper, the kind of places studied here seem to be able to capture two out of the three things that people value most in a park: what the authors, following Grahn and Stigsdotter (2003), call the "serene" and "space," whereas "nature," the third category, is more dependent on size. However, the findings here suggest that while they make an important point, these scholars may have overestimated the importance of size: while size is one way through which one can achieve "enough space to not frequently encounter other people, or to avoid experiencing disturbance from traffic etc." (Engström & Gren, 2017, p. 21), a more nuanced and detailed study of how architectural articulations shape the use and experience of public space would offer further means by which to create such conditions (see Okba, Cutini, Leccese, Salvadori, & Zemmouri, 2021).

These spaces explored in this paper offer further potentials for delivering resilience, both indirectly (as calm, secluded, and quiet space), and through their "un-use." While the most intensely used spaces may need to adapt to primarily human conditions and intense wear-and-tear, these sites demonstrate further, largely untapped, potential for including "the other," and for "wildlife" and species of plants and animals that don't play nicely with the bustling high-street. This suggests possibilities for ecological networks to be established in parallel to human systems, operating not at and *through* the main human arteries but covering similar ground, without *excluding* humans or forming peripheries.

This is not to suggest that these spaces are ideal. Their capacity to hold alterity should not be over-romanticized either in how far it reaches, in how allowing they are, or in that such alterity is always only positive. If the most vibrant spaces prevent certain things happening, so do the characters of these spaces, including positive aspects of the former. In the current state of the given examples, some of the capacities and potentials discussed are rather prevented than supported—by car-parking, outdoor dining areas, or other acts. My intent has not been to romanticize these places, but rather to address their potential as spaces of rest that are remarkably close to intense,

[1] While I have not investigated how disruptions would affect the configurative system or change accessibilities to amenities (Abshirini & Koch, 2017; Carpenter, 2015; Cutini, Farese, & Rabino, 2020; Koch & Miranda, 2013), arguably there is a link between the preliminarily observed demands for multiplicity and resilience against disruptions in a spatial system. Such multiplicity would, furthermore, be in line with the first principle of "building resilience" as presented by Karen Kotschy et al: "Maintain diversity and redundancy" (Kotschy, Biggs, Daw, Folke, & West, 2015). Neither have I directly addressed resilience in relation to urban ecosystems or ecosystem services (Barthel & Kyttä, 2020; Biggs, Schlüter, & Schoon, 2015; Erixon Aalto, Marcus, & Torsvall, 2018; Marcus, Berghauser Pont, & Barthel, 2019).

vibrant urban spaces—and to open up for more careful consideration of how to handle such spaces, respecting and working with this quality, including their *non-use*.

That it is relatively easy to create spaces of low use in dense urban fabrics does not mean that it is easy to make such spaces *qualitative*, nor that they by necessity support deeper or more intense interactions. If the intent is to work with these kinds of places and offer a triad of resilience values in the form of a "pause" from urban vibrancy, openings for alternate activities and identities, and a capacity to host change of use of public space in extraordinary conditions, further questions remain with respect to these demands. In addition, while their social character may offer possibilities for other relations between humans and non-humans to be construed than in the most populated, intensely used public spaces, this presents a largely untapped resource.

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Resume

Daniel Koch is a docent in Architecture and researcher in urban design and urban theory at the KTH School of Architecture, where he leads the development of the profile critical morphology and spatial analysis. He is also co-programme director of the master's programme in Sustainable Urban Planning and Design. His research investigates spatial configuration, diagrams and abstractions, and processes of subjectification within the larger frame of architectural theory and design, as well as urban sustainability and diversity.

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To integrate or not to integrate? A matter of choice for universities

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Abstract

What is the right location for a university campus? Universities have a preponderant role in today's societal models. They have been in the core of development — economic, social, sustainable, inter alia — and their role within urban context has changed in order to respond to the university mission — that nowadays includes of civic engagement as well as a stronger participation in economies, through the development of startups and innovation ecosystems. This paper relies on the premise that, even in a post-pandemic world, the Campus is still a window to the world, it can shape the perception people have of the University, can be used as a branding asset and, most of all, impacts the lives of everyone living, learning, and working there. The Campus is a very powerful tool, one that universities worldwide have been using as a way of positioning themselves, of attracting students and faculty, and also creating synergies and relationships with companies. It shapes the relationships created inside and outside of it. As such, this research argues that universities can be key elements in generating and enabling dynamic synergies, promoting the presence of students, academics, and learning spaces in urban contexts. To accomplish this, universities should preserve their spatial identity and uniqueness, while guaranteeing the existence of adequate places for all learning related activities and embodying inclusion and sustainable development, promoting encounters and interaction. These two needs, for inclusion and livelihood while safeguarding some privacy coexist creating some tension for all campus users. With this issue in mind, this paper explores an analytical framework for university campuses within urban fabrics, understanding the different types of urban insertion and connections established with local and regional players, and exploring the dichotomy between closeness centrality and betweenness centrality, as variables than can be used to balance the tension between integration and privacy that affects university campuses and academic communities worldwide. Four compact university campuses that host similar functions are used to test the methodology: Simon Fraser University in Burnaby, Canada; Aalto University in Espoo, Finland; MIT in Cambridge, MA, USA; and Yale University, in New Haven, USA. This paper relies on syntactic analysis to provide deeper information and some clarification on the university location and accessibility within the urban fabrics.

Keywords: university campus, integration, choice, centrality, university synergies.

1. Introduction

Universities have always played a dominant role in modern societies. The effect of university facilities in urban dynamics has progressively become more complex, affecting directly all users

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(academia and non-academia), and reaching all spheres of society. Merely their physical presence is already an element of change. University activities impact in many ways their vicinity and wider communities to the mutual benefit of both (Knight 1995, den Heijer 2011), interfering in the process of urban development, in parameters such as employment, housing, mobility, leisure and consumer activities (Indovina 1997). As central elements in the economy, universities can contribute to urban regeneration, not only directly by improving the built environment quality, but also reclaiming city areas and funds from public regional players. Today's idea of university shows an entrepreneurial entity, able to actively contribute for the social fabric and engaging in social, economic and cultural challenges (Corneil and Parsons 2007).

As Temple (2009, 2014) advocates, the physical space is one of the most powerful tools available for the university to express and convey its identity, namely its values, mission and cultural background. Not only is the university able to express its identity through the physical space (Edwards 2003, Hajrasouliha and Ewing 2016), but it can also communicate its presence, purpose and domain (Dober 1992). Furthermore, campus configuration, including proximity and adjacency relationships, can foster exposure and interactions that permit successful collaborations and outputs (Kenney et al. 2005).

Several authors emphasise the importance of establishing relationships, connections and synergies between university campuses and their host cities (Gibbons et al. 1994, Conceição and Heitor 1999, Duderstadt 2002, Christiaanse and Hoeger 2007, den Heijer 2011, Campos Calvo-Sotelo 2015). Nevertheless, there is a shortage of literature focusing on the description of the spatial properties that enable these relationships and which may, in particular, contribute towards supporting urban activity and vitality in a balanced and sustainable manner, i.e. without forgetting that university precincts are academic facilities requiring a spatial identity that guarantees adequate places for learning and its related intellectual activities.

According to Engwicht. "cities were invented to facilitate exchange of information, friendship, material goods, culture, knowledge, insight, skills, and also the exchange of emotional, psychological, and spiritual support" (1992, p. 17). And so were university precincts. Space quality can inform and impact on human behaviour and activity, and there is a close connection between the qualities of the urban space and the quality of the activities performed there (Whyte 1980, Beck 2009). One can argue that there is a close connection between the quality of a university's physical space and the quality of university life.

Nevertheless, universities throughout history have experienced several different movements of approximation and isolation towards their hosting cities. From generating urban fabric and enabling interaction, to moving away from city centers, generating heavy and unsustainable commuting movements, universities have been shifting from ivory tower to engaged institution at different times and contexts.

This paper examines the configurational features that can contribute positively to the integration and development of university precincts in urban & social areas. The purpose is to identify location properties that influence the campus' ability to become integrated and embedded in its urban setting. University campuses are defined as the areas occupied by a university and where its functions and activities take place. In the scope of this paper, only campuses that host all activities consentaneous with the presence of people on a 24/7 basis were considered. The cases were chosen from a larger sample, and each of them is representative of a type of university precinct according to their morphological features (Cannas da Silva 2017).

2. Methodology

Space syntax theory aims at understanding the performance of built environments (Hillier et al. 1983) and its ability for hosting human activities and functions by relating social variables to built

spaces, through a precise method of description. It relies on the premise that space has social implications and affects users' behaviours and the possibility to shape interactions, since the system structure of space in which various activities occur can influence movement, encounter, and avoidance, as well as generates social relations (Hillier and Hanson 1984).

Space Syntax provides a method to describe space by means of a measurable, non-arbitrary and reproducible representation (Heitor and Pinelo Silva 2015) in which built spaces (ranging from buildings to cities) are defined as configurations, i.e., elements in a relational environment, evaluated according to the relationships they establish.

It considers space in terms of abstract properties of topological nature rather than in terms of geometric measures. Thus, spatial layouts are described regarding the pattern of connections between spaces and the extent to which each space is directly connected to other spaces, i.e. how far each element is from all others, according to a specified measure of distance; and, how many paths run through each element (Peponis 2016, p. 39).

The axial map is a simplification of the city's pattern through "the most parsimonious set of straight lines that intersect to form a network covering all possible ways of moving around the city" (Peponis 2016, p. 38). This representation covers lines of physical and visual continuity among interconnected spaces, since when analysing urban space, movement is regarded as the basic function of street spaces, and so spaces are reduced to "the longest accessible lines that cover all convex spaces in a map"(Al-Sayed et al. 2014). The axial map description operates as a macro analysis of the urban structure. It allows for an even representation of information in topological relationship and with assessable horizontal distances, whether these distances might be topological, metric or angular.

Segment maps are a derivation of axial maps later introduced by Turner (2004) which considers the segment as the elementary components of the street network. Street segments consist of the segment section between two intersection points. For instance, an axial line that is intersected by two others is composed of three segments, and thus, when analysed in a segment map, each of the three sections is considered as one element in the system. One of the key aspects of segment analysis is that they enable analysis on angular distances, becoming a very powerful tool to emulate the perception of streets continuity and assess how much energy is spent along a trip or when one moves from one space to another one.

Space syntax allows for a diverse range of analysis (Heitor and Serra 2016). In this research, it is used to analyse the universities position within the surrounding urban system and explore to what extent the university precinct is integrated in the urban fabric and has the potential for cross-exchanges. Thus, in this paper, axial maps and segment maps are used, and the focus is on two main variables: closeness centrality – integration; and betweeness centrality – choice.

Closeness centrality – integration represents the distance from each object in the system (each axial line) to all the others, characterizing the relationships among lines according to the number of changes in direction from each element to all the other within the system. This analysis evaluates each visual segment from more segregated (located deeper in the system, i.e., needing more changes in direction in order to be reached from all other locations) to more integrated, i.e., reached within fewest changes in direction.

Betweeness centrality – choice, measures the "quantity of movement that passes through each spatial element on shortest or simplest trips between all pairs of spatial elements in a system" (Hillier et al. 2012). Thus, integration – closeness – represents the "to-movement potential of a space", while choice – betweeness – represents the "through-movement potential"(Hillier et al. 2012).

Integration allows measuring the easiness in access from any other point in the system, showing the potential of the university surroundings to be a destination, or rather, showing whether the university premises are in a place with the potential to be a destination in random movements. Choice, in opposition, shows the potential of the university premises to be in a place that enables "passing by" movement, that is, that is usually used in random dislocations from origins and to destinations that do not include the university's location. The higher the choice value of a place, the more the line or segment where it is located is on the path of movement between all pairs of spatial elements within the system, that is, the more movement crosses it on shortest or simplest trips within the system. This measure approximates the university's potential to enable serendipitous relationships between academics and outside users.

Space Syntax analysis of the sample of university precincts was carried out in three steps: 1) the representation of the spatial elements and their relationships by means of axial map and segment map; 2) the analysis of these elements and relationships among them.

Integration and choice are dimensionless, so they are not evaluated in any unit. They rely on the graph defined by all street lines, considered nodes, and their intersections, considered connections. Therefore, even when the maps present a metric scale, that does not apply to the analysis of integration, and does not change it. It just allows for comparison regarding the dimensions of the systems analysed.

Attempts to normalize choice and integration in order to enable comparing different cities were made by Hillier and Yang (Hillier et al. 2012). These normalized variables refer exclusively to segment maps, for the possibilities this measures enable, and are based on angular choice and integration. These two variables – Normalized angular choice (NACH) and normalized angular integration (NAIN) – represent a development in the field of space syntax that starts from integration and choice and permits to compare results among different cities. Besides, segment maps, and particularly angular analysis have proven to be quite accurate when it comes to evaluate street movement potential (Hillier et al. 2012). Moreover these normalized variables have proven to be strongly correlated with movement (Hillier et al. 2012) and thus provide additional clarification on the movement potential of the places where university premises are located.

Thus, segment maps were used as the basis for comparison and normalized angular choice (NACH) and normalized angular integration (NAIN) were applied, to complement the axial analyses of integration and choice.

In this section, all cities and university campuses are analysed in comparison, in terms of their foreground and background structures, to justify the university's presence in urban dynamics, according to its location and insertion in the city's structure. Cities present a dual structure through which all activity and movement flow. This dual structure, divided into "foreground network" and "background network", each of them with specific topological, metric and geometric properties (Hillier 2014). The "foreground" consists of the network that links all the centres at all scales, i.e. the skeleton, while the "background", though nested in the foreground, is mostly made of neighbourhood areas, with a focus on the residential and all related functions. While the former is made of longer and straighter lines, derives from micro-economic activity, grounded on invariant principles, and tends to assume a generic form, the latter relies on shorter segments, with mostly right angles among them, creating a grid-like structure which relies strongly on social and cultural factors (Hillier 2014). Therefore, while the foreground network is organized to achieve maximum movement potential and thus tends to be highly integrated, the background network behaves in a more secluded way. Since the background includes most segments in a system, it can be represented by the mean values obtained for any variable.

On this study, this analysis allows to understand whether a university is positioned within the foreground or the background network of its hosting city, thus informing on its character and movement attraction potential. When a university is in the foreground network it is likely to be

highly crossed by on random travels, to be visible within the urban system, to behave as a landmark and a reference point within the city. Opposing, when a university precinct is located within the background network it tends to be more appropriated by the neighbourhood and more likely to be used as part of it but can be disregarded as an important element for the city at a global scale. Hence, it is less likely to be used as a path on random movements, but rather to be reached only if it is a destination. In all cases, university premises do not have the structure to be part of the foreground network. Rather, their precincts are an integrant part the background network. It is the proximity to the foreground, or the fact that some of the segments included in the university precinct are part of the foreground network that changes its likelihood to be used as a path by external users.

The analysis of NACH gives information on the structure of the urban system. The mean NACH informs on the degree to which the background network forms a continuous grid with direct connections (Hillier et al. 2012) while the maximum NACH informs on how the foreground network structures the system. The higher the value of maximum NACH, the more structured a system is. Similarly, the higher the mean NACH is, the more continuous the background structure is.

NAIN, on the other hand, gives information on the ease of accessibility, that is, on proximity among segments. Maximum NAIN represents the ease of accessibility in the foreground network, while the mean value represents the same factor in the background network. A summary of the information comprised in this values can be found in the table below.

Table 1 NACH and NAIN variables and their meaning

	Mean	**Maximum**
NAIN	To-movement potential Background network	To-movement potential Foreground network
NACH	Through-movement potential Background network	Through-movement potential Foreground network

Hillier and Yang (Hillier et al. 2012) refer that the the maximum value of NACH for small systems can be around 1.4, but that, in general, this value reaches numbers between 1.5 and 1.6 or even slightly higher. This would be the case in cities with a strong structure. The mean value for NACH usually falls between 0.7 and 1.2, the more regular the grid, the highest this number.

To provide a comparison, segment maps were developed for each of the case studies. For the NACH analysis the colour gradation was adjusted to make them comparable, adjusting the blue values to below 0.8 and the red values to above 1.4, which corresponds to the foreground structure to make it more visible. For the NAIN analysis, the maps present a colour gradation by quantiles, that is, the same percentage of each colour is visible in the map, making them easier to compare.

3. Analysis and Results

Four university campuses and hosting cities are analysed. These cases were chosen as a part of a larger research (Cannas da Silva 2017), and they represent a specific campus typology which considers the precinct as an (almost) autonomous entity – campus as a city.

These campuses supply everything needed to host the main functions of the university and support the continuous presence of people. The campus hosts not only the learning, researching and some leisure activities, but also all the functions that support the living activities of its population (for instance, residences or halls, canteens, medical services, and so forth). These precincts attempt to shield their users from exterior disturbances and activities. Nevertheless, in most cases, they also welcome outside users. They can either be in the outskirts or even outside urban regions, but they can also be established within the tissue of the hosting city. Still, they can establish themselves as independent entities, which could function almost autonomously. The first two types are inner focused – the precinct is closed over itself - while the last two are outward focused, that is, is opened to the exterior environment, allowing for visibility and permeability.

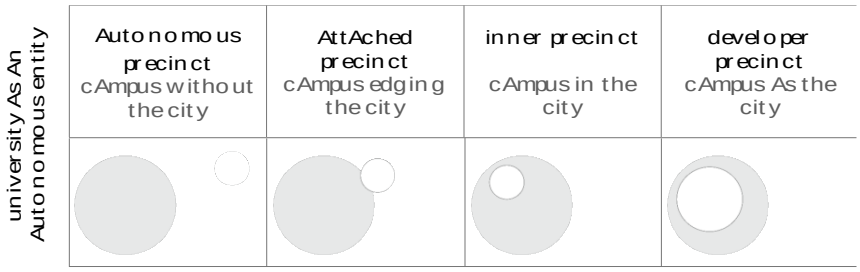

Figure 1 Types of university campuses that function as autonomous entities

3.1. Simon Fraser University – Burnaby, Canada, 1965

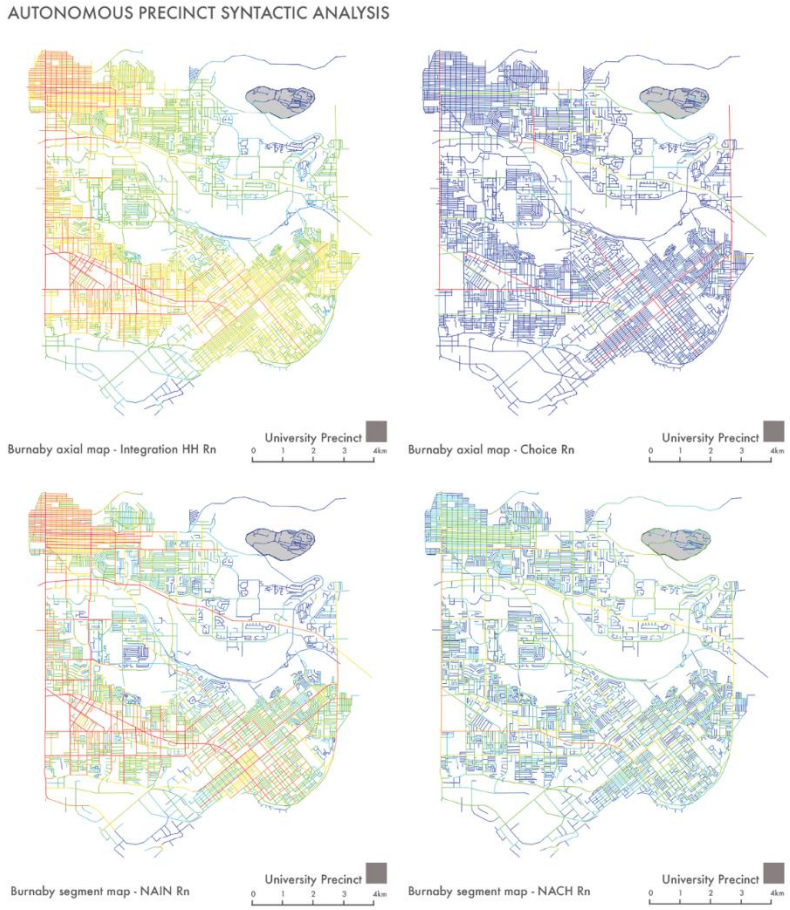

Figure 2 Burnaby Axial and Segment Maps - Simon Fraser University Campus Assessment

The most integrated streets on the network are in the north-western and south-western sections of the city. The university campus, located on the northeastern area of the city, appears in one of the most segregated areas.

The city presents a mean Integration value of 0.7593, showing 0 as minimum value and as maximum 1.1057 (an integration range of 1.1057). The values above the 3rd quartile (making the 4th quartile), i.e., the 25% more integrated areas, show values of 0.8718 or higher.

The university, identified in a grey shadow, presents integration values below the average of the city. The sum of the axes that are encompassed by the area of the university present an average integration value of approximately 54% of the average integration value for the whole system. The university is in the 25% less integrated streets in the network of Burnaby.

The analysis of choice enhances the results of integration. As can be observed in the figure, the lines which present the highest values of choice correspond mainly to highly integrated areas.

The university precinct does not include any axial line with a relevant choice value, which means it has a very low probability of being crossed on travels that do not include the university as either an origin or a destination. Nevertheless, its main access shows a choice value above the average of the system and occupies the 25% of streets more likely to be passed through on random travels. Despite this value, for the location of the university on the top of the Burnaby Mountain, it is unlikely that the access to the university is used by travellers on random travels not aiming to reach the university.

Burnaby presents a mean NACH of 0.911, at a global scale (Rn) and a maximum value of 1.606, while the sum of the segments comprised within Simon Fraser University's precinct, reaches a maximum value of 1.289 and a mean value of 0.815. In terms of NAIN, the city presents a mean value of 1.069 and a maximum of 1.652 while the precinct shows a mean value of 0.571 and a maximum value of 0.862.

These results are consistent with those obtained in the axial analysis, emphasizing the segregation of the university precinct and its low probability of being crossed in random travels.

Despite this fact, the city of Burnaby presents a strong structure, as proved by its values of maximum and mean NACH. The background structure seems more relevant than the foreground, depicting the foreground structure as almost encircling the city, much more dominant on the western edge, limited by the city of Vancouver.

3.2. Aalto University – Otaniemi Campus – Espoo, Finland, 1961

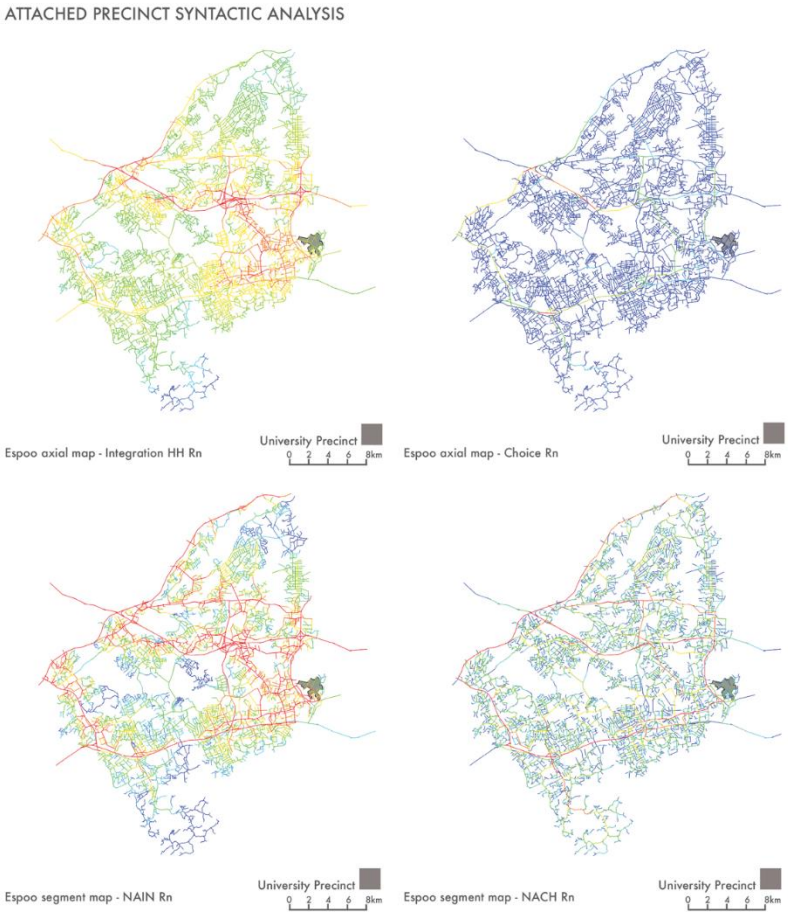

Figure 3 Espoo Axial and Segment Maps - Aalto University Campus Otaniemi Assessment

The analysis of Aalto University considers Espoo as the hosting city, even though both Espoo and the campus benefit from the proximity with the city of Helsinki. From the map analysis it becomes clear that the more integrated streets on the network are in the western sections of the city, which are also the ones connecting Espoo to the capital.

The city presents a mean Integration of 0.2788068, showing as minimum value 0.11367346 and as maximum 0.39258346, which shows a very small range for integration values, of 0.27891. The values above the 3rd quartile, i.e., the 25% more integrated areas, show values of 0.3098369 or higher.

The university, identified in a grey shadow, presents integration values above the average of the city. The sum of the axes that are encompassed by the area of the university present an average integration value 0.02 points higher than the average for the whole system. The university is located in the 40% more integrated streets in the network of Espoo.

The analysis of choice shows the dominance of a structural network system connecting Espoo to its adjacent municipalities on the east and west and linking the city from north to south. Aalto university campus is located beside some of the important axes, nevertheless it is not crossed or encircled by any of those, granting it some privacy while ensuring very good road accessibility.

The university campus presents lower choice values, which places its segments on the 75% more likely to be walked through paths.

The main access presents a choice value among the 25% with highest values within the system.

The location of the precinct, beside the main bridge connecting Espoo to Helsinki, is likely to increase the traffic near or within the precinct, since this bridge is one of the important entry points in the capital from Espoo.

Espoo presents a mean NACH of 0.603, at a global scale (Rn) and a maximum value of 1.509, while the sum of the segments comprised within the Otaniemi precinct, reaches a maximum value of 1.209 and a mean value of 0.741. In terms of NAIN, the city presents a mean value of 0.452 and a maximum of 0.693 while the precinct shows a mean value of 0.488 and a maximum value of 0.581. Espoo presents the lowest values of the set for both mean NACH and mean NAIN, which is representative of the high fragmentation of the city's structure, and the weakness of the background network, strongly relying on the foreground to become interconnected. The foreground network also presents low values compared to the other cases. The city of Espoo presents the lowest value of maximum NAIN when compared to the other cities in the set.

Such low values can be explained by the system's configuration, since NACH can present rather low values when measuring systems in areas not yet fully developed or unurbanized. Even though this is not the case of Espoo, the city's two-dimensional configuration might appear similar to that of an unurbanized region, with several discontinuities, for the fragmentation of its territory, mostly caused by the presence of several water bodies and other natural elements.

Nevertheless, the university precinct is in a predominant area, showing rather high values of both NACH and NAIN at a global scale. Thus, the potential of movement in both to- and through travels around the Otaniemi precinct is very high, making it a very accessible destination, but also probably a highly crossed elements in random travels not including it, rendering the university very visible throughout the community, especially those who commute to and from Helsinki.

3.3. Massachusetts Institute of Technology – Cambridge, MA, USA, 1916

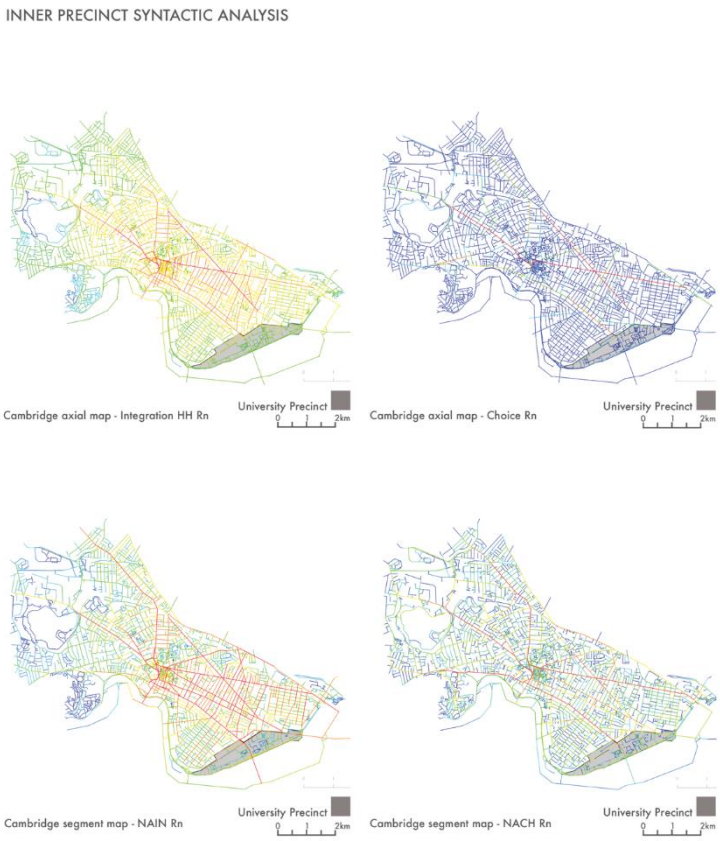

Figure 4 Cambridge, Massachusetts axial and segment maps and MIT Campus Assessment

The axial map of Cambridge shows the integration core in the central area of Harvard Square and Harvard Yard, emphasizing east-west connections towards Boston.

The city presents a mean integration of 0.7607691, showing a minimum value 0.19885656 and a maximum integration of 1.1969923. Therefore, integration in Cambridge has a range of 0.9981357. Streets with integration levels above the 3rd quartile of values, i.e., the 25% more integrated areas, show values of 0.8870931 or higher.

The precinct of MIT, identified in a grey shadow, presents integration values slightly below the average of the city. Even though the precinct is fully inserted within the city's fabric, its location at the edge and by the river contributes for this situation. Nevertheless, if we consider the full metropolitan area of Boston the results will be dramatically different and the axes that encircle and cross MIT's precinct would present much higher integration results. The sum of the axes that are encompassed by the area of the university present an average integration value approximately 0,4 points below the average for the whole system, which places MIT in the 75% more integrated areas.

The analysis of choice reiterates the importance of the integration core, since the streets that present higher integration values also present the highest choice values. Since choice is a good movement predictor, it is arguable that these streets are not only easy to reach but also successful in attracting flows of movement and activities.

The university campus presents lower choice values, in the 2nd quartile of values, although its main access is one of the 25% axes with higher values within the system.

In a broader map, probably the university would attain higher choice values, especially on the segment identified as main access, mainly because of its proximity to the bridges connecting to the centre of Boston. Nevertheless, and considering only the limits of the municipality, the MIT's precinct doesn't show a high probability of being walked through on the way to any other destiny.

Cambridge presents a mean NACH of 0.892, at a global scale (Rn) and a maximum value of 1.564, while the sum of the segments comprised within the MIT precinct, reaches a maximum value of 1.401 and a mean value of 0.858. In terms of NAIN, the city presents a mean value of 1.023 and a maximum of 1.631 while the precinct shows a mean value of 0.975 and a maximum value of 1.470.

Cambridge presents the highest value of mean NACH for a city after Burnaby, which is consistent with a very strong background structure, with few discontinuities, but rather several direct connections, on a grid-like system. Maximum NACH for the city of Cambridge reaches a usual value, and the city presents a strong structure, grounded on the foreground network, which unifies the foreground and acts as main connector to the adjacent municipalities.

MIT presents very similar (even though slightly lower) values of NACH in comparison with the city of Cambridge.

As can be observed in these maps, MIT presents a structure similar of that of a city, with foreground and background networks within the precinct. Its main axes, presenting higher values of both NACH and NAIN are and integrant part of the city's foreground network, presenting strong potential of both to- and through-movement. Its internal structure, consistent with typical background network in the city of Cambridge, acts as a neighbourhood, less intelligible and harder to read than the main axes, and creating more segregated areas, shielding the interior of the university precinct from the outside. In terms of NAIN values, the precinct shows also very similar results to those of the city when analysing the mean value, and a maximum value slightly lower than the city, but still showing a strong difference from the mean values, which emphasizes its dual structure of foreground and background in terms of urban configuration. It is remarkable the proximity in terms of values between the city of Cambridge and MIT, making the precinct a good representation for the city, i.e., an element from which the city's structure can be perceived.

3.4. Yale University – New Haven, CT, USA, 1716

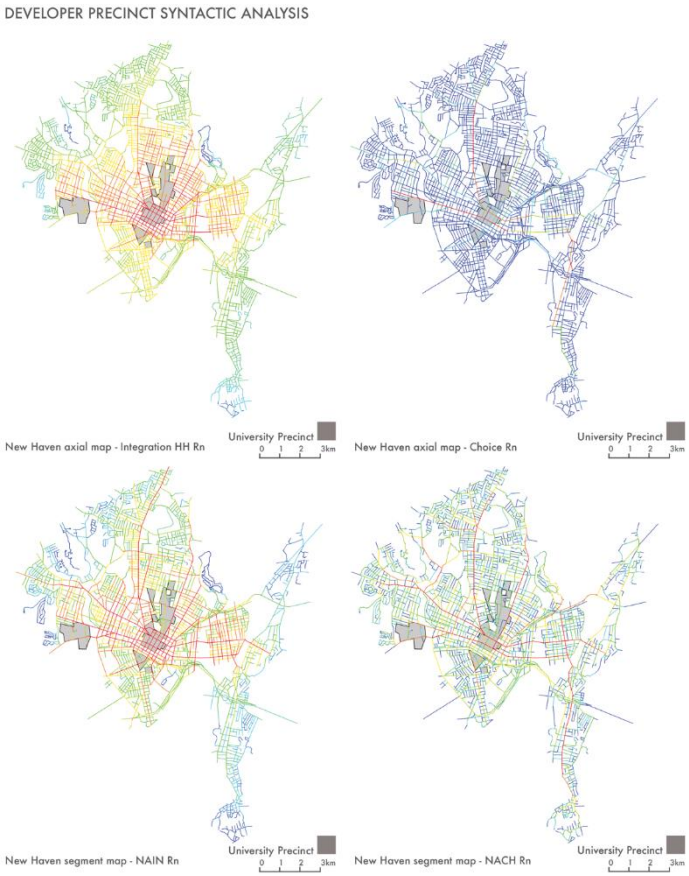

Figure 5 New Haven Axial and Segment Map. Yale University Campus Assessment.

The city of New Haven developed from and because of the university, and that justifies the fact that the university is in the integration core, and alongside the most important expansion axes. In fact, on the city's development, the university and the church occupied the most prominent areas within the city, besides the main yard, in the centre of New Haven.

New Haven presents an integration range of 0.764713849, from a minimum value of 0.13960013 to a maximum of 0.90431398. The mean value for the integration in the city is 0.56135328. The third quartile of values reaches a value of 0.689776334. The sum of the axes that are inscribed and around the university grounds presents an average value of 0.763369499, placing the university axial lines on the integration core, within the 25% more integrated areas.

In terms of choice, a distinction in the axes encircling or connecting to the university premises is perceived, especially in its central areas.

The university premises present a choice value much higher than the average of the city, even above the limit of the 3rd quartile of choice values, placing the university premises within the 25% axes more prone to be used in random travels not originating or terminating in campus.

The main access of the university campus (in the scope of this paper, it was considered College Street as the main access), is one of the segments within the 25% axes with higher choice.

New Haven presents a mean NACH value of 0.820 and a maximum value of 1.594 at a global scale. The precinct of Yale university presents a mean NACH value of 0.999 and a maximum pf 1.594 as well as the city, since the segment with the highest value is located within the university's precinct. As far as NAIN is concerned, the city presents a mean value of 0.857 and a maximum of 1.365, and the university precinct shows a mean value of 1.074 and the same maximum value of the city. Again, the most integrated segment is included within the university precinct. These very high integration levels make the precinct of Yale University an area with very high to-movement potential.

The precinct of Yale university presents the second highest mean NACH value of the set of case studies, much higher than the value presented by the city of New Haven. This places the University precinct in-between background and foreground network, with some of its axes clearly belonging to the latter, and several others being on the transition between both or acting as dual elements, with a strong presence in local life, but also important at a global scale.

It also presents the highest value of NACH among the selected university precincts, making it the one with stronger through-movement potential within this set. It justifies and is justified by the deep relation between university and city, and is consistent with this type of cases, in which university and city are intertwined and develop through one-another. This gives the university the potential to attract a wide range of users, businesses, and activities to its area.

4. Discussion

The results of the axial analysis are summarized in the tables below:

Table 2 Axial analysis summary

City	City axial lines	University axial lines	% of area	University mean integration	Main access integration	University mean choice	Main access choice
Burnaby	3941	147	4	1st quartile	1st quartile	3rd quartile	4th quartile
Espoo	6440	42	0,7	3rd quartile	3rd quartile	2nd quartile	4th quartile
Cambridge	3479	269	8	2nd quartile	3rd quartile	2nd quartile	4th quartile
New Haven	2360	106	4	4th quartile	4th quartile	4th quartile	4th quartile

Table 3 Segment Analysis Summary

City/Campus	MEAN NACH RN	MAX NACH RN	MEAN NAIN RN	MAX NAIN RN
Burnaby	0,911	1,606	1,069	1,652
Simon Fraser University	0,815	1,289	0,571	0,862
Espoo	0,603	1,509	0,452	0,693
Aalto University	0,741	1,209	0,488	0,581
Cambridge	0,892	1,564	1,023	1,631
MIT	0,858	1,401	0,975	1,470
New Haven	0,820	1,594	0,857	1,365
Yale University	0,999	1,594	1,074	1,365

The percentage of axial lines the universities occupy vary substantially, from 0,7% of the total of the city, in the case of Espoo, to 8% of the urban region, in the case of Cambridge. This value alone is not an accountable measure of the university's impact on the area, nevertheless it clearly affects university's visibility and its influence in urban politics and other dynamics, for the fraction it occupies and dominates within the urban territory.

The case of Burnaby – an autonomous precinct – shows very low integration values within the city, but high choice values. This means that the precinct is probably not used by the exterior community as part of their environment, but rather passed by in travels across the Burnaby Mountain. Nevertheless, the university's character of behaving as a "city in a microcosm" (Turner 1984) appears justified in its internal structure, with a foreground and background network of its own when considering smaller radii of analysis.

Espoo – an attached precinct – shows a mean integration value above the average of the city, and low mean choice within the precinct, despite the very high value of choice of its main access. These values are probably influenced by the fragmentation of the urban fabric of the city, since it would be expected that the mean integration of the precinct was lower. The values of choice, however, are easier to explain. Within the precinct, most of the streets do not belong to the shortest path among origins in destinations for the whole system, nevertheless, the main access considered is one of the few axes connecting Espoo to Helsinki, on the East, especially on the southern area of both cities. In a more comprehensive map, probably the values of choice of this region would be much higher.

The whole city presents the lowest values of mean NACH and NAIN, representative of a very weak background structure, and a very fragmented fabric. In this case, the foreground structure becomes more relevant, being used in most travels between different areas, since it assumes a very important connection role among areas. Since the precinct is in an adjacent area to the foreground network, it becomes more visible and likely to be visited in travels. The precinct itself behaves as background network and presents similar dimensions than many of the other fragmented sections of the urban territory, behaving as a unit within the fabric. The fact that the values of mean NACH and NAIN for the precinct are slightly higher than the ones observed when analysing the whole city, is a reflex of the structure of the precinct, as a (less weak than the average of the city) urban unit.

The case of Cambridge – an inner precinct – is distinct than the others. On the one hand, the presence of the university exceeds that of MIT, since Harvard University also occupies an important position within the city. Together, they add up to a very large portion of the urban fabric, and consequentially, of the axial lines. In this particular case, the university becomes extremely relevant for the context where it is inserted, and both universities benefit from the presence and direct competition of the other. However, considering only MIT, both mean integration and mean choice do not present very high levels, probably due to its location at the edge of the city. If we consider greater Boston instead of Cambridge as limits for the urban region, however, results will be very different, and MIT will occupy the centre of the region. Nevertheless, and considering the importance of MIT and its precinct for the cities of Cambridge and Boston, its low integration and choice do not diminish its urban capacity and urban attractiveness, since the precinct can act as an

attractor and a generator of movement. Still, if we consider its topological accessibility solely, and disregard the fact that MIT's premises are landmarks within the city of Cambridge, the precinct is in an area that does not enable its visibility or make it an attractive destination within the surroundings for external users.

Despite its openness and its central location, close to the integration core, MIT presents an urban structure of its own, with a foreground network on the main campus axis, and a background network composing its inner territory. This dual structure, in the case of MIT, contributes for the success of the precinct. On the one hand, the importance of the main axes and their visibility within the system of the city of Cambridge, makes the university highly visible, and an important element in the dynamics of the city, not only for its location, but for the emphasis it places on opening its premises to the community and offering several activities and events for both academic and civil community. On the other hand, the seclusion of the inner areas of the precinct, creates the necessary isolation for the development of some activities. The precinct organizes in a very rational way the most public uses in its most visible area, and the most private in its internal areas, that are characteristically difficult to navigate and less intelligible. In opposition to the situation observed in Espoo, its inner structure does not behave as background network because the system is fragmented or discontinuous. It does such for the configuration of its inner structure, purposely designed.

The case of New Haven – a developer precinct – is rather different than the previously described. In this case, the university coincides with the integration core, it is the centre of the urban settlement both in terms of closeness and betweeness, becoming a very attractive place, whether just to cross by on any travel, for the accessibility it provides, or becoming a destination just for its configurational properties.

The case of the city of New Haven, representing the developer precincts, shows the particularity of the university precinct occupying the areas located in the integration core, and also being a part of simultaneously the foreground and the background network. This urban behaviour can be extremely beneficial for the university, for it creates spaces with different characters, that can be used for different purposes. The most visible, with highest through-movement potential, can be a factor of promoting the university, making it highly visible for the exterior community, and creating a character of openness towards the city. The most secluded areas can be used for more private functions, such as residences and dorms, or high security research laboratories. Considering that this type of universities includes all necessary living functions within its premises, it can be an enabler for urban regeneration, since it guarantees the presence of people in the city centre at all times of the day. Table 4 presents a summary of the analysis giving emphasis to the potential movement each type of university precinct has.

Table 4 Syntactic analysis summary

PRECINCT TYPE	INTEGRATION	CHOICE	NAIN	NACH	NETWORK	POTENTIAL OF MOVEMENT
AUTONOMOUS PRECINCT	Very Low	High	Very Low	Low	Background	Low to- and through-movement potential
ATTACHED PRECINCT	Low	Low	Low	Low	Background	Low to- and through-movement potential
INNER PRECINCt	Low	Low	Low	High	Background, connected to foreground	High through- movement potential
DEVELOPER PRECINCT	Very high	Very high	Very high	Very high	Foreground and background	High to- and through-movement potential

5. Conclusions

Most of the university precincts assessed are somehow rooted and connected to a city, even when located in secluded locations. Even though, in general, they show low integration values, that reflect on their ability to become highly visible destinations and attraction elements within the urban fabric, they also show higher maximum choice values (the maximum choice value within the campus is usually its main access) than the average of the cities where they are inserted. This points towards a tendency for university campuses that host all functions consentaneous with the constant presence of people to be highly visible in random movement, to be places that can be seen while navigating through cities, but not becoming the targets for travels.

So, if we observe a trend towards achieving a certain degree of seclusion, protecting the academic environment from the city, we can also note a contrasting option of becoming visible to the community in general. These placement features can be an asset used by universities to position themselves as active players in the urban environment, while benefitting from the privacy granted to them by the low integration values.

In a context where universities must reach out to several stakeholders, these characteristics might be very beneficial, helping to create and highlight a posture of openness towards the urban environment that fosters the creation of links and connections, bridging the “academic divide”.

More studies should be developed to reinforce or verify these premises, but space syntax has proven a valuable tool to provide insights into key aspects, such as the need to enhance visibility and improve integration, according to the Universities’ strategic plans and positioning goals.

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Resume

Luísa Cannas da Silva is a licensed architect and holds a PhD in architecture. Her research interests include learning spaces and workspaces with a particular focus on space use analysis, mainly recurring to space syntax methodologies. She is a science communicator who has designed science exhibitions and learning materials, both in university and museum contexts. She currently works as a Learning and Experience Designer for Executive Education at Nova School of Business and Economics.

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Linking space syntax and cluster analysis to design and plan temporary housing neighborhoods: A taxonomy of sites in Norcia

Camilla Pezzica*
Valerio Cutini**

Abstract

Building Back Better in disaster recovery and reconstruction requires the adoption of integrated and context-sensitive approaches to the design and planning of Temporary Housing (TH) sites. However, there is a lack of methods for enabling successful outcomes in housing assistance provision, e.g. via a quantitative evaluation of the social-spatial qualities of the sites, and supporting the negotiation of urban design changes and the development of a coherent end-of-life plan. The paper aims to uncover formal analogies between different TH sites' layouts by linking Space Syntax and Clustering analysis within an unsupervised machine-learning pipeline, which can consider a virtually unlimited number of configurational qualities and how they vary across different scales. The potential benefits of the proposal are illustrated through its application to the study of 20 TH sites built in Norcia after the 2016-2017 Central Italy earthquakes. The results indicate the proposal enables distinguishing different types of spatial arrangements according to local strategic priorities and suggest the opportunity to extend the study in the future to set up rules of thumb for the design of site layout options. The paper ultimately aims to equip local administrations and contracted professionals with a much-needed tool to develop and rapidly audit proposals for temporary neighbourhoods oriented at enhancing the resilience of disaster-affected towns both in the medium and in the long term.

Keywords: temporary housing, space syntax, cluster analysis, neighbourhood design, disaster recovery

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1. Introduction

During the last decades, the incidence of disasters that stem from natural hazards has increased considerably (EM-DAT [no date]), threatening the housing security of the many people currently living in areas suffering from inherent socioeconomic and spatial vulnerabilities. Following disasters, damage to housing accounts for 40% to 90% of all damage to private properties, showing an increase at a global level from 1990 onwards (Wahba et al. 2018). Experts therefore advocate a closer integration of urban contingencies in urban planning (Borsekova and Nijkamp 2019) and agree on the need to advance Disaster Risk Reduction (DRR) policies and practices, including via Building Back Better (BBB) in disaster recovery and reconstruction (Kennedy et al. 2008).

A growing awareness of the scale of the problem and increasing concern about "humanitarian aftershocks" increasing pre-existing vulnerabilities (Alexander 1989; Davis and Alexander 2015; Contreras et al. 2017) have recently pushed forward research in the area of post-disaster housing assistance, whose volume of publications is rapidly expanding in multiple directions (Yi and Yang 2014). In particular, operational research studies have focused on developing Decision Support Systems for selecting the location of the TH sites (El-Anwar and Chen 2013; Hosseini et al. 2018) or the design of the TH units (Hosseini et al. 2016), often relying on multi-criteria optimisation methods (El-Anwar et al. 2010; El-Anwar and Chen 2014; Rakes et al. 2014; Perrucci and Baroud 2018). However, research on analytical methods supporting the spatial design of socially adequate temporary housing (TH) neighborhoods which add to the resilience of disaster-affected settlements, and enabling the assessment of different site layouts, is still in its infancy.

In practice, the problem of designing temporary neighborhoods is addressed mainly in qualitative terms. Within the Italian context, which represents the background of the empirical research presented in this paper, spatial layouts of TH are broadly distinguished among three archetypical arrangements, namely detached houses, courtyard or terraced housing arrangements (Figure 1), including possible hybrid solutions, with no clear indication of social and spatial performance requirements (CONSIP & NDCP 2014). Strategic and managerial guidelines for the design and planning of TH, published after the 2016-2017 Central Italy earthquakes (i.e., the lastest major earthquake disaster in Italy to date), contain only generic inputs for designing their spatial layouts. In a nutshell, they recommend that TH sites are built as close as possible to the disaster-affected areas, compact and equipped with all the necessary services and infrastructure, including connections to the permanent road network (NDCP 2016; Presidenza del Consiglio dei Ministri 2017). However these requirements (as well as the permanent nature of the reinforced concrete foundations used in Central Italy) imply a change of land use which contradicts the character of impermanence of TH plans. Furthermore, the lack of clarity and guidance regarding the design of temporary neighborhoods has in the recent past fuelled conflicts between local stakeholders and external decision-makers, e.g., over the implementation of detached TH arrangement (Oggioni et al. 2019).

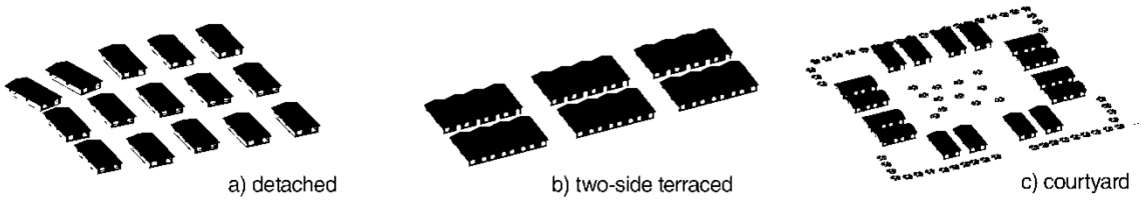

Figure 1 TH sites' typologies. Image adapted from (CONSIP & NDCP 2014).

Albeit overlooked in current technical specifications, TH layouts are important determinant of the success of TH assistance interventions. On the one hand, they influence the street network patters, contributing to the accessibility of TH sites. On the other hand, they determine different opportunities for human-to-human face-to-face interaction (or avoidance). Additionally, since TH

neighborhoods can hardly be considered temporary, they should be designed and planned in a way that is consistent with the configurational qualities of local social-spatial patterns to ensure their long-term social, cultural, economic and environmental (in terms of resources' consumption) sustainability. This appears crucial when intervening on "inner" mountainous, and thus fragile, territories subjected to shrinking (Rotondo et al. 2020).

This paper seeks to move steps towards the evidence-based management of disaster-stricken cities by contributing to the construction of a broader Computation Planning Support System (CPSS), which adopts an integrated and context-sensitive approach to the design and planning of Temporary Housing (TH) sites. To this end it proposes a method designed to find natural groupings among hybrid layout arrangements - which defy the typological description of the three pure archetypical TH sites' arrangements (i.e., detached, terraced, courtyard) - without a priori expectations regarding the result. In this sense its application is exploratory in nature and exploits the explanatory power of different unsupervised machine learning methods to yield useful insights. The objective is to visualise relationships in multidimensional datasets, besides creating opportunities to create higher-level attributes from existing ones, to be used to establish urban design targets and inform design moves.

This paper links Space Syntax and Cluster analysis to enable the statistical learning of configurational patterns relevant to the design and planning of TH neighbourhoods. Both official and open data are used to feed different configurational analysis models, whose outputs are then aggregated and further analysed via machine learning using three different algorithms. The proposal and its potential benefits are illustrated through its application to the study of 20 TH sites built in Norcia after the 2016-2017 Central Italy earthquakes. The paper is organised as follows. The theoretical background is presented in Section 2. Section 3 explains the methodology and results are then illustrated in Section 4. The discussion and conclusions can be found in Sections 5 and 6, respectively.

2. Exploring Spatial Patterns of TH Layouts

Following a visual tradition inaugurated by the 1748 map of Rome by Giambattista Nolli, morphological differences in patterns of urbanisation can be qualitatively observed using figure-ground maps, see for instance the TH sites of Norcia in Figure 2. The image shows that most of the neighbourhood designs for Norcia's TH sites are variations of simple terraced arrangements, sometimes interrupted by small pockets. The maps enable making some simple observations based on the coarseness, griddedness, and permeability of their spatial layouts and can help convey complicated spatial concepts (e.g., about the different spatial order of planned and organically grown settlements) to different publics (Boeing 2019a). However, these representations cannot offer a quantitative indication of how spatial qualities vary within TH neighbourhoods and how these are related at a broader scale, determining hierarchies in movement and accessibility patterns in cities. To grasp more complex and subtle functional relationships, we need robust spatial analysis methods grounded in theory and the support of machine learning to deal with multidimensionality.

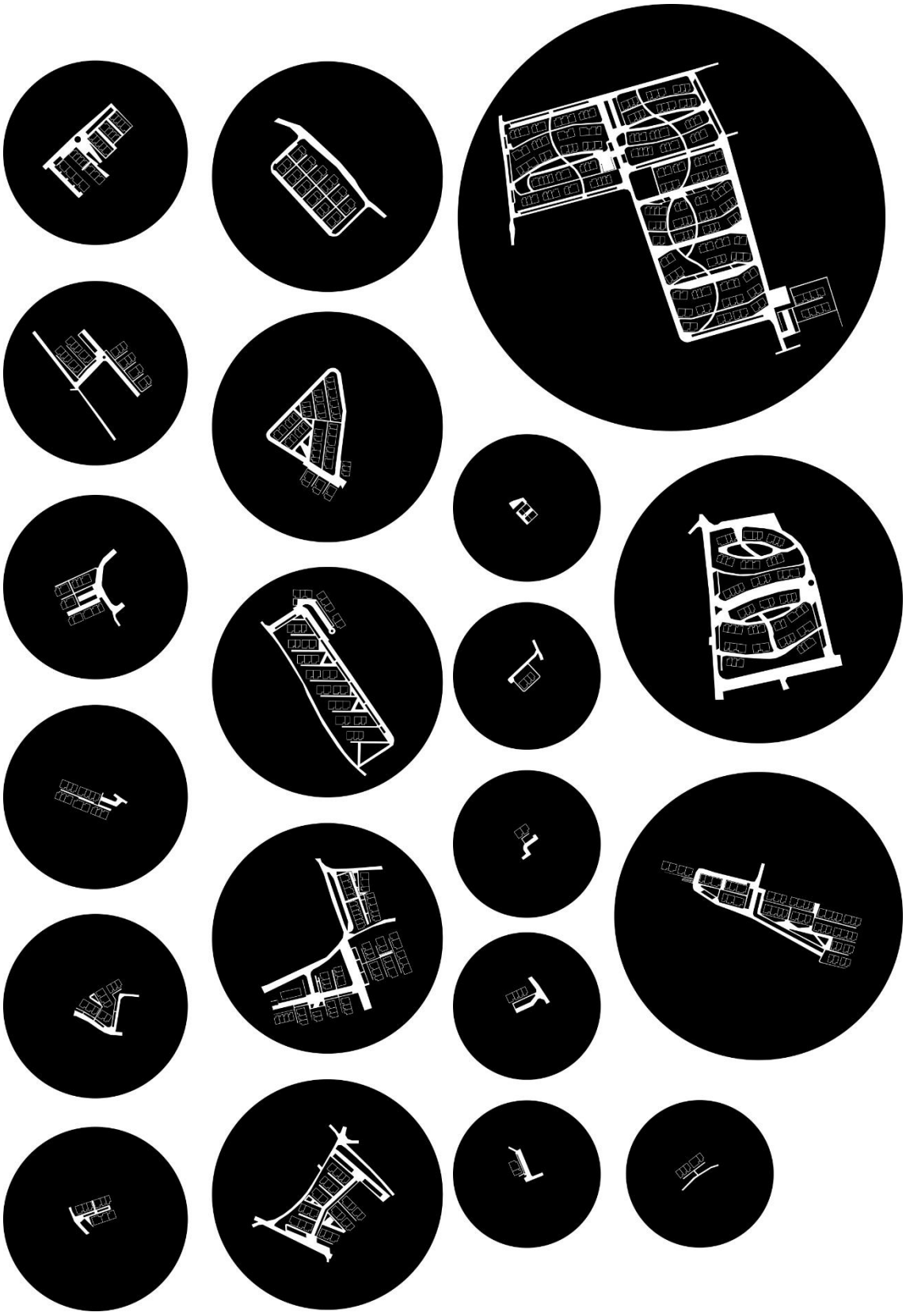

Figure 2 Norcia 20 TH sites layouts. The space considered in the spatial permeability analysis is represented in white.

This research adopts the configurational analysis approach (Hillier and Hanson 1984) and statistical learning (Hastie et al. 2009) to study the spatial permeability patterns of built examples of TH sites layouts. This approach is essentially grounded in two main conceptual pillars. On one hand, the assumption of a configurational point of view involves focusing on the relationships of

the spatial elements rather than on their intrinsic geometric or morphologic features: "human space is not just about the properties of individual spaces, but about the inter-relations between the many spaces that make up the spatial layout of a building or a city" (Hillier, 2005, p. 98). On the other hand, the assumption of a city as a socio-spatial system, in which the blocks and buildings shape the space of interaction between activities and individual behaviour, and the intrinsic integration and complementarity of spatial properties and social aspects are what makes the configurational parameters resulting from the analysis of an urban settlement suitable for reproducing its potential to match both the expected positional values of the places and the behavioural patterns of the located community. As Hillier put it, we should think of space "not as the background to human activity, but as an intrinsic aspect of everything humans do" (Hillier 2005, p.98).

When referred, as in this case, to temporary housing, two fundamental issues are therefore concretely to be explored: the first, more obvious and usually considered, concerns the spatial relationships of the TH settlement with respect to the pre-existing city, so as to reproduce the positional values of the settlement and the hierarchical relationships in terms of connection, integration and segregation; the second is subtler and less explored, as it refers to the intrinsic configurational properties of the TH settlement, to the spatial organization of its internal geography and to the behavioural pattern it prefigures. Precisely, to this end, the Space Syntax approach combines multiple configurational indicators suitable to statistically appreciate the degree of similarity of different TH layouts, considering how well these reproduce the original qualities of the disaster-affected town. In other words, the proposal focuses on the multidimensional learning of configurational qualities that contribute to define the spatial identity of different temporary neighbourhoods built after disasters.

The rationale behind this proposal is that statistical algorithms using weak clues can effectively inform TH-related decisions because most post-disaster decision-making situations tend to be noisy, if not wicked (i.e. teaching experts the wrong lessons), (Hogarth et al. 2015). This means that experts' intuitions are likely to be unreliable in this context since the environment is not regular enough to be predictable and regularities cannot be learned through prolonged practice (Kahneman 2011).

3. Materials and Methods

This research is the natural continuation of a set of previous investigations (Pezzica et al. 2020; Chioni et al. 2021; Pezzica et al. 2021), which illustrated the potential of adopting Space Syntax analysis to generate scenarios useful to assess the socio-spatial impact of TH sites. At a methodological level, this research is connected to the latter of these, focused on the urban scale, in which Space Syntax and Cluster analysis were used to analyse hidden trade-offs between properties of street network resilience and efficiency following to the construction of TH sites (Pezzica et al. 2021). Moving the focus to the neighbourhood scale, this research illustrates how a similar method can be used to classify in an unsupervised way different TH layouts based on a given set of configurational qualities, which contribute to determine their socio-spatial performance at different scales.

The 20 TH sites built in Norcia after the 2016-2017 Central Italy earthquakes were chosen as the testbed for the analysis because they present a suitable variety of sizes, morphologies and locations in the municipal street network, and Norcia hosts the highest number of TH units (639, as of 2019) as well as more TH sites than most municipalities in the Central Italy seismic crater. This study considers the spatial permeability of TH sites as well as their relationship with the "destroyed" city (Ruggiero 2018), whose transition post-disaster is affected by the construction of the TH sites. Although a specific selection of configurational indices is used to this end in this study, the method supports the choice of a virtually unlimited number of different combinations as required by different practical applications.

As shown in Figure 3, this study is performed in three steps:

- Space syntax analysis (ASA + VGA) as described in Section 3.1.
- Calculation of summative configurational metrics, where required.
- Cluster analysis (HC, K-means and FCM) as described in Section 3.2.

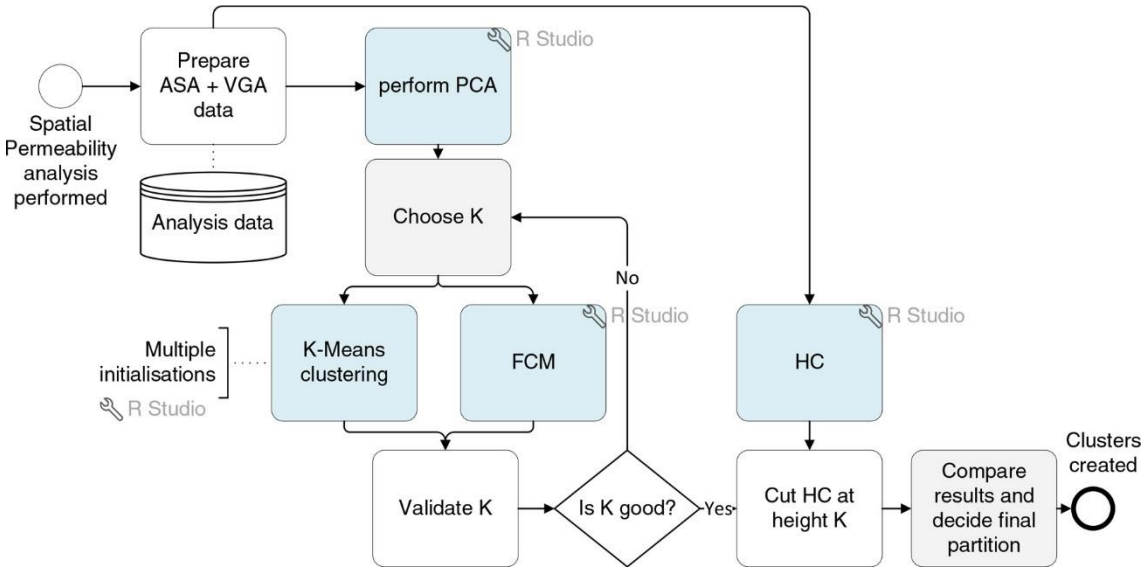

Figure 3 Cluster analysis methodology, including HC, K-Means and FCM.

3.1. Space Syntax analysis

To prepare the data for the Cluster analysis, first, a Space Syntax Visual Graph Analysis (VGA), (Turner et al. 2001), and an Angular Segment Analysis (ASA), (Turner 2007), are performed to extract the configurational indices which describe the levels of global and local accessibility of the TH sites as well as the morphologic characteristics of the TH sites' layouts, including their visual complexity, convexity, control, connectivity etc. In the end a 28-dimensional description of each TH site layout (Annex A) is obtained by calculating the median (i.e., the middle value of the value distribution taken in sorted order) and the Gini coefficients (Gini 1910), of all chosen configurational indices. This enriches their description as shown in the Principal Component Analysis (PCA) plot in Figure 4, which helps exploring data visually through a low-dimensional representation which captures the directions in which it has maximal variance (James et al. 2013). After joining all summative metric in one table, these were then scaled (using a data standardisation method known as Z-score normalisation) and used as inputs to the Cluster analysis.

In this paper, the ASA outputs were extracted from Norcia's street network analysis by clipping the map with the boundary polygons of all the TH sites in a GIS environment. Next, each segment within the boundary was assigned an attribute with the name of the corresponding TH neighbourhood. This allowed grouping the data by site (in R Studio, RStudio Team 2015) and calculating for each settlement the corresponding summative metrics. When a mean value should normally be considered (e.g., street segment length, connectivity), for consistency, the median of the distribution was calculated instead.

The VGA was performed separately for each layout (using a 1m grid), so results could be compressed immediately for each site and then joined with those from the ASA within R studio. Coherently with a view of TH sites as integral parts of a recovering town, this exploration focuses on the experience of a generic visitor moving around a TH settlement. Therefore, in addition to the footprints of the TH units, their immediate premises (which in Central Italy have been often

protected by a fence by their inhabitants), the green areas, and the parking lots, were excluded from the VGA analysis. These features create an urban design interface at the neighbourhood scale, which effectively defines user groups and generates patterns of encounter or avoidance among residents, and between them and external visitors. Hence, albeit their consideration could represent an interesting starting point for future studies, this analysis falls out of the scope of this investigation.

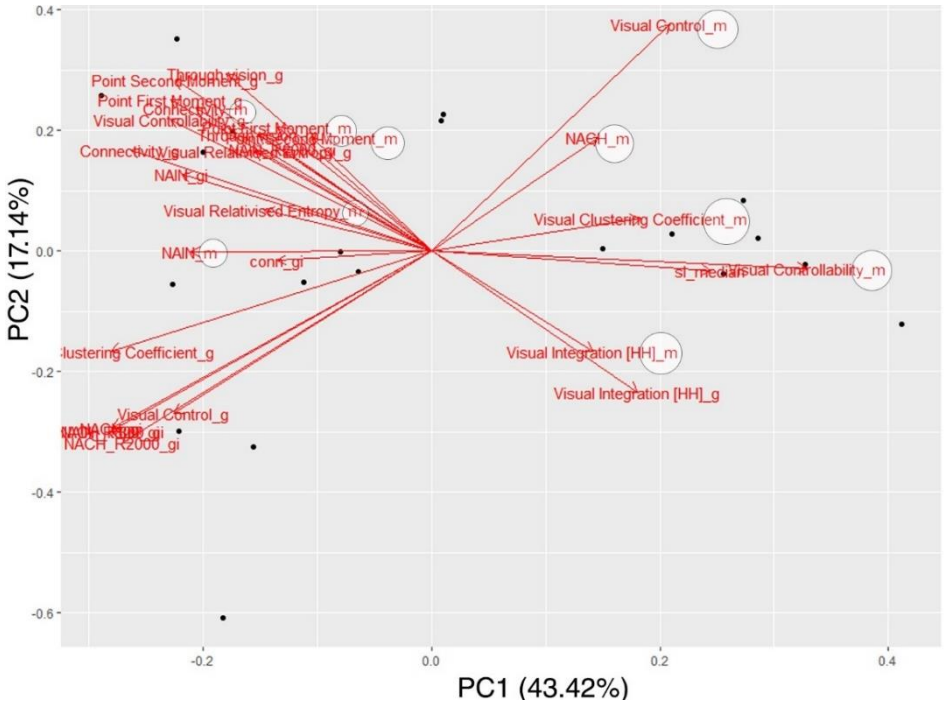

Figure 4 PCA (before K-means analysis), Median (suffix _m) and Gini coefficient (suffix_g).

3.2. Cluster analysis

Cluster analysis has been studied since the 1960s and clustering algorithms are numerous. They can be either hierarchical, which divide the pattern in an iterative way, or based on partitioning, which assign data to a number (K) of clusters using an optimisation function (Saxena et al. 2017). As illustrated in Figure 3, this study adopts and cross-compares results from three clustering algorithms: (i) Hierarchical Clustering (HC); (ii) K-means clustering; and the more sophisticated Fuzzy C-Means (FCM) clustering method (also known as soft K-means).

HC is an agglomerative clustering method which creates a hierarchical structure that can be cut at a certain height after the analysis, following a bottom-up process which starts from assigning a cluster to each datapoint. Starting from the bottom and moving up in the hierarchy, these are recursively paired at each level, by selecting the smallest intergroup dissimilarity. Starting from n elements, the algorithm will always define $n-1$ levels, each representing a specific grouping of the datapoints into disjoint clusters of observations (Hastie et al. 2009). HC plots show these groupings in an ordered sequence, but their interpretation is left to the urban analyst, who must decide which level (if any) represents an ideal cut of the output rooted binary tree, also known as dendrogram. This algorithm has been used in urban analysis research studies (Crucitti et al. 2006; Louf and Barthelemy 2014; Boeing 2019b) to synchronously compare different urban street networks. Here, the HC dendrogram is used to visualise the taxonomic relationships between different layouts of TH sites in Norcia.

Differently from HC, K-means (Pakhira 2014) and FCM are partitioning methods, which provide different outputs according to the choice made for (K). First described by (MacQueen 1967), K-

means clustering is a simple and widely known iterative descent algorithm, which assigns each datapoint to one unique cluster. It works with quantitative data and uses the squared Euclidean distance as a dissimilarity measure for the grouping. The process converges to a solution rapidly, without the need of sophisticated termination criteria (Kubat 2017). The fuzzy K-means clustering version first developed by (Dunn 1973), assigns to each data point a membership coefficient (

Table1), which indicates the level of fit of each datapoint with each cluster. Therefore, FCM makes probabilistic rather than deterministic assignment of TH layouts to cluster centres and coincides with K-Means if membership coefficients become 0 and 1. In fuzzy methods, if a preferential assignment cannot be made, the same datapoint can have membership in more than one cluster; what makes FCM less prone to create uninteresting locally optimal data partitions. As in the case of HC, K-means and FCM require an appropriate attribute scaling as part of the data preparation to prevent distorting the measured distances between attribute vectors. Moreover, when deploying K-means and FCM methods, attention should be paid to the initialisation of the partition.

Importantly, in both K-Means and FCM, K (i.e., the number of clusters) needs to be inputted. Since in this application the goal of the Cluster analysis goal is to provide a descriptive statistic for gauging to which extent the analysed TH sites fall into natural distinct groupings, K is initially unknown and needs to be estimated from the data. Therefore, a statistical validation step is added to both (not to the HC as this does not affect the clustering result). This is essentially an assessment of how good a partition is based on the calculation of one or more internal validity indices among the many proposed in the scientific literature. The evaluation involves assessing the quality of clusters as well as their optimal number. To this end, for the K-means it is used the NbClust package for R (Charrad et al. 2014), which makes readily available and directly comparable several indices by using a single function call. Specifically, this study used the silhouette (Kaufman and Rousseeuw 1990) and gap statistic (Tibshirani et al. 2001) methods. Additionally, since most of these indices work with hard memberships and cannot be used for fuzzy clustering applications within R, the results of FCM are evaluated using an additional four internal validity indices, which are available in the “fclust” package for R by (Ferraro and Giordani 2015). These are the: Fuzzy Silhouette Index (F.Sil., the higher the better); Modified Partition Coefficient (MPC, the higher the better in a scale from 0 to 1); Partition Coefficient (PC, the higher the better); and Partition Entropy (PE, the lower the better).

After running the K-means and FCM algorithms for K= 2, 3, 4, 5, 6 and 7 it was clear that the best partition from a statistical standpoint could be found for K=2 (as shown in the Silhouette plot in the bottom-right corner of Figure 5). However, the results for K=3 are presented in this paper as these are more interesting to discuss, obtained acceptable clustering validation results and, in all cases, are consistent with the K=2 partition although, in general, when the cluster membership changes, K-means and FCM groupings can change in arbitrary ways (Hastie et al. 2009). This behaviour differs from that of HC, which naturally retains all the information about higher- and lower- level associations. Finally, once the value of K was decided, the HC, K-means and FCM clustering methods were used on the same dataset to identify a final clustering result, robust to algorithm and metrics’ variations. In case of ambiguity a layout was assigned to the cluster receiving more “votes” and considering the membership values suggested by the FCM.

In this paper, the level of inter-cluster separation is measured using the complete linkage method, which determines the similarity of two groups by calculating the maximum (Euclidean) distance between any element of one cluster to any element of the other. The use of the Euclidean distance for this calculation, is what requires performing the data rescaling step before the analysis, to re-centre the values of the summative metrics (mean 0) to prevent metrics with higher weights from skewing the Cluster analysis results.

4. Results

This section is divided in two parts: the first (Section 4.1) presents the results of the analysis considering the TH sites layouts in isolation from the rest; the second (Section 4.2) links the results of the analysis to the planning regulations of Norcia and to the morphology of the destroyed city.

4.1. Taxonomy of TH sites in Norcia

As shown in Figures 5-7, which illustrate the results obtained from the K-means, FCM and HC analysis respectively, the three clustering algorithms assigned 18/20 TH sites unanimously to either Clusters 1, 2 or 3. Only in two cases, namely the TH sites of Montedoro and Valcaldara, one of the three methods assigned the layout to Cluster 1 instead of 3, or vice versa. The indecision regarding the assignments of these two TH sites to one or the other cluster is reflected in the FCM probabilistic values since their relative memberships to clusters 1 and 3 appear somehow comparable (Table 1). This could have been expected if we consider that Clusters 1 and 3 are close one to another whereas Cluster 2 appears more clearly separated from them. Indeed, as mirrored in Figure 7, for K=2 the analysis groups together Clusters 3 and 1. Hence, instead of than "clustering", we could use the term "segmentation" to describe more accurately the intra-cluster division obtained for K=3, albeit the former is used in the text for matters of simplicity. As described in Section 3.2, in the end, the assignment of these two TH sites was decided based on the clustering result obtained from two out of three algorithms. The final grouping rsults are shown in Figures 8 and 9.

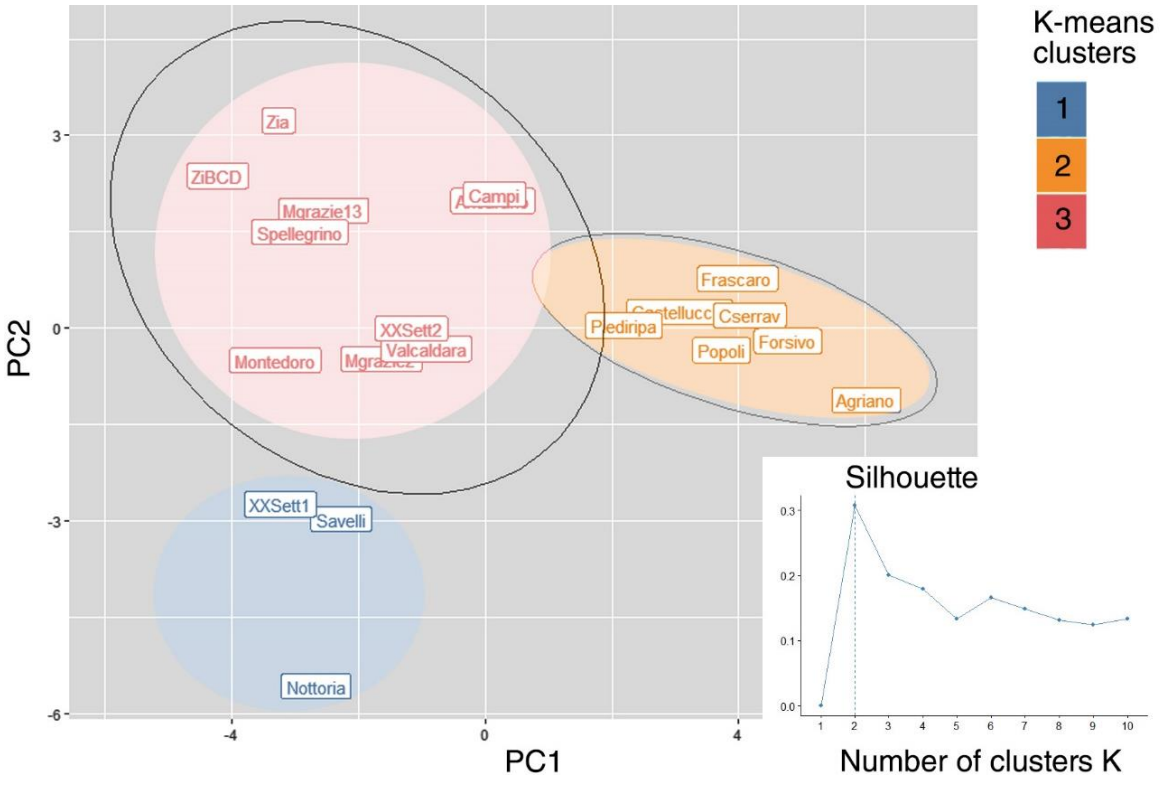

Figure 5 K-means analysis (K=3). In the corner the plot used to evaluate the choice of K

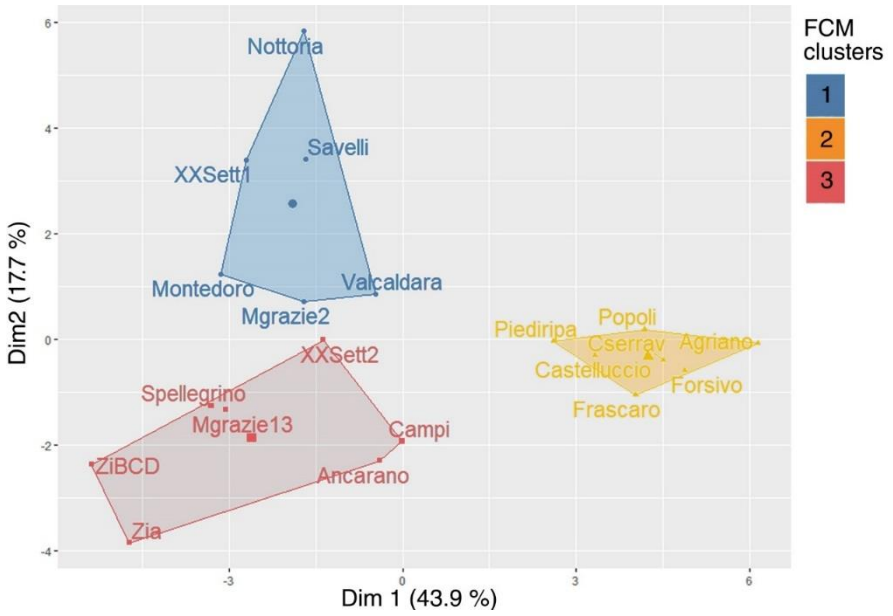

Figure 6 FCM (K=3)

Table 1 FCM membership coefficients.

	Cluster 1	**Cluster 2**	**Cluster 3**
Agriano	0.218573678319838	0.55314515823891	0.228281163441252
Ancarano	0.290312974173666	0.250939380359542	0.458747645466792
Campi	0.267222331532113	0.234272813177824	0.498504855290064
Castelluccio	0.214812140020607	0.543453960753009	0.241733899226384
Cserrav	0.102787683096174	0.783658313816487	0.113554003087338
Forsivo	0.206411131219699	0.570784809862456	0.222804058917845
Frascaro	0.193035013107517	0.59484784626083	0.212117140631653
Mgrazie13	0.339549669205141	0.121906827244888	0.538543503549971
Mgrazie2	0.480577868235047	0.110119566044045	0.409302565720907
Montedoro	**0.590493257268913**	0.0620264623751992	**0.347480280355888**
Nottoria	0.519033887686083	0.182414841433934	0.298551270879983
Piediripa	0.20125276942297	0.570414702915743	0.228332527661287
Popoli	0.144371026392816	0.702315273864646	0.153313699742538
Savelli	0.616280742367203	0.113795539817464	0.269923717815333
Spellegrino	0.334875457103565	0.0807471287339077	0.584377414162527
Valcaldara	**0.42823958287465**	0.144243916442863	**0.427516500682486**
XXSett1	0.621475308185735	0.0992853821318792	0.279239309682386
XXSett2	0.424598063725587	0.0667541268707096	0.508647809403703
Zia	0.340328977324271	0.154777096175658	0.504893926500072
ZiBCD	0.366799454594893	0.110467810280798	0.522732735124309

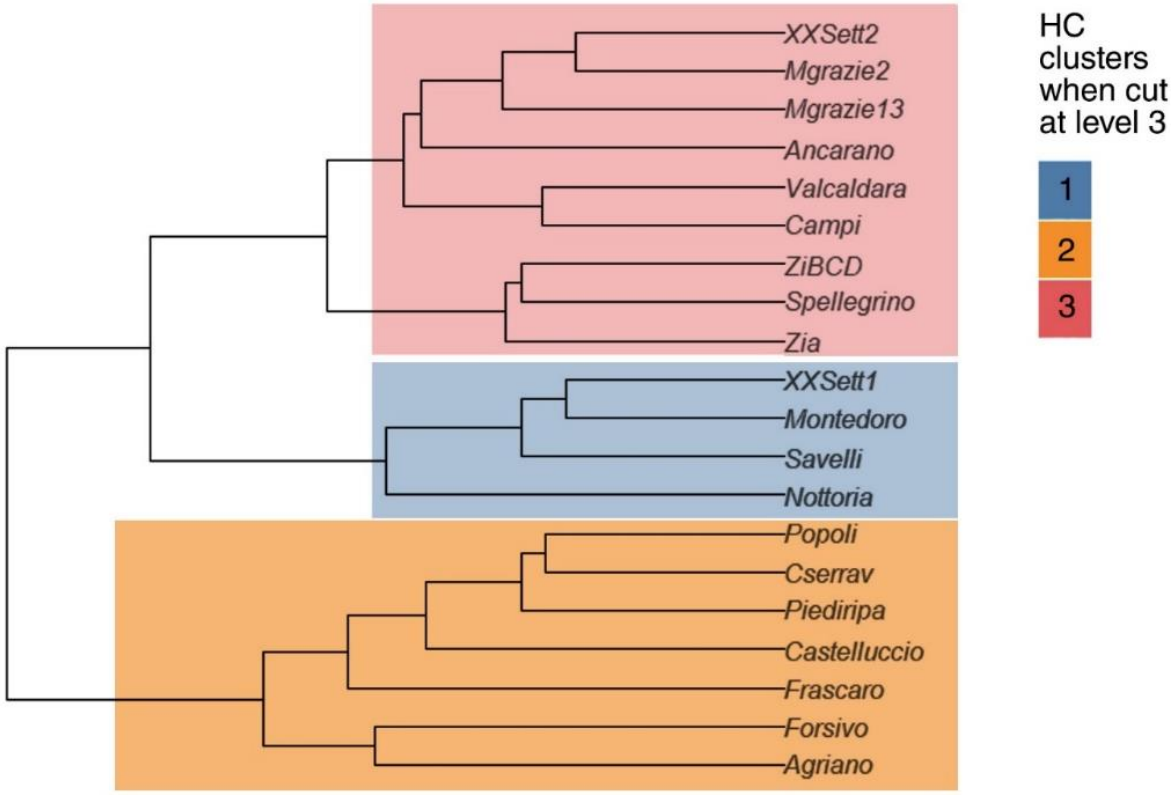

Figure 7 HC-derived dendrogram. The colours show the result when the tree is cut at K=3.

At a first glance at Figure 9, it may appear that TH layouts have been grouped according to the relative dimension of the sites. However, through a more careful observation, it is possible to notice that this correspondence is not always there. For instance, Frascaro is assigned to Cluster 2 although it is medium-sized. Nottoria is assigned to Cluster 1, and Valcaldara is assigned to Cluster 3, albeit both are small. Thus, although the size certainly constrains the spatial arrangement possibilities, the outcome indicates that the division is based on more subtle characteristics. To facilitate the interpretation of these results, the clusters were also represented using the same three colours within a ®Tableau sharable and interactive dashboard, of which Figure 8 is a print screen. In Figure 8, the dimension of the circles representing the clusters is set to be directly proportional to the number of TH units in each settlement. Moreover, geolocating the clusters enables displaying their relative distance to Norcia city centre, as well as the topography of the area in which they are built. The image shows that neither distance nor dimensions can fully explain the logic of the partition, which seems a good indication of the goodness of the approach and of the potential usefulness of the proposed method for the multidimensional analysis of complex spatial patterns.

Thus, an alternative reading of results is proposed, which, coherently with the analysed data, is more focused on the morphology of the temporary neighbourhoods. Figure 9 shows that the TH sites in Cluster 3 have more complex layouts, with gradual angular changes, loops, varying TH units' orientations, and hierarchical width of paths, including some outstanding larger open spaces. Although the TH units are arranged in rows, they have some hybrid qualities which resemble those of courtyard arrangements and seem to offer a more sophisticated spatial permeability interface. Albeit qualitatively close to those in Cluster 3, the sites belonging to Cluster 1 present harsh 90 degrees turns and lack variations in the way their TH units are arranged. When present, open spaces are concentrated at the centre and present a compact boundary. Finally, Cluster 2 includes quite simple layout arrangements, which can be reduced a few convex elements with an elongated shape.

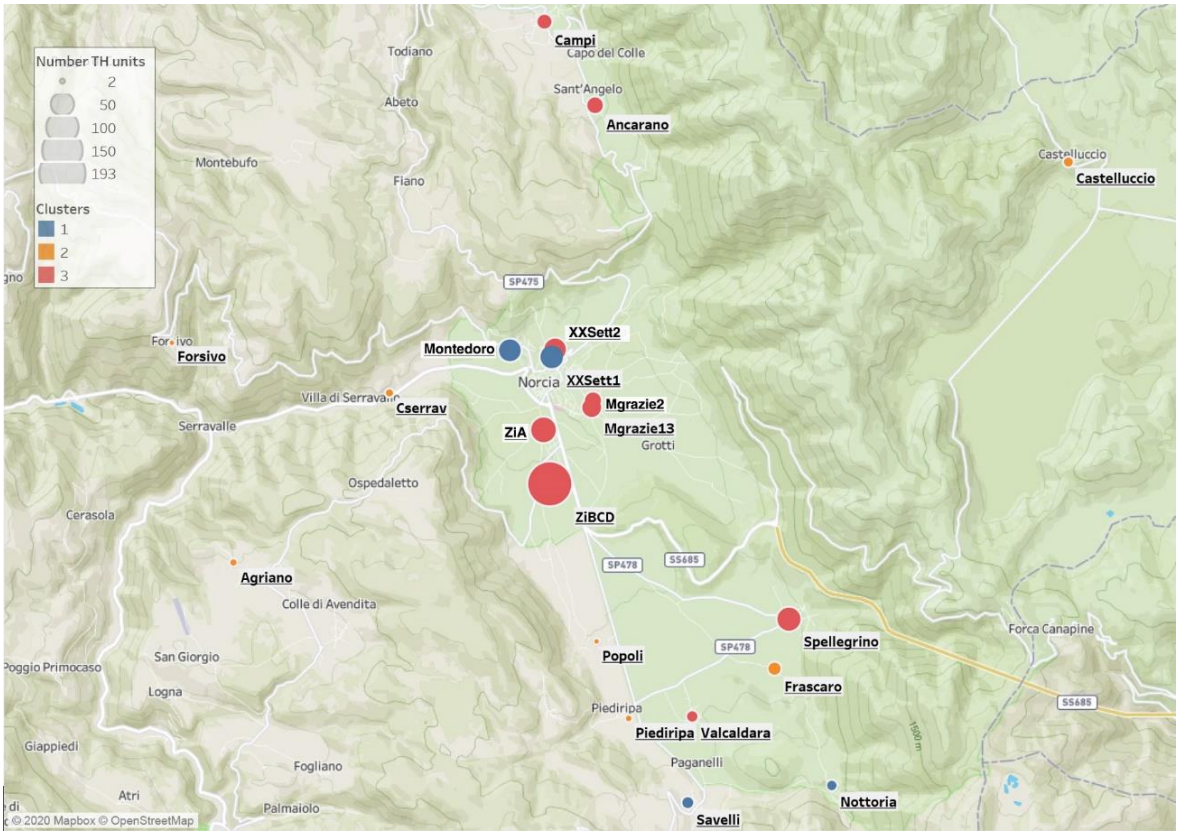

Figure 8 Final clustering result of Norcia TH sites transferred on a ®Tableau dashboard.

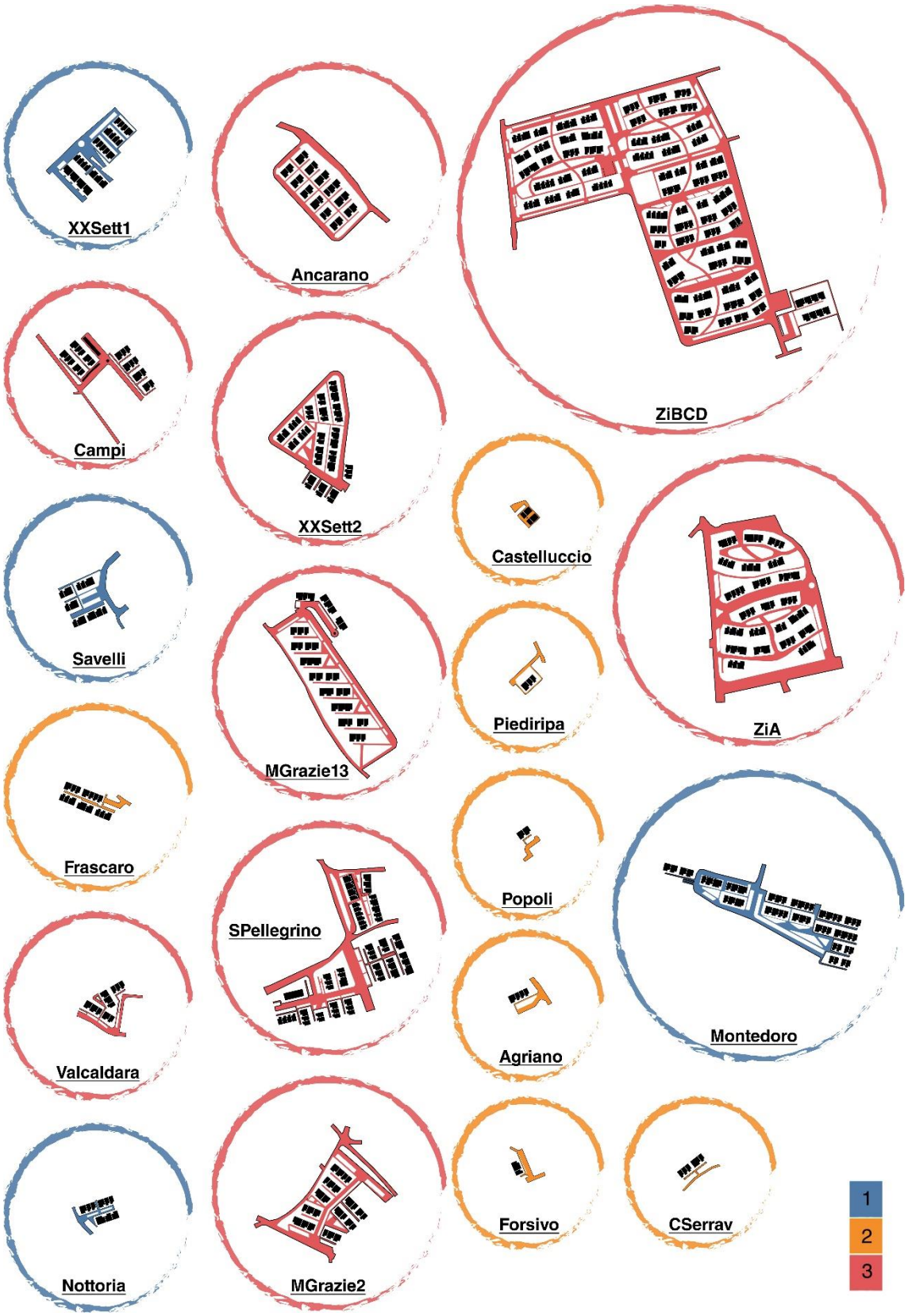

Figure 9 Norcia TH sites layouts summative clustering result K=3.

Finer grain differences, such as those between Castelluccio, Piediripa and Agriano (which present one looping spatial element) and the remaining sites of Cluster 2, can be appreciated only for bigger values of K (see for instance Figure 10, in the right corner). At this level of segmentation, it is possible to observe a difference between Montedoro and the other TH sites in Cluster 1. In fact,

the FCM groups it together with TH sites belonging to cluster 3 at K=3, which here is further divided in three subgroups. However, the clustering validation indices indicate that these intra-cluster differences are less relevant than at level 3, and thus possibly not worth considering. In fact, F.Sil. at K=7 evaluates at 0.20 (down from 0.42 at K=3), PE results 1.37 (up from 0.94), PC 0.39 (down from 0.44) and MPC 0.28 (up from 0.15). Furthermore, limiting their number allows making considerations relevant to the evaluation of real-world planning outputs and layout design guidance drafting. Additionally, referring to a smaller number of clusters is more practical if the objective is to expand the analysis to a larger number of examples. This seems a path worth pursuing in future research for achieving a more comprehensive taxonomy of TH sites' layouts in Italy, considering that Norcia's layouts are mostly hybrid row housing arrangements.

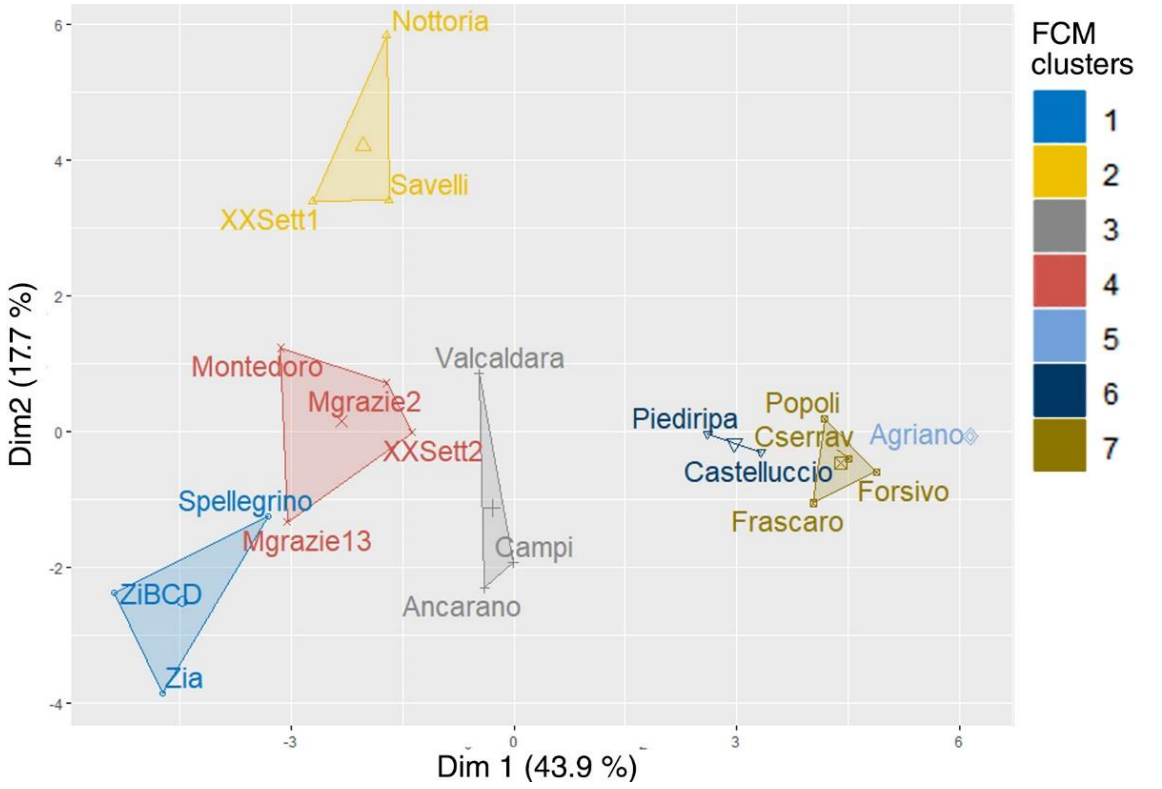

Figure 10 FCM (K=7)

4.2. The form of Temporary Neighbourhoods and The City

To understand how these results connect to the city of Norcia and its planning, the three clusters of temporary neighbourhoods represented in Figure 9 are here further analysed in terms of how well they relate to the new land use destinations assigned to the TH sites by the new general plan of Norcia, known as Piano Regolatore Generale (PRG). The latter was deposited in May 2019 (Norcia Municipality 2019) and approved by the major of the city on the 7th of October 2020, after receiving a positive result from the Environmental Impact Assessment (i.e., the VIA). The PRG will drive the reconstruction of the city in the years to come, while determining the future of the TH sites, to which the plan assigns one or more of the following functions, if any:

A. Area equipped or to be equipped for recreational-tourist-sport uses.
B. Public endowments.
C. Civil Protection use.
D. Mainly residential area.
E. Site for activities and services - tourism, sport, leisure, hospitality.
F. Reuse of facilities for hospitality-tourism.

G. Site for activities and services.
H. Relocation area.

In Table 2 these planned land uses are assigned to the relevant TH site (and cluster) using a Boolean index: Y for Yes and an N for No. In two cases, namely Piediripa and Popoli, no indication of future use was found in the PRG and therefore all possible functions are marked with an N in the table. To allow an easier visualisation of patterns, the clusters in column 3 are coloured using the same colour coding adopted in the plots presented in Section 4.1. The letters corresponding to the different uses are assigned different colour gradients, according to the corresponding functional themes (i.e., green for recreational, tourism etc., blue for residential including relocation, yellow for services both public and not).

By looking at Table 2 it is possible to observe the neat prevalence of the generic civil protection use (in violet), although in TH sites with more than 15 TH units this is coupled with other uses (except from Mgrazie2). Cluster 3 is assigned the vast majority of residential and hospitality uses. Interestingly, Ancarano, Campi and San Pellegrino (Figure 11), which are all located "far" from the city centre (see Figure 8) but belonging to Cluster 3 and having a medium size, have all been planned to have a continued residential use. Conversely the largest TH sites, i.e., Zia and ZiBCD have been assigned a hospitality role, somehow continuing their original vocation for temporary urbanism. Additionally, the TH sites belonging to Cluster 2, which are all modest in size (except for Frascaro which presents 15 TH units), seem to lack a clear functional future role. Considering that smaller sites have also a higher cost (CONSIP & NDCP 2014), the picture indicates the controversial role of this group/cluster of TH settlements, which opens doors to a discussion about the possibility to implement different technical solutions for this spatial typology of TH site.

Table 2 Future uses of Norcia TH sites, PRG 2019.

TH site	TH units	clusters	A	B	C	D	E	F	G	H
Montedoro	49	1	N	N	N	Y	N	N	N	N
Nottoria	9	1	N	Y	N	N	N	N	N	N
Savelli	12	1	N	N	Y	N	N	N	N	N
XXSett1	53	1	N	Y	Y	N	N	Y	N	N
Agriano	4	2	N	N	Y	N	N	N	N	N
Castelluccio	8	2	N	Y	N	N	N	N	N	N
Cserrav	5	2	N	Y	Y	N	N	N	N	N
Forsivo	2	2	N	N	Y	N	N	Y	N	N
Frascaro	15	2	N	N	Y	Y	N	N	N	N
Piediripa	3	2	N	N	N	N	N	N	N	N
Popoli	2	2	N	N	N	N	N	N	N	N
Ancarano	25	3	N	Y	Y	N	N	N	N	Y
Campi	20	3	N	N	N	Y	N	N	N	N
Mgrazie13	36	3	Y	N	Y	N	N	N	N	N
Mgrazie2	26	3	N	N	Y	N	N	N	N	N
Spellegrino	55	3	N	Y	Y	Y	N	N	N	N
Valcaldara	11	3	N	N	Y	N	N	N	N	N
XXSett2	48	3	N	N	N	Y	N	N	N	N
Zia	63	3	N	N	Y	N	Y	N	N	N
ZiBCD	193	3	N	N	Y	N	Y	Y	Y	N

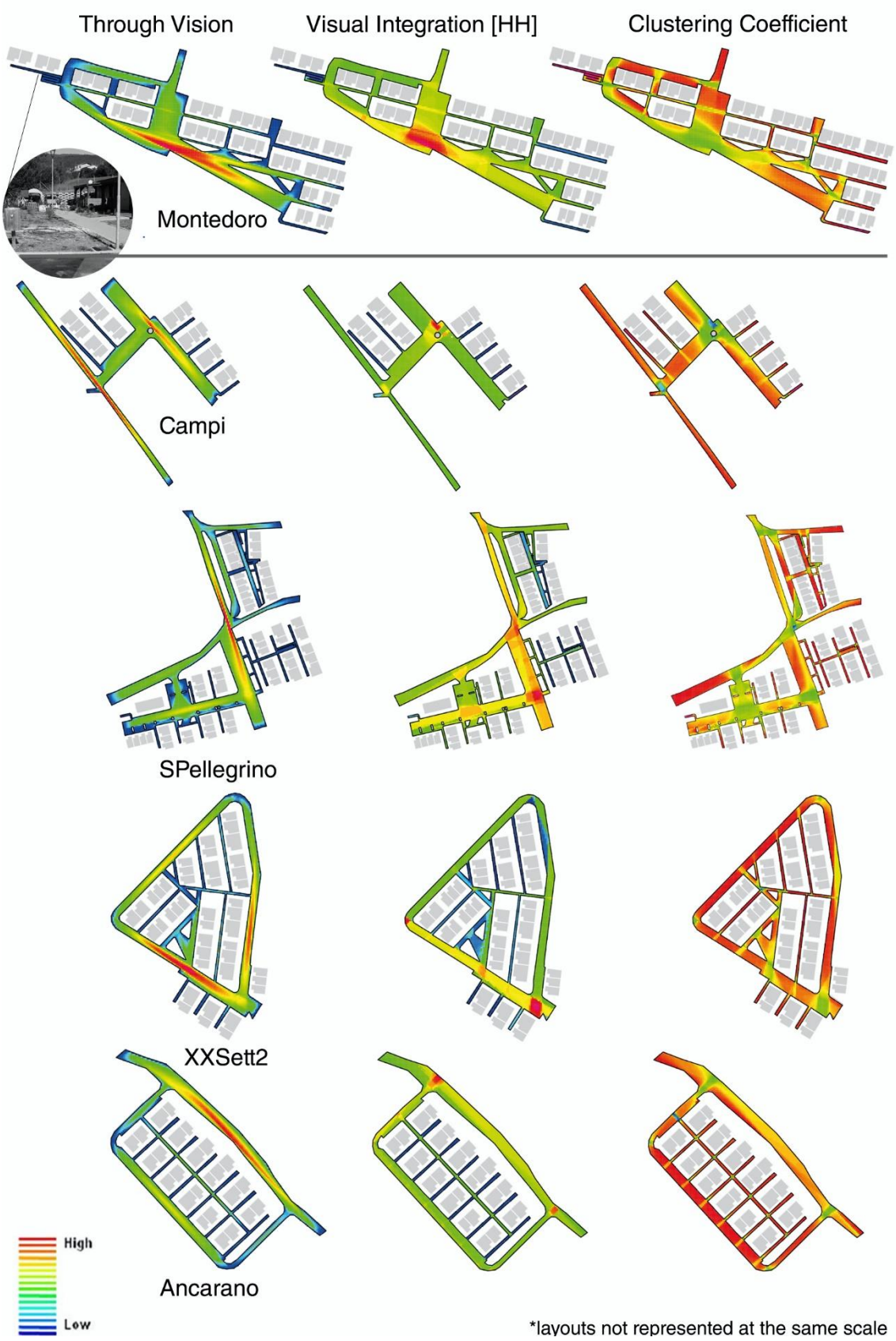

Figure 11 VGA Through Vision, Visual Integration, Clustering Coefficient of the TH sites in Clusters 1 and 3, which have been assigned a future residential use.

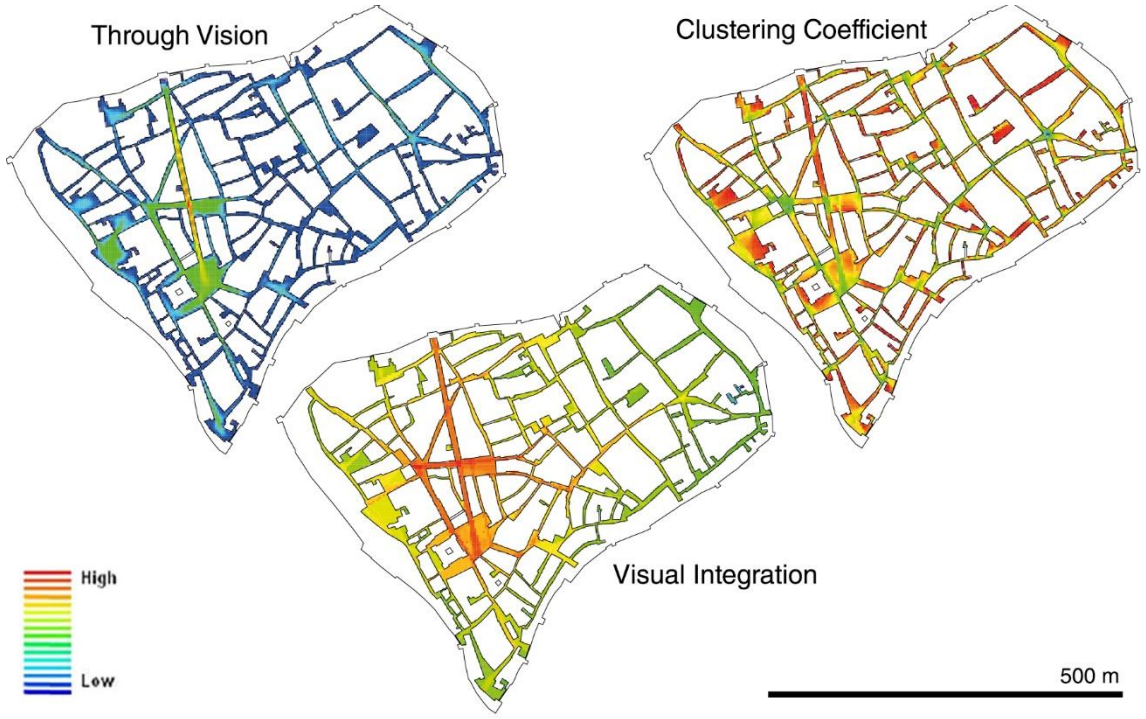

Figure 12 VGA Norcia city centre. Through Vision, Visual Integration, Clustering Coefficient

Providing good spatial qualities is particularly important for those sites which will be prevalently residential in the future. Figures 11 and 12, show the distribution of three of the key VGA indices, namely Visual Integration (to-movement), Clustering Coefficient (see and being seen) and Through Vision (through movement), in the future residential sites belonging to Clusters 1 and 3, and in Norcia's city centre. By looking at them, it is possible to observe the different spatial permeability patterns originated by planned and self-organised historic neighbourhoods, in order. Within the site layouts, we can find small green areas which clutter the permeability of the TH sites, fragmenting spaces that could have a gathering function. Sometimes, the remaining permeable space is also occupied with bike racks, benches, and other elements of urban furniture, while some green areas are used by the residents for private "temporary" installations such as inflatable pools, urban gardening lots etc. By contrast, the city centre (shown in Figure 12) presents a neater organisation of the public open space, with large and permeable public meeting places and smaller, less accessible, and yet still compact, semi-private ones.

But how spatially (diss)similar is the city centre to the TH sites? To respond to this question, the clustering analysis was repeated, this time considering only 18 VGA dimensions and adding the VGA data of Norcia's city centre, i.e., the area enclosed by the historic walls of the town. In this case, the results of the analysis (the comparison is done at K=3) show only a few variations with respect to the former one. Specifically, Campi, MGrazie2, XXSett2 and Valcaldara now belong to Cluster 1 rather than to Cluster 3 (these assignations were determined following the same democratic voting principle as before, based on the results shown in Figures 13-15). However, as previously mentioned, Clusters 1 and 3 are not as distant from each other as they are from Cluster 2. As it could have been expected, Norcia city centre was assigned to Cluster 3, albeit in the plots it always appears somehow distant from the other TH sites belonging to the same group. Furthermore, when incrementing the number of partitions (K) in the FCM, Norcia's city centre is assigned to a separate sub-cluster together with the two TH sites built in the industrial area, and destined to a hospitality and services' use, namely ZiA and ZiBCD. Although the FCM plot is not shown to avoid confusion, the HC dendrogram in Figure 15 shows a closer proximity of the city centre configuration with that of ZiA, than with those of all the other TH site layouts. This confirms the initial hypothesis that its spatial qualities are not fully replicated in the temporary housing settlements. When it comes to

this, it seems worth noting that an interview conducted by Chioni (2019) in the TH site of Borgo1 TH in Arquata del Tronto, which was built following similar principles, shows that residents can perceive this as a gap in the design of the temporary neighbourhoods as they aspired to a closer resemblance of these and the two.

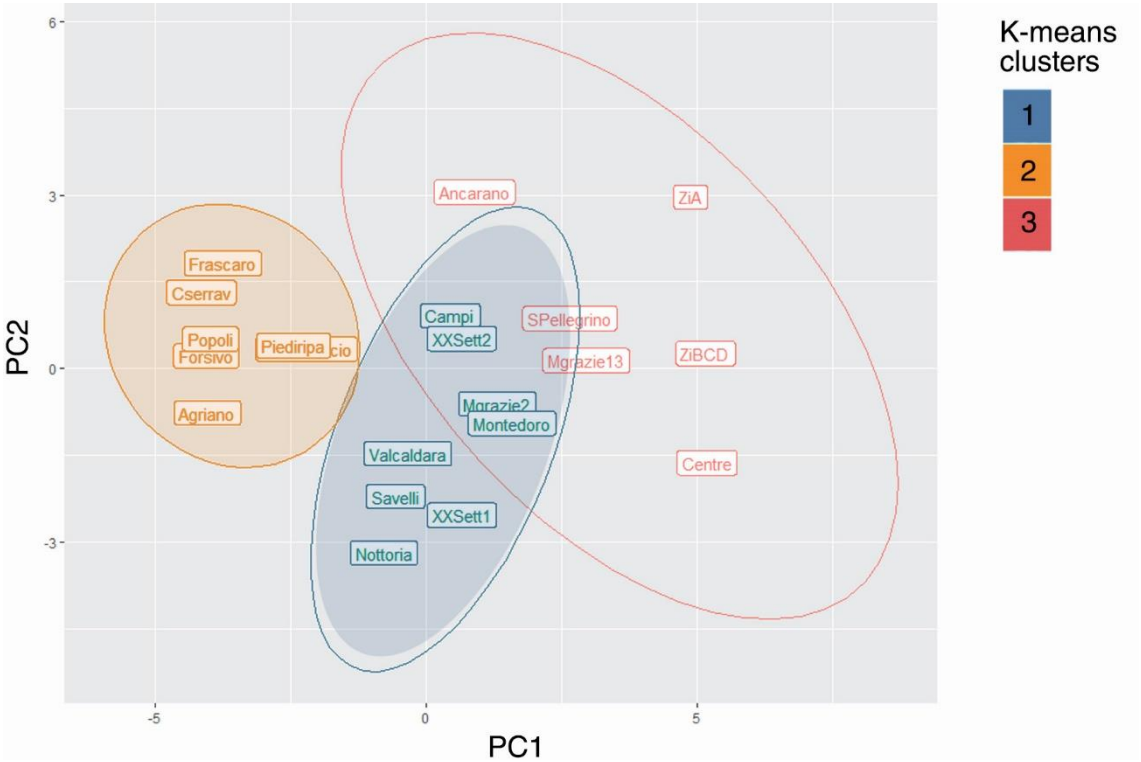

Figure 13 K-means analysis (K=3), VGA indices and city centre.

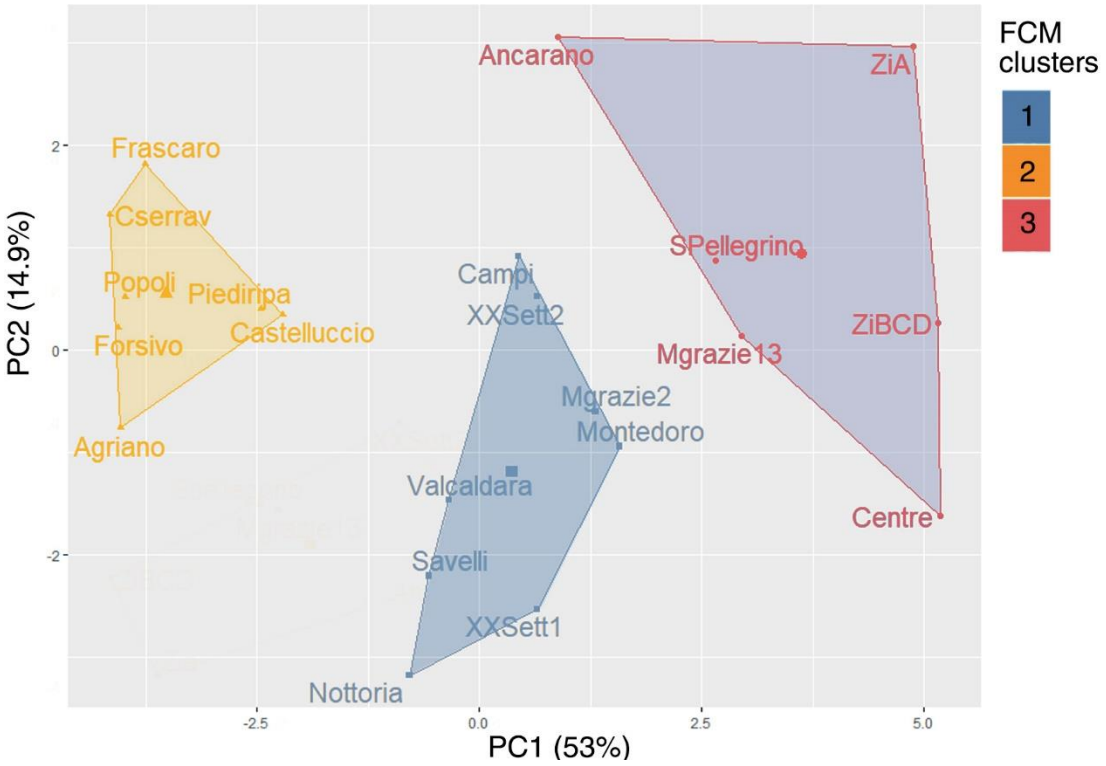

Figure 14 FCM VGA with city centre (K=3).

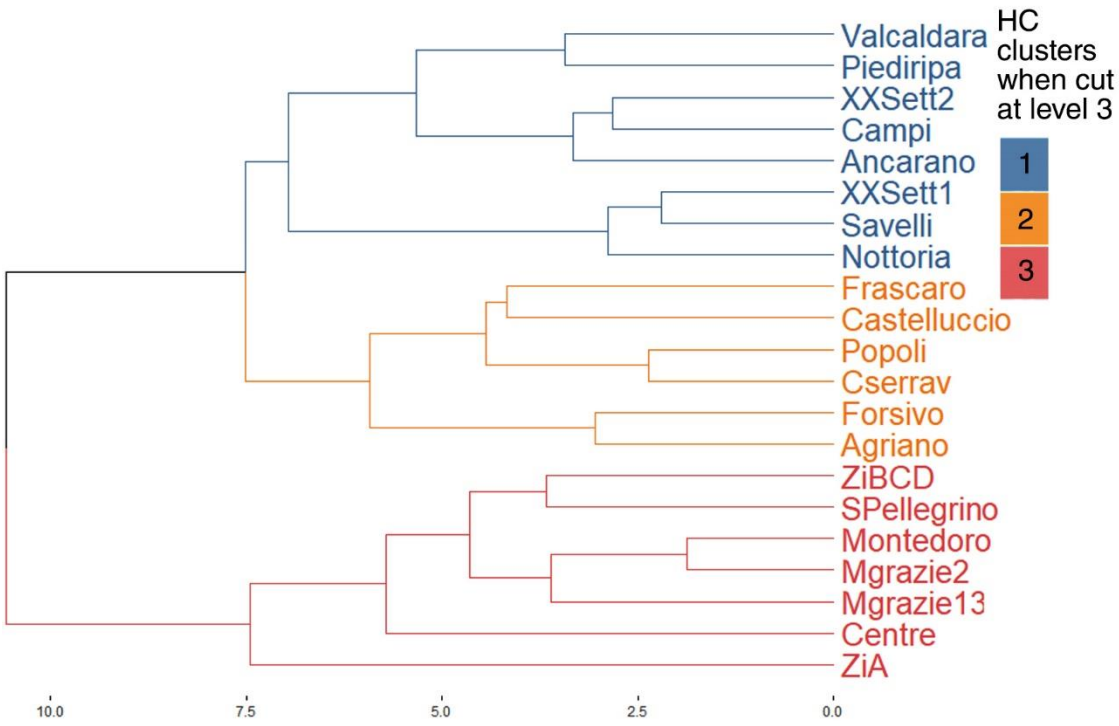

Figure 15 HC-derived VGA dendrogram with the tree is cut at K=3.

5. Discussion

TH assistance programmes require a more effective coordination through time and space, which can be achieved through the systematic assessment of candidate TH planning and layout design proposals. This paper moved another step towards the development of a Computation Planning Support System (CPSS) for the evidence-based design and planning of TH assistance after rapid-onset urban disasters. If we consider Space Syntax the language of space, then configurational and cluster analysis visualisations become the object of an interpretative effort to translate the mapped spatial relationships into planning propositions. Statistical learning methods and related visualisations can be seen as tools which support a process of critical reflection about built TH plans/designs as discussed in this paper.

Although the empirical basis of this study should be further expanded to yield generalisable results, the analysis presented in this paper identifies a mismatch between the designed form and the functional program of Norcia's TH sites. One explanation for this outcome is the lack of sufficient and clear guidance in relation to the arrangement of TH units within their sites in the context of a temporary neighbourhood. In fact, if not curious, it is at least atypical that the temporary neighbourhoods which present the highest configurational quality for residential use in their spatial design are those located in the industrial area of the town and assigned a future hospitality use. By contrast, those which according to the PRG will continue having a residential function, will need a regenerative urban design intervention to enhance their current qualities.

The approach adopted in the analysis of Norcia's TH sites offered the opportunity to conduct a nuanced multidimensional exploration of different TH layout arrangements, which could have been simply labelled as a form of "row housing" in a single terraced disposition. The proposed method enabled distinguishing TH sites with a more pronounced element of hybridity with courtyard layouts, while clarifying how opportunities for richer social interactions are weakened by a fragmented urban design that favours social separation and privacy. From an operational standpoint, the flexibility of the method proved important to synchronously consider the ASA and VGA data, although the former did not have, in the analysed case, a major impact on the final

clustering results. While this may have been expected considering that the layout of Norcia appeared the most stable in the diachronic urban scale analysis presented in (Pezzica et al., 2020), this indicates also that the method is sufficiently robust to input variations.

The proposed machine learning pipeline supported a nuanced interpretation of urban planning outcomes and design processes from a critical realism perspective (researcher as a critical thinker, inventor and discoverer), which could feed forward TH planning and design theory and practice. The critical realism approach enables studying causal relationships between spatial configuration and social phenomena, including individuals' actions (of experts and of lay people), however it requires interdisciplinary integration to arrive at valid knowledge as it assumes that both physical structures (e.g., space or buildings) and agency have independent causal powers (Næss 2015). This means that to generate actionable results we would need access to post-occupancy studies, besides scaling up the number of examples to create a reference benchmark. This would indeed increase the cluster analysis explanatory power, empirical support, and interpretation precision in describing the functioning of transitional settlements from a socio-spatial perspective.

The proposed approach can effectively support different tasks. In a previous study it was shown that one is to enable the analysis of spatial trade-offs and pattern discovery in diachronic spatial configurations to grasp the influence of street network configuration on physical urban resilience and how TH plans (actual or predicted) can add or detract from this. This paper demonstrated how the proposal can help exploring multidimensional relationships between components of urban form and visual/spatial permeability levels, considering how these relate to the present and future functions of temporary neighbourhoods. In addition to this, the combined use of Space Syntax and Cluster analysis can enable a wider range of explorations (Kubat 2017). For instance, knowledge of clusters can be exploited to: (i) estimate missing attribute values; (ii) optimize (e.g., Bayesian) classification tasks by using the centroids of the clusters; (iii) serve as input in supervised learning pipelines.

6. Conclusions

This contribution offers a new instrument to reflect on the design and spatial quality of existing and future temporary neighbourhoods built after disasters, bringing a different flavour and depth to the configurational analysis through the use of statistical learning for pattern discovery. The paper demonstrated that linking Space Syntax and Machine Learning enhances possibilities for analysis automation, replicability, and flexibility, and can assist understanding of how local people perceive and interact with the spaces of the transitional city, and in particular its TH sites. The application of the proposal to the case of Norcia illustrates how multidimensional configurational assessments could make human-centred spatial performance targets quantifiable and explicit towards increasing experts' accountability and facilitating collaboration with key stakeholders, as well as communication with the public. The results obtained in this case seem highly promising, in that they prove that the proposed combination of Space Syntax and unsupervised Cluster analysis can effectively support the design and planning of TH sites, by augmenting decision-makers' capacity to:

- Comparatively evaluate alternative spatial arrangements for TH sites in terms of how they influence the socio-spatial performance of temporary neighbourhoods and predict their impact on urban systems and their parts.
- Represent, understand, and then resolve, in an informed way, potential contradictions amid the form and function of TH sites to enable the achievement of local planning priorities in disaster recovery and reconstruction.

This research suggests the need to carefully negotiate in the disaster preparedness phase the relative weighting of technical components according to strategic and policy priorities, so this can

be reflected in future strategic framework agreements for the supply and delivery of TH. These should recognise the importance of spatial configuration for the achievement of social and cultural sustainability targets. Although 28 configurational indices of urban street network centrality and layout spatial permeability were selected in the analysis of Norcia's TH sites, the proposal enables the selection of a virtually unlimited number of indices of different nature relevant to inform planning and design actions. Working with Big(er) Data may require making some changes in the selection of the specific clustering algorithms to reduce time complexity; however, the overall analysis pipeline should not change substantially.

By expanding the study of natural groupings in TH layout data to a higher number of cases the defining qualities of the clusters are likely to become clearer and more meaningful to urban and architectural design, seen as a process of interpretation and reflexive synthesis. If clusters of temporary neighbourhoods could be clearly associated to levels of socio-spatial performance (e.g., assessed via a post-occupancy study), the results obtained from the application of the proposed analysis method may become particularly useful to feed forward future practices in the design and planning of TH sites. In this case, the analysis could in fact generate opportunities to set minimum urban design spatial permeability targets, which consider multiple interdependent dimensions, thus boosting DRR-oriented innovation in policymaking. This in turn open possibilities to the development of quick to deploy rules of thumb for the design of site layout options for temporary neighbourhoods built after disasters.

While increasing the range of applications, integrating the configurational, the social and the environmental perspectives seems a highly interesting direction for future studies exploring the dynamic interplay between efficiency, resilience, and urban form. Future research could consider exploring the spatial qualities of the sites at the neighbourhood scale together with their environmental performance, thus bridging the urban and the architectural design levels. This may allow to better separate clusters with TH units oriented in multiple directions, as it requires considering the third dimension and how it adds to the resilience of the temporary neighbourhoods, thus enabling a clear-cut differentiation between (and comparative assessment of) one- and multiple-storey layouts. Moreover, future studies should clarify how social habits and behavioural patterns interact with urban form at the scale of temporary neighbourhoods.

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Resume

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Annex A

ASA normalised values Norcia TH sites

TH site	N.CH_g	N.IN_g	N.CH_m	N.IN_m	N.CH2000_g	N.IN2000_g	N.CH800_g	N.IN800_g	conn_g
Montedoro	1.3721	1.0367	-0.7958	0.4000	0.9747	0.8133	1.0021	1.0021	0.0910
Nottoria	2.3444	-0.9531	-1.5218	0.2792	2.5259	-0.8493	2.1832	2.1832	0.2831
Savelli	1.0145	0.8761	-0.8287	0.2527	1.2436	0.1767	1.4034	1.4034	1.9550
XXSett1	1.3891	1.0484	-0.9268	0.7181	1.3762	0.6566	1.5636	1.5636	-0.4489
Agriano	-1.2775	-1.9899	2.6681	-1.6802	-1.5319	-2.1391	-1.5974	-1.5974	0.7912
Castelluccio	-0.9280	-1.4617	-0.4323	-2.0560	-0.9028	-1.0533	-0.8640	-0.8640	-2.1189
Cserrav	-0.9332	-0.2982	-0.3175	0.6700	-1.0741	-0.4275	-1.0814	-1.0814	-0.3582
Forsivo	-0.9497	-0.7701	0.6717	-2.2965	-0.8644	1.7736	-1.2206	-1.2206	-0.5072
Frascaro	-1.0045	0.2964	1.3478	0.3698	-0.6600	-0.1073	-0.7651	-0.7651	0.8189
Piediripa	-0.8523	-0.6134	-0.9953	0.7691	-0.7470	-0.6800	-0.5203	-0.5203	-0.9284
Popoli	-0.9916	-0.3401	-0.4214	-0.0421	-0.9449	-0.2751	-0.9406	-0.9406	-2.1189
Ancarano	-0.2008	-0.6877	-1.1572	-0.8573	-0.3010	-0.6506	-0.1750	-0.1750	0.9251
Campi	-0.7295	0.7063	0.7361	-0.9321	-0.6094	1.1097	-0.4767	-0.4767	-0.8717
Mgrazie13	0.4185	-0.5148	1.0222	0.7762	0.3449	-0.6443	0.3131	0.3131	0.0203
Mgrazie2	0.5254	-1.0544	-0.0981	0.8909	0.4938	-1.1911	0.5033	0.5033	0.0874
Spellegrino	0.2029	1.7288	0.4321	0.3801	0.3794	0.4965	0.5250	0.5250	0.1566
Valcaldara	-0.2177	0.6951	0.3938	0.3707	0.0030	0.5932	0.1145	0.1145	0.3025
XXSett2	0.6902	0.4243	0.3630	0.5024	0.5099	-0.2286	0.3809	0.3809	0.1283
Zia	-0.1367	1.0783	0.2795	0.8883	-0.2269	1.2716	-0.2537	-0.2537	0.8782
ZiBCD	0.2645	0.7930	-0.4195	0.5968	0.0111	1.3549	-0.0945	-0.0945	0.9146

Geometry-based normalised values Norcia TH sites

TH site	x	y	TH units	sl_m
Montedoro	13.086771	42.798535	49	-0.7078
Nottoria	13.155918	42.729921	9	-0.1651
Savelli	13.124981	42.72721	12	-0.9295
XXSett1	13.095772	42.797497	53	-0.1358
Agriano	13.027397	42.765085	4	3.2881
Castelluccio	13.206744	42.828198	8	-0.4042
Cserrav	13.060902	42.791823	5	0.9809
Forsivo	13.014165	42.799722	2	1.1524
Frascaro	13.143627	42.748345	15	1.2305
Piediripa	13.112281	42.740495	3	0.1165
Popoli	13.105384	42.752637	2	-0.8594
Ancarano	13.105076	42.837134	25	0.0956
Campi	13.0942	42.8503	20	-0.0357
Mgrazie13	13.104355	42.789506	36	-0.5469
Mgrazie2	13.104632	42.79064	26	-0.3667
Spellegrino	13.146716	42.756153	55	-0.5631
Valcaldara	13.125947	42.740805	11	-0.8295
XXSett2	13.096489	42.798681	48	-0.3495
Zia	13.094	42.786	63	-0.5724
ZiBCD	13.095339	42.777482	193	-0.3984

VGA normalised values Norcia TH sites

TH site	Conn_g	T.V_g	Clust.C_g	V.Ctrl_g	V.Int._g	V.Ctrllab_g	V.Rel.Entr_g	P.1stM_g	P.2ndM_g
Montedoro	0.2511	0.3326	0.9078	0.4622	-0.8104	0.2880	-0.0797	0.5660	0.7823
Nottoria	-0.7373	-1.3637	1.3036	1.5929	0.6235	-0.1730	-0.3151	-1.1171	-1.1407
Savelli	-0.1460	-0.8041	0.5650	1.0577	0.6753	-0.4605	-0.6768	-0.5788	-0.8937
XXSett1	0.0571	-0.7147	1.9393	1.7542	0.1616	-0.5679	0.4936	-0.3513	-0.2492
Agriano	-1.4434	-1.6166	-0.4464	-0.1749	1.7424	-1.0073	-1.6456	-1.6975	-1.8860
Castelluccio	-0.8336	-0.6429	-0.1744	-1.0297	-1.0218	0.2778	-0.6156	-1.0618	-1.2519
Cserrav	-1.2870	-1.0678	-1.2873	-0.5753	0.4777	-1.7413	0.6032	-1.2497	-1.4562
Forsivo	-1.0286	-0.8269	-1.3011	0.2173	2.3105	-0.4071	-1.4548	-0.9074	-0.8745
Frascaro	-1.9788	-0.9716	-1.4194	-1.7056	-0.6971	-1.9588	-2.1248	-1.1935	-0.2829
Piediripa	-0.3501	-0.3586	-1.1190	-0.8612	1.3389	-0.7112	-0.0430	-0.1230	0.0069
Popoli	-1.2407	-0.8563	-0.6152	-1.1889	1.5819	-1.9408	0.6490	-1.1293	-1.1897
Ancarano	0.2130	0.0602	-1.4485	-0.8768	-1.2009	1.4810	0.5427	-0.1147	-0.2889
Campi	-0.4295	0.2900	-0.2599	-0.5911	-0.4529	0.6011	1.5754	0.1659	0.4811
Mgrazie13	1.1964	1.3083	0.7424	-0.0698	-0.3906	1.7382	0.2687	1.3332	1.2837
Mgrazie2	0.2658	0.0371	0.4031	0.7409	-1.1514	0.7581	-1.1612	0.0178	-0.0200
Spellegrino	0.7948	0.4596	0.6631	-0.0135	0.2373	0.8077	1.6313	0.4754	0.5922
Valcaldara	0.3699	-0.0677	0.2135	0.9924	0.6819	0.1012	1.4177	0.0451	-0.0760
XXSett2	-0.0323	-0.3705	-0.0865	0.6020	-0.3254	-0.3040	0.0238	-0.1630	-0.1527
Zia	0.3035	0.1878	0.9119	0.0849	-0.8380	0.5435	0.4474	0.4201	0.5813
ZiBCD	1.5524	1.4369	0.7710	1.1374	-0.5732	0.7158	0.0530	1.4540	1.3865

VGA normalised values Norcia TH sites

TH site	Conn_m	T.V_m	Clust.C_m	V.Ctrl_m	V.Int._m	V.Ctrllab_m	V.Rel.Entr_m	P.1stM_m	P.2ndM_m
Montedoro	-0.1372	-0.4099	-0.4973	-0.7456	-0.7199	-0.5572	-0.0845	-0.3555	-0.3630
Nottoria	-0.1505	-0.2617	-0.4231	-2.7165	1.0543	-0.2585	-0.1885	-0.5659	-0.5161
Savelli	-0.5227	-0.4957	-0.8496	-1.2009	0.3466	-0.6855	-0.2227	-0.5673	-0.4801
XXSett1	-0.2581	-0.3508	-0.9957	-0.9750	0.1864	-0.6796	-0.2153	-0.4073	-0.4065
Agriano	-0.6449	-0.6295	-0.1077	-0.0923	1.9509	0.9115	-0.8263	-0.6759	-0.5472
Castelluccio	-1.1580	-0.8136	1.3203	0.1610	-0.6074	0.7221	-0.0979	-0.8290	-0.5954
Cserrav	-1.1793	-0.7958	1.1296	1.6271	-0.1950	1.9026	-0.9124	-0.8149	-0.5847
Forsivo	-0.6157	-0.6644	0.8659	0.9979	3.3406	1.8769	-0.9519	-0.6837	-0.5530
Frascaro	-1.0038	-0.7461	-0.1480	1.8007	-0.6631	1.7320	-0.5215	-0.7779	-0.5809
Piediripa	-0.9905	-0.7600	1.6458	-0.1374	-0.1280	0.4065	-1.2915	-0.7857	-0.5776
Popoli	-1.0650	-0.7984	-0.0285	0.7504	0.6304	1.4562	-1.4337	-0.8219	-0.5937
Ancarano	0.7295	0.0492	0.7113	0.9266	-0.0265	0.5341	-0.2836	0.5353	0.4825
Campi	-0.0601	-0.2636	0.7266	-0.2795	-0.0763	0.0762	-0.3986	-0.1958	-0.1800
Mgrazie13	-0.1585	-0.2046	0.1555	0.6466	-0.2052	-1.0753	0.7711	-0.2539	-0.2236
Mgrazie2	-0.0840	-0.2449	-0.4976	-0.3384	-0.4947	-0.4486	0.2821	-0.1921	-0.1975
Spellegrino	0.8863	0.3948	-0.6647	-0.1034	-0.2055	-0.6476	-0.6059	0.4720	0.3539
Valcaldara	-0.8390	-0.6986	0.6612	-1.1833	-0.0946	0.0293	-0.7872	-0.7077	-0.5446
XXSett2	0.3573	0.0224	0.5621	0.2203	0.1449	-0.3890	0.2346	0.1734	0.1143
Zia	2.7233	2.1033	-1.4352	0.5773	0.0836	-0.8317	0.0764	1.6833	1.4923
ZiBCD	0.9342	1.0563	-0.9031	-0.5420	-0.2560	-1.4688	0.8944	0.6754	0.7201

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Transformation of urban form in Shkodër during the Ottoman period

Ermal Shpuza*

Abstract

Urban form in Shkodër is studied according to six stages during the period 1479-1913, which are reconstructed based on historical descriptions, maps, photographs, and the spatial interpretation of the Venetian cadastral registry in 1416. Like other Ottoman cities in the Balkans, the old quarters in Shkodër evolved by preserving the original medieval street network, while the new part of the city grew by expanding suburbs with dendritic street patterns and large plots along existing intercity arterial roads. The unique location of the city confined by hilly ranges and surrounded by three rivers and a lake produced a distinctive urban form due to the position of the external bazaar and the crisscrossing of arterial roads. The comparative space syntax analysis of the street network for each stage reveals a gradual transformation in the spatial structure of the city broken by two stark changes: during the early Ottoman period when the bazaar became distinctively more central in comparison to the living quarters, and after the opening of new boulevards during the late Ottoman period when the new urban center that emerged in the new city drew the spatial integration away from the historical bazaar.

Keywords: street network, space syntax, urban morphology, Albania, historical city

1. A Frontier City Surrounded by Three Rivers

While Shkodër (Scodra, Scutari, Skadar, Iskenderiye, Işkodra[1]) is celebrated as the foremost historic city and the cultural cradle of Albania, little is known of its history of urban form. Historical and archeological research on the city so far has produced scant findings on the fortifications and the extent of the urban area during the Roman, Byzantine, and medieval periods (Hoxha, 2003; Korkuti & Petruso, 1993; Kamsi, 1976), while the study of built form during the Ottoman period (1479-1913) has been limited to key public buildings, infrastructure and military works (Kiel, 1990), and domestic architecture (Riza, 1972) without addressing the urban form, despite the latter undergoing profound changes during this time. The paper presents an attempt to reconstruct Shkodër's historical urban form during the last five centuries and shed light on the spatial transformation while the city changed from an important Venetian stronghold in northwest Albania to a prosperous Ottoman provincial center. The study employs the comparative space syntax analysis of the city's street network in six historical stages.

[1] Latin, Italian, Slavic, and Turkish exonyms are shown in brackets in the first mention of key toponyms as they appear in historical literature.

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For the most part, the transformation of Balkan cities during the Ottoman period is characterized by the process of Ottomanizing existing Byzantine cities through the process of inserting Ottoman architecture into the medieval fabric, and the extension of suburbs with sparse dendritic street patterns. Cities established during the Ottoman period in the Balkans are rare, with examples such as Sarajevo (Bosna Saray), Novi Pazar (Yeni Pazar), Elbasan, Giannitsa (Yenice), and Ruse (Ruscuk). Since the new part of Shkodër grew disjoint from its medieval core by weaving an Ottoman urban fabric along intercity arterial roads and forming a new urban center away from the historical bazaar, the paper inquires whether Shkodër's urban formation shares the characteristics of a new Ottoman city built from scratch.

The city is located not far from the historical western frontier of the Ottoman Empire in the Balkans. The frontier closely coincides with the Theodosius Line, the demarcation between western and eastern parts of the Roman Empire, which later survived as the most extraordinary divide in the Mediterranean (Braudel, 1972), becoming the fault line between Roman Catholic and Greek Orthodox Churches. During the rule of the Bushati family (1751-1831) Shkodër grew into an important economic hub as the center of a de-facto autonomous *pashalik*. Despite its remoteness from Istanbul (Dumont, 1874), the access to the Adriatic via the river port made the city a *network system* node (Hohenberg and Lees, 1995) of commerce from Anatolia to Venice (Pedani, 2008) and the illicit trade to the eastern Mediterranean (Blumi, 2010). From this viewpoint, the paper inquires whether Shkodër's peripheral location in the Ottoman sphere and its close historical links with Ragusa and Venice produced different features of urban form compared to other Turko-Balkan cities.

The urban form of Shkodër and its transformation over time is tied to the unique physiography of the plain bound by the mountainous range of Tarabosh-Rozafa-Tepe, the shores of Lake Shkodër, and three rivers Bunë (Barbana, Bojana, Boyana), Kir (Clausula, Clia), and Drin (Oriundus, Drino, Dirin). While the Bunë has maintained a stable course from the lake to the Adriatic, the Kir has altered its course on the upper plain where the new city expanded, and its old beds were transformed over the centuries into canals for operating mills (Figure 1). After extraordinary floods in 1846, the Drin, which is the second largest river of the Adriatic, changed course to flow northward into the Drinasë stream (Drinassa, Drimac) along the embankment of the old city, and subsequently into the Bunë. By 1858, the northern distributary became the main one causing the erosion of large parts of the medieval quarters of Tabak and Ajasëm, the frequent flooding of the Bazaar, and the creation of sandbars in the Bunë's delta that blocked the access of large ships from the sea to the river port. The study of Shkodër's transformation is therefore discussed considering changes to the riverine morphology over time.

2. Hypothetical Reconstruction of Historical Urban Form

While the transformation of the city occurred gradually, the study focuses on six stages: 1) 1446, during the Venetian period (1396-1479); 2) 1646, by which time the city had been established as an Ottoman sanjak center; 3) 1746 when the city was divided into two parts during the feudal struggles between two main clans; 4) 1846, at the peak of its economic development just before the river Drin's new branch first appeared near the city; 5) 1858 when the Drin's northern distributary became the main one leading to the erosion of vast areas of the old quarters; 6) 1913, at the end of the Ottoman rule by which time new boulevards were opened in the spirit of Tanzimat modernizations.

The study of Shkodër's transformation is hampered by the lack of historical maps, as is the case for other cities in the region (Karamustafa, 1992). So far, we know of no map of the city produced during the Ottoman period. The earliest accurate plan of the city, showing the street network and the buildings, was produced by the British in 1913 (Hobbs, 1913) (Figure 1), while the first known aerial photograph was taken by the Italian Airforce during WWI (Royal Italian Navy, 1918) showing the Bazaar and the southern half of the new city. I have employed two subsequent maps to

determine the location of mill waterways and plot boundaries (Rossi & Boroli, 1923; D'Ascensi and Miserocchi, 1938).

To reconstruct the city's form during the Venetian period, I have augmented the historical research (Jireček, 1916; Kamsi, 1976; Schmitt, 2001; Šufflay, 1924; Valentini 1967) with a spatial interpretation of the Venetian cadastral registry of Shkodër in 1416 (Zamputi, 1977), which comes only in text and lacks drawings. While the toponyms of the villages in the registry have, for the most part, survived unchanged to the present, almost all toponyms within the urban area and the *contado* (*contrata*)[2] of Sopra Scutari and Soto Scutari (Upper Shkodër and Lower Shkodër) have been replaced[3]. Since the listing of the properties in the villages both on the upper and lower plains are listed in a clockwise order starting with those closest to the city, I have used a clockwise listing of properties in the *contado* to determine their location.

To reconstruct Shkodër's urban form during the Ottoman period, I have relied on Bushati's seminal work on the history of the city (Bushati, 1998), which gives invaluable descriptions of quarters, streets, waterways, mills, the bazaar, and public buildings; the accounts by Evliya Çelebi who visited the city in 1662 (Dankoff and Elsie, 2000); historical photographs starting in 1863 (Elsie; Marubi); and writings by European travelers and envoys to the city during the 19th century. For the reconstruction of the streets in the quarters eroded by the Drin, I have relied on the plot boundaries shown in the 1938 map.

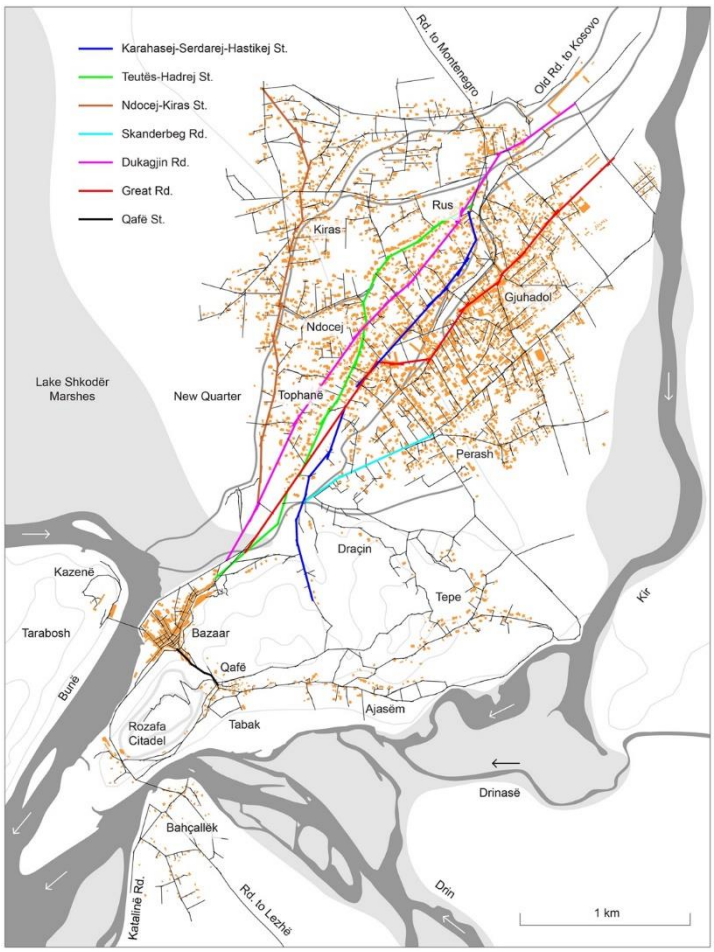

Figure 1 Street network, building footprints, and main toponyms of Shkodër in 1913 drawn according to the British map (Hobbs, 1913). Marshes and floodplains are shown in light gray, waterways in gray, and main arterials in color as per the inset legend.

[2] Arable land, pastures, vineyards, and forests owned by citizens within a radius of about 5 kilometers around the city (Schmitt, 2001: 96).
[3] It is likely that during the medieval times urban dwellers used different toponyms from the rural population, which were lost after the emigration of the entire city to Venice as per the treaty of the surrender of Shkodër after the second Ottoman siege in 1479.

3. The Use of Space Syntax Analysis for Historical Research

Space syntax is a theory and set of analytical techniques that address the spatial description of the built form from a social viewpoint (Hillier and Hanson, 1984). For a concise review of main theorems, methods and applications, see (Peponis and Wineman, 2002; Bafna, 2003). Space syntax studies of cities have usually employed axial map representations, which are constructed by drawing the fewest and the longest straight lines to cover the open public space of streets and squares and are analyzed according to graph-theoretic measures. Relational patterns among the lines are studied to explain both the social dimensions of the urban form and the spatial aspects of society. In this study, I use the topological measures of connectivity C, integration I (topological depth relativized for size), choice B (betweenness centrality), spatial intelligibility (the regression coefficient R^2 in the plot C vs. I), and the geometric measure of street length L.

A growing number of studies have employed space syntax methods to understand the spatial transformation of cities over time (Griffiths, 2010). Some have addressed urban transformation based on comparisons among cases within countries and regions such as Adriatic and Ionian littoral (Shpuza, 2009; Shpuza, 2014), Anatolia and Turkey (Kubat, 1997; Topçu, 2019), Brazil (Medeiros et al., 2003), England and Iran (Karimi, 2000; Azimzadeh & Klarquist, 2003). Others have focused on single cases to investigate changes to the urban form brought by colonization, independence, and modernization such as Algiers and Zanzibar (Rashid, 2021), Amsterdam (Read, 2000), Belgrade (Fouillade Orsini, 2018), Istanbul (Kubat, 1999), and Zagreb (Zaninović et al., 2018). On the one hand, these studies have contributed techniques for the historical study of cities, on the other hand, they have amassed a database of historical research that enables comparative interpretations, especially with the cases in the Balkans and the Ottoman Empire, which share a socio-cultural context with Shkodër.

4. The Venetian Shkodër

The understanding of urban form during the Venetian period is crucial for two main reasons: First, that the social norms in medieval Albanian cities (Nadin, 2010; Schmitt, 2001), likely produced a different spatial culture and urban form compared to the Ottoman city, which reflected different customs brought by the Islamic influence; Second, since the medieval street network and intercity arteries formed the basis on which the Ottoman-era city expanded.

During the medieval period, the city was composed of three main parts: the quarters within the citadel on top of Rozafa hill; the quarters outside the walls (*borgo*, *varosh*), which were located on the slopes around the citadel and extended eastward to present-day Ajasëm, and two quarters of Casene and Gardens across the rivers, which were connected via bridges[4]. The medieval market was smaller than the modern-era bazaar and occupied its southern sector. The medieval urban fabric would have been constituted with an *altstadt* street pattern (Marshall, 2005) like medieval quarters preserved inside the citadels of neighboring cities of Ulqin (Dulcigno, Ulcinj, Ülgün) and Tivar (Antivari, Bar) (Bošković, et al., 1981; Mijović and Kovačević, 1975). The medieval quarters were organized along a few main arteries[5]. Via del Canaro (Bërdicë Rd.[6]) - Via Publica (Dukagjin Rd.) coincided with the major Roman road from Dyrrhachium to Doclea-Narona and connected the Gardens with the market and further north with the hamlet of Oliari[7]. There, the road bifurcated

[4] The bridge on Bunë during the Venetian era was located to the south of the modern-era bridge, near the Church of St. Blaise, part of the quarter of Ragusan merchants.
[5] In the cadastral registry, the streets inside the urban area are indiscriminately referred to as *via de comun* (commune streets), whereas streets in Sopra Scutari and Soto Scutari are explained with specific names (Zamputi, 1977).
[6] Streets are referred to with names used until WW2, as in the 1923 map.
[7] Oliari (Zamputi, 1977: 30, 256) is mentioned in 1395 as the residence of Konstantin Balsha (Balšić) (Miklosich, 1858: 228). The hamlet did not vanish, as claimed by Jireček (1916: 110), but likely survived as Rus, which is first mentioned by Bolizza in 1614 (Zamputi, 1963: 260).

into Via Schiavanesca (Tuz St.) leading to Montenegro, and Via Tartaresca[8] (Dukagjin Rd.) leading to Drisht and further to Kosovo (Figure 2(a)). A second arterial, Via del Drinase extended along the right bank of Drinasë to the south of the citadel and survived until the erosion by the Drin in 1858. Given the frequent movements of the Kir to the east of the city[9], it is likely that the two lesser arterials Oliari-Tepe and Zdrale-Perash-Tepe were not opened yet. Two main canals through the upper plain of Sopra Scutari, Fossado de Oliari and Fossado de Bucem, passed by the namesake hamlets and discharged into Bunë to the north of the market (Figure 2(b)). The canals maintained the same location and operated mills until 1929 (Bushati, 1998: v2, 385).

The syntactic analysis of Shkodër's street network during the Venetian period reveals an L-shaped integration core that includes the arterial road above the market and Qafë St. (Figure 1). The core is distributed gradually to include the loop at the base of Rozafa hill, while the quarter within the citadel is the most segregated area from the rest of the city. The lines with the highest choice include Qafë St., the street above the market, and the main street outside the walls linking the citadel with the varosh below. From there, the choice values are gradually distributed to include the loop street at the base of the hill and the two bridges. Shkodër's spatial structure thus resembles medieval city centers across the Adriatic (Shpuza, 2009) and some pre-Ottoman cities in Anatolia (Kubat, 1997), while the low integration of the city overall (Table 1) is to be attributed more to the separation of the city's quarters due to the physiographic constraints of the hilly terrain and the rivers rather than the organization of street patterns.

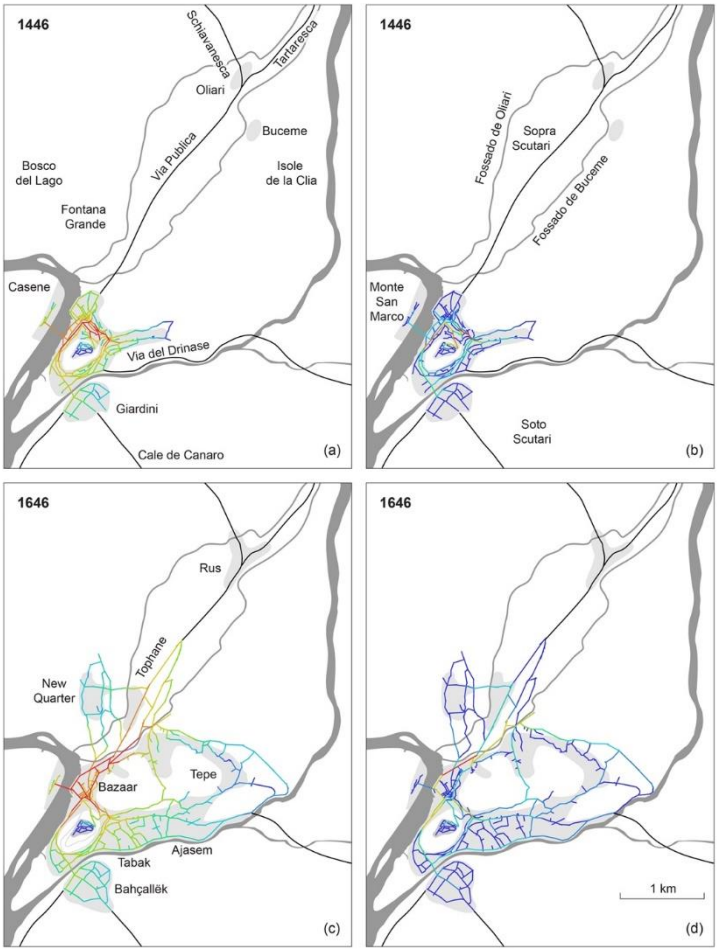

Figure 2 Axial map of Shkodër's street network during the Venetian period (1446) and early Ottoman period (1646) colored according to values of integration (a, c) and choice (b, d).

[8] *Schiavanesca* (Slavic) refers to the territory of Montenegro, while *Tartaresca* (Tatar), refers to couriers used at the time since parts of the Balkans had already fallen under Turkish rule.

[9] As indicated by the toponym Isole de la Clia (Kir Islands), located to the east of Buceme (present-day Gjuhadol).

5. Shkodër During the Early Ottoman Period

Shkodër was the last Albanian city to fall to the Ottomans after the long siege of 1478- 1479, during which time all the surrounding medieval cities - Balëz (Balezo), Drisht (Drivasto), Sardë (Sarda, Sardoniki), Danjë (Dagno), Sapë, Shas (Suazzo, Svač), and Zhabjak (Sabiach, Žabljak Crnojevića) - were obliterated and reemerged only as insignificant villages. The city survived and was chosen as the center of an Ottoman provincial center. Its resilience is attributed not only to the powerful fortress located on an inaccessible hilltop controlling the passage between the two plains and the navigation between the sea and the lake, but also to the presence of waterways that supported trade, provided water, and operated watermills and tanneries.

During the early Ottoman period, the city consisted of two main parts, the living quarters and the bazaar, since the citadel now retained only military functions (Kiel, 1990). The quarters had expanded on the hills to the north and east of the citadel[10] (Figures 3(a) and (c)). The bazaar had extended to the north of the medieval market, and due to the confinement in the narrow strip of land between the riverfront and the hills (Figures 3(b) and (d)), it related to the rest of the city as an exobazaar (Busch-Zantner, 1932), a position it maintained even after the city expanded on the upper plain. After the urban expansion had captured all the sides of Tepe hills, two suburbs11 appeared on the upper plain - once the Venetian contado of Sopra Scutari - disjoint from the medieval city by the marshes to the north of the Bazaar (Figure 2(c).

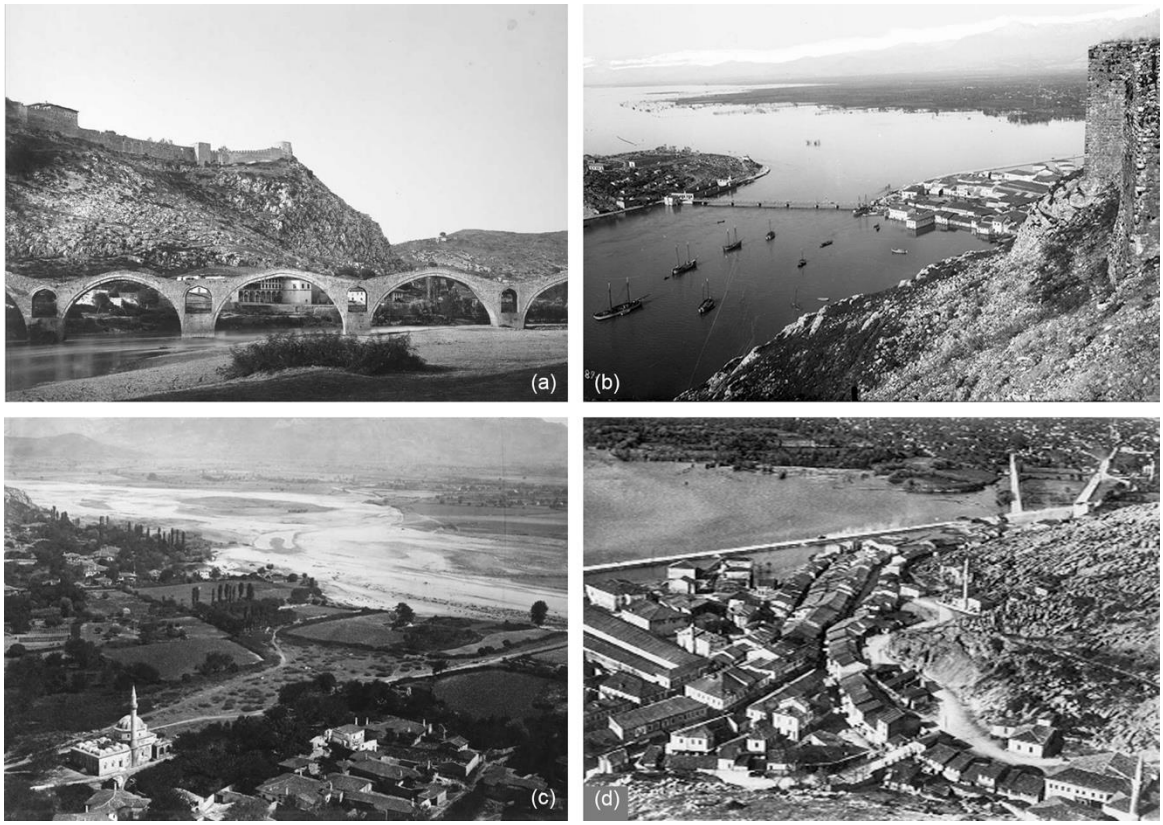

Figure 3 Old quarters of Shkodër in 1863: a) looking northeast, showing bridge on Drinasë/Drin, the citadel with Venetian fortifications, and the remnants of Tabak quarter; b) north from the citadel, showing the Bazaar and the bridge on Bunë; c) southeast from the citadel, showing the erosion by the Drin and the remnants of Tabak quarter; d) looking northwest, Bazaar confined between the riverfront, the marshes, and the hills.

[10] Evliya Çelebi describes Shkodër in 1662 as a town of 15 quarters, which are located around the citadel, the bazaar, 1800 houses, and 11 mosques (Dankoff & Elsie, 2000). While the low elevation varosh quarters were rebuilt during the Ottoman period, those high up on the hill were abandoned after being destroyed during the first siege in 1467 (Kamsi, 1976).

[11] New Quarter and Tophanë, which was established after the construction of the mosque in 1617 (Bushati, 1998: v1, 98).

The spatial structure of the early Ottoman Shkodër exhibits two significant differences to the medieval city: First, the integration core had expanded north to include all the streets circumventing the Bazaar (Figure 2(c)), of which the riverfront promenade has the highest choice controlling the through-movement among all parts of the city (Figure 2(d)). The integration core still included Qafë St. (Figure 1) - the entrance to the Bazaar from the east -, which had attracted the buildings of the court, police, and hotels (Bushati, 1998: v1, 64-69). Second, while the integration core in the Venetian city included the living quarters at the base of the hill, the living quarters in the early Ottoman period are markedly segregated in contrast to the bazaar. Also, as the city expanded during this period, both its integration and intelligibility dropped (Table 1). However, such change is attributed to the stretching of the city around the hills since the streets maintained their medieval character, lacking any application of Islamic dendritic patterns.

Table 1 Measures of axial map analysis of Shkodër's street network compared across six historical stages 1446-1913, and the new part of the city in 1913 considered separately: number of axial lines *N*, mean values of length *L*, connectivity *C*, integration *I*, and normalized choice *B*, and the index of intelligibility measured with the regression coefficient R^2 in *C* vs *I* plots.

Year	*N*	*L*	*C*	*I*	*B*	R^2
1446	317	76.8	3.016	0.539	0.071	0.135
1646	536	95.8	2.855	0.409	0.062	0.076
1746	828	95.6	2.833	0.412	0.044	0.072
1846	1003	103.1	2.891	0.434	0.036	0.091
1858	986	100.8	2.856	0.442	0.036	0.102
1913	1313	99.6	2.847	0.555	0.023	0.1
1913 (new)	815	111.8	2.94	0.747	0.024	0.193

6. Shkodër During the Middle Ottoman Period

As the city grew thanks to the manufacturing and the flourishing trade across the Mediterranean (Shkodra, 1984), additional suburbs were formed on the upper plain[12], according to the Ottoman urban strategy of the time (Krstikj, 2013; Yenen, 1992). The upper plain was preferred to the lower one, despite its exposure to northern winds, given the presence of canals that operated mills, and the high quality of underground water. The new suburbs attracted a mixed population of Muslims and Catholics[13], although, by the beginning of the 19th century, the Catholics had concentrated in the northeast of the new city. The new suburbs were centered along medieval arterials, at their crossings with the canals, and around the medieval hamlets.

By the first half of the 18th century, the suburbs on the upper plain had expanded to produce a city equally split in two by the marshes. Shkodër's spatial divide mirrored the schism between the Bushati clan, which controlled the old quarters, and the Çausholli and Maxharri clans, which controlled the new suburbs (Ippen, 1907: 25). The city's spatial structure around 1746 reinforces the transformation that had started during the early Ottoman period: spatial segregation of the quarters and the integration of the central arterials and the bazaar, as indicated by comparable values of syntactic measures between 1646 and 1746 (Table 1). The integration core had extended further to the north to include Dukagjin Rd. (Venetian-period Via Publica), followed by three other

[12] As indicated by the dating of the new mosques: Rus in 1711, Ndocej in 1723, and Perash in 1745 (Bushati, 1998: v1, 183, 189, 199)
[13] Catholics were allowed to settle in the city in 1700, starting in Tophanë (Bushati, 1998: v1, 101), while the construction of new churches and seminaries was permitted in 1851.

arterials: 1) Ndocej-Kiras St., which alternates on both sides of Kiras (Oliari) canal providing a short-cut connection to Montenegro; 2) Karahasej-Serdarej-Hastikej St., which used to connect Rus with Qafë and Drinasë Rd. over the hills and bypassing the Bazaar; and 3) Teutës-Hadrej St., which starts from the Bazaar and meanders on both sides of Dukagjin Rd. (Figure 1, Figure 3(a)). This set of arterials, which created the spatial backbone of the new city, is quite peculiar when compared to arterial roads in Turko-Balkan cities in general (Pinon, 2008), and the neighboring vilayet centers of Skopje (Shkup, Üsküp), Bitola (Manastir), and Ioannina (Janinë, Yanya) in particular (Krstikj, 2013; Shundovska, 2015; Barbie du Bocage, 1820), where arterials fan out of the bazaars creating triangular superblocks. The position of Shkodër's original arterials was dictated by the narrow strip of land between the canals (Fossado de Oliari and Fossado de Bucem) while negotiating the crossing of the Kir's changing route. Their original role of connecting the medieval city with the surrounding region and beyond was augmented to facilitate the connection of the new neighborhoods with the bazaar during the Ottoman period.

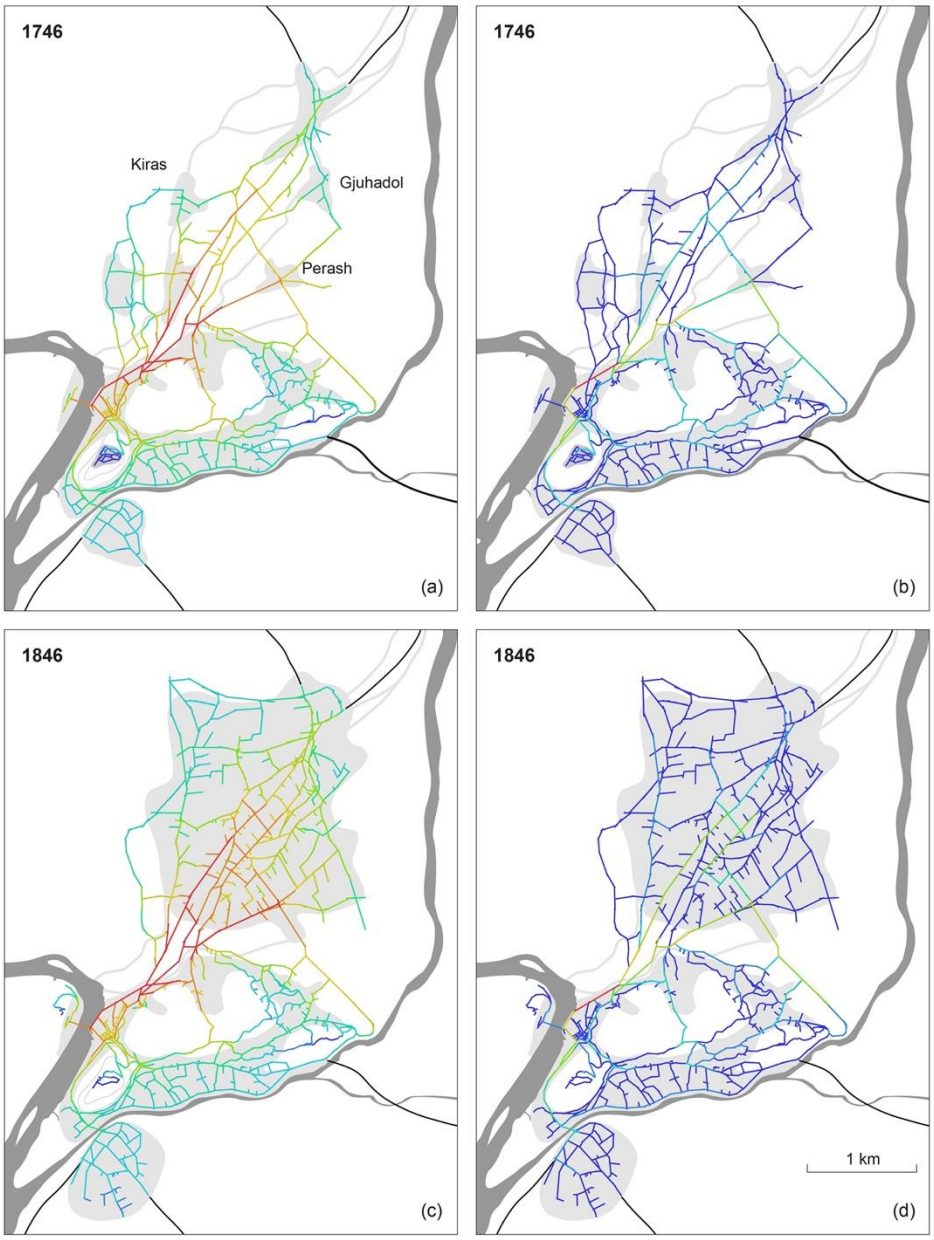

Figure 4 Axial map of Shkodër's street network during the middle Ottoman period (1746) and (1846) colored according to values of integration (a, c) and choice (b, d).

The street network in the upper plain developed through the process of weaving new streets onto the existing medieval arteries, although at this stage the network was still sparse[14]. The new streets closely matched the patterns of cul-de-sacs and zigzagging alleys found throughout Ottoman cities in the Balkans (Pinon, 2008), which reflect the social norms brought by the Islamic culture centered on the privacy of households and the lack of connections between the quarters, although they were wider than traditional Islamic cities. The streets were lined with high stone walls that usually lacked windows and were punctured only by gates whose size and detail symbolized the household status.

Between 1746 and 1846, the gravity center of the city had moved further north, as additional streets were open in the upper plain due to the subdivision or internal blocks and by the extension of peripheral streets both to the west and east. However, the spatial structure of the city shows little change both in terms of integration and choice during this time (Table 1), reinforcing the contrast between highly integrated north-south arterials and segregated residential quarters, and the complete lack of direct east-west connections between the quarters.

7. Shkodër During the Late Ottoman Period

The formation of the new city occurred alongside the maturing of Shkodër's traditional çardak house as a subtype of the Ottoman sofa house (Riza, 1972; Shpuza, 1995). In the old quarters, the house adopted to the land subdivision and medieval street network of the old quarters, occupying narrow lots with small yards and sharing party walls (Figure 3(c)), giving these quarters the character of an Ottomanized city. In the new quarters, the house was surrounded by large gardens (Figure 5(a)), and together with public buildings such as mosques, madrasas, baths, shops, and cemeteries, it crystallized into the urban fabric of a new Ottoman city.

By the mid 19th century, the city continued its shift on the upper plain, despite having passed its economic zenith following the end of the autonomous pashalik, the rerouting of trade routes in the Balkans, and the Mediterranean, and the population loss due to plague. The urban densification and expansion of the new city were accelerated by the relocation of Muslims from the old quarters after the diversion of the Drin in 1858, and the growth of Catholic quarters in the eastside (Gruber, 2006). While the traditional house was equally used across the religious divide (Figures 5(a) and (b)), plots and urban blocks were generally smaller in the Catholic quarters, thus producing scalar disparities in the built form, which are attributed more to differences in economic status than social norms. Despite the erosion of substantial parts of old quarters in 1858, the spatial structure of the city maintained the status quo, with small increases in spatial intelligibility (Table 1), while the Bazaar promenade kept its role as the street controlling most through movement in the city (Figures 6(a) and (b)).

[14] In 1846, three blocks on the west side of the new city exceeded 0.2 km^2 in area.

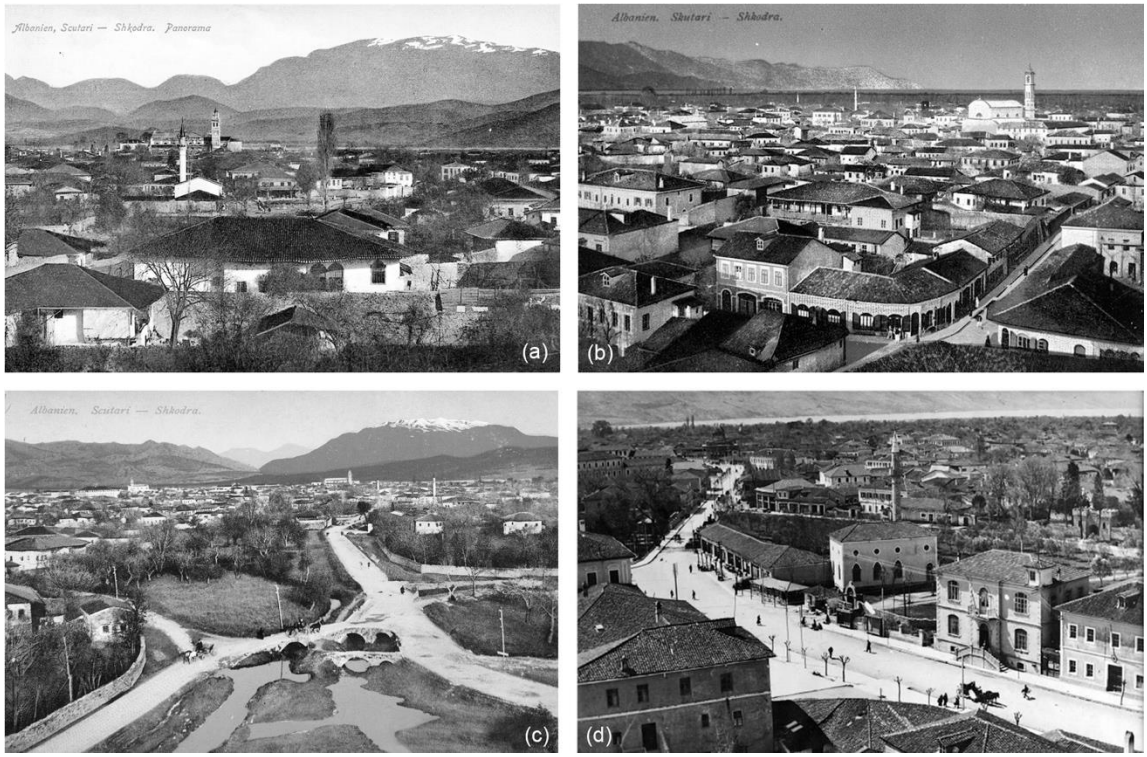

Figure 5 New part of Shkodër circa 1917: a) traditional houses with large gardens in Muslim quarters; b) densely clustered traditional houses in Catholic quarters; c) marshes separating the southern edge of the new city from the Bazaar; d) Great Rd. in the new city center.

During the second part of the 19th century, the new city had densified adequately in the upper plain and the integration core had expanded sufficiently northward, to give rise to a new urban center. The new center developed between Parrucë and Gjuhadol, rather than further west at Rus, where the two Venetian era roads split, given the extension of the city to the northeast. The consolidation of the new center was accelerated after several public works projects were completed, as per the Tanzimat modernization efforts across the empire (Çelik, 1986). The new boulevard Great Road (Udha e Madhe) connected the new center directly with the Bazaar by cutting through the middle of the old arterials; a second boulevard Skanderbeg Rd. connected Perash quarter in the east with the Bazaar; and a new administrative and military complex was built along Great Rd. (Tuzi et al., 2014). The opening of Great Rd. was followed by the construction of new shops along its northern segment which transferred some retail functions from the exobazaar to within the new city. The opening of the new boulevards led to the most notable increase in the city's spatial integration over the entire period of investigation (Table 1), and the shifting of the segment with the highest choice from the Bazaar to Great Rd. in the new city (Figure 6). Also, the integration core was strengthened into the Great Rd. and diminishing the role of arterials such as Dukagjin Rd. and Skanderbeg Rd.

By the end of the Ottoman period, the new city had matured by drawing all the administrative and military functions from the citadel, and a proportion of retail functions away from the old bazaar. The original medieval quarters had become further segregated from the new quarters and had rarified into remote suburbs of the new city. The spatial analysis of the new city, removing the old quarters and the bazaar, shows the highest integration and intelligibility of all historical stages (Table 1). Nevertheless, Shkodër's spatial integration and intelligibility by the end of Ottoman rule in 1913 are low compared to many contemporary cities in the region, given the lack of east-west connections between the quarters.

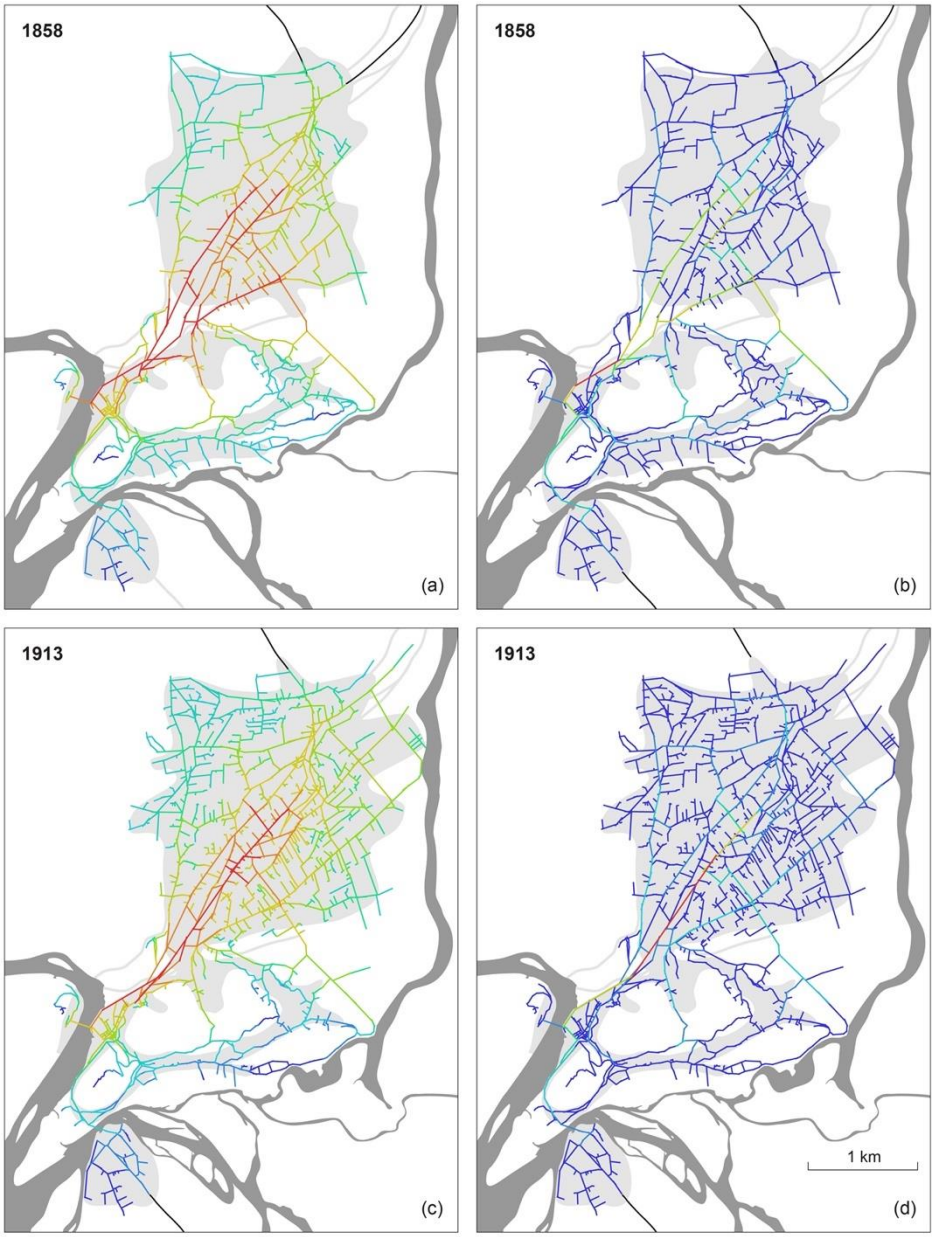

Figure 6 Axial map of Shkodër's street network during the late Ottoman period after the diversion of Drin (1858) and the opening of new boulevards (1913) colored according to values of integration (a, c) and choice (b, d).

8. Conclusion

Shkodër followed similar transformation processes to other Balkan cities whereby, on the one hand, the old quarters were Ottomanized after the insertion of Ottoman architecture into the medieval fabric while preserving unchanged the street network and land subdivision, and on the other hand, new suburbs developed as Ottoman urban fabrics of sparse dendritic street networks with large plots that accommodated detached houses surrounded by gardens.

The unusual physiography of the terrain surrounded by three rivers, two of which had changed course over time, led to Shkodër's unique urban form and transformative processes: First, given the presence of marshes north of the Bazaar, the new quarters developed disjoint leading over time to the crystallization of a new city away from its medieval center. Second, the main arterials that started from the Bazaar did not radiate into triangular superblocks as in other Balkan cities, rather they crisscrossed in the narrow strip of land bound by the canals. Third, due to the shifting of the Kir river, the eastern part of the upper plain became suitable for development later leading to a

gradual northeast expansion of the city thus a peculiar redistribution of the roles of the arteries in structuring the street network over time. Fourth, the erosion of the medieval quarters after the diversion of the Drin led to both the densification of the new city and the gradual segregation of the remaining old parts.

Shkodër is located not far from the fault line that divides east and west, surrounded by a hinterland that partially converted to Islam and partly maintained the Roman Catholic faith. After the entire urban population emigrated to Venice in 1479, Shkodër originally reemerged as a city with a Muslim population, while Catholics were allowed to settle only in 1700. By the second half of the 19th century, the Catholics had concentrated in the quarters in the northeast of the new city. Given the preference of the Muslims for large gardens that supported small-scale agriculture, and the lower original economic status of Catholic families, the northeast quarters developed with a denser urban fabric based on smaller plots compared to Muslim quarters in the west, albeit using the same traditional house type. The subsequent densification of the street network toward the northeast led to the shifting of the integration core away from the ancient arterial Dukagjin Rd (Via Publica) to the new boulevard Great Rd. further east., and the creation of a new center in the upper city. The study of Shkodër's history of urban form is important for informing historical preservation and urban design and contributes towards comparative and historical urban studies in the region and beyond.

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Resume

Ermal Shpuza is a Professor of Architecture at Kennesaw State University, USA. His research interests span spatial analysis, urban morphology, complex systems in cities, workplace design, and design computing. He studies the evolution of Adriatic and Ionian coastal cities, urban transformation in the Balkans, shape description, the affinity between block shape and street patterns, and interaction between floorplate shape and circulation in buildings. He teaches courses in spatial analysis, urban design and planning theory, and environmental technology, and studios in urban design and environmental design. He received his architectural education from the Polytechnic University of Tirana, the Bartlett, University College London, and the Georgia Institute of Technology.

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Investigating morphological changes of a capital city: The case of Ankara

Melike Boz Günay*
Ayşe Sema Kubat**

Abstract

Capital cities have a major role in carrying the symbolic meanings of their countries. Planning decisions and historical periods affect their urban forms and development processes. This research examines the morphological evaluation of Ankara—the capital city of Turkey—and provides an approach to understanding its unique physical structure. Ankara has witnessed strategically important planning periods through its history that are reflected in its urban form. The historical periods affecting the developing process of the capital city are analyzed through a mathematical method called "Space Syntax" which contributes to the field of urban morphology with a quantitative perspective. The analytical framework investigates the changing process of Ankara's unique urban axis and morphological structure. Its different historical periods show that the capital city is constantly changing. Ankara's monumental city axis, which shows its traces since the formation of the city, still exists today. However, this unique axis, which connects the historical core areas of the capital city, has lost its potential today. Due to economic and political demands, the main axis, namely Atatürk Boulevard, has been replaced by a newly formed western artery. Understanding Ankara's forming and changing process will enhance its subsequent development plans. By evaluating a unique capital city from Turkey with a morphological perspective, this research will contribute an approach to future studies.

Keywords: Ankara, capital city, urban morphology, space syntax

1. Introduction

The phenomenon of urban change is one of the most significant issues to evaluate a city's evolving process from past to present. Planning and design decisions developed for cities are the main factors that contribute to the changing process. These strategic decisions affect the city formation on macro to micro scales. As cities develop and grow, the morphological character of the city changes and capital cities have the central role affected by this change. Capital cities have a character for being a symbol for their countries that makes them special. Each capital city in the world has different historical, economic, cultural, and political backgrounds, and the city form is evolved around the effects of these processes. Urban morphology provides a multi-disciplined research area by examining the reflections of these effects on the urban form. Through

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morphological analysis of a capital city, this research aims to understand its unique urban structure and the factors of the city's having a role as a capital.

This research focuses on Turkey's capital city—Ankara—affected by many planning and design decisions throughout its historical development process. In turn, they have brought many changes to the morphological structure of the city. This research examines whether or not the special areas that carry a distinct role in a city's becoming the capital have maintained their meaningful existence until today. The characteristic features and planning processes from past to present, which make a city unique and make it the capital, are analysed morphologically with the Space Syntax method, a special mathematical approach.

2. Conceptual and Theoretical Background

Urban morphology, which contributes to urban form investigation on various disciplines, is the main approach behind this research. Rapaport (1977) emphasises that city is a system that includes many economic, social, cultural, political, and historical backgrounds. As an interdisciplinary field, urban morphology has the opportunity to reflect the past and future goals of the city (Malfroy, 2004). In this context, changes in the urban form will bring about differences and transform the physical environment. Therefore, it is critical to analyze forming and developing processes of the cities and evaluate them from a morphological perspective.

Many countries in the world are known for their capital cities. Their symbolic meanings affect the city's urban character and development strategy. In capital cities, it is observed that the spatial formation of the city and the political process are interrelated issues (Lefebvre, 1991). In the historical process, the first capitals emerge as central areas representing the political system for their countries (Kılınç, 2013). In the east, countries such as Mesopotamia, India, and China, and in the western world, the same aim is observed in the establishment of many of the cities belonging to the Renaissance Period (Tankut, 1990). When the formation and development processes of capital cities in history are examined, Washington, which was founded in the late 18th century, Ankara, which was established in the first half of the 20th century, Brasilia and Islamabad, which were established after the Second World War, have been chosen as the capital cities because of political and geographical differences. However, what unites these cities at a common point is that they reflect the first urban planning processes for their countries (Kılınç, 2013).

Tankut (1990) explains the effects of economic, social, and political factors on urban form with four sample capital cities—Canberra, Ankara, Islamabad, and Brasilia—that carry the political decisions' effects on their urban structure with a striking common feature as shown in Figure 1. While the main goal in the establishment of Canberra is to be a national capital city, in Ankara, it is to create a city model that represents the Republican Period. The process of Brasilia's being a capital city is based on reflecting the economic development periods of the city. In Islamabad, the concept of nationality comes to the fore, aiming to symbolize the state.

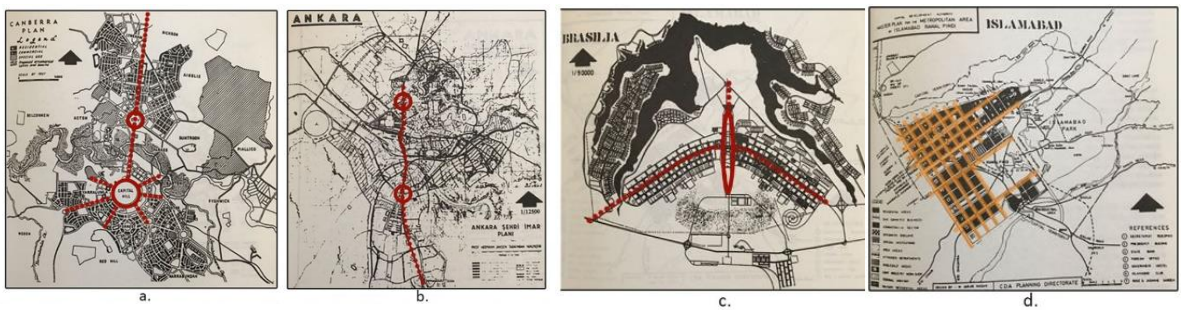

Figure 1 Plans of four sample capital cities (a. Canberra, b. Ankara, c. Brasilia, d. Islamabad; schematised by the author from Tankut, 1990).

Tankut (1990) defines the urban formation process as a nationality concept and states that the four example capital cities have a national symbol as their common feature. However, they have

different characteristics with their locations, political systems, histories, and the capital city images they reflect. The "created center" decision can be observed in Canberra, Ankara, and Brasilia, and the striking city axis draws attention in these cities. On the contrary, this decision is not observed in Islamabad; it is an example of a multifunctional capital city and has a regular plan open to growth (Tankut, 1990, p.18). However, the political effects can be obviously observed as a common finding in these examples through the existence of a special urban axis which the city shaped itself around. The leading inference that can be made from the study of Tankut's approach is that a city's becoming a capital is shaped around the specific factors and decisions which affect the city's development process.

The other distinctive research focuses on Brasilia's morphological transformation process (Holanda et al., 2015). The Space Syntax method provides an analytical evaluation to analyze the urban system in the mentioned research. Brasilia's changing urban development phases and centrality factors have been analyzed using the Space Syntax method's parameters. It has been analyzed to what extent the urban parts that form Brasilia have an integrated structure, and the spatial structure has been analytically characterized. In addition, the urban qualities that form the central functions have been examined through Space Syntax. In the study, it has been observed that the central core of the capital city, which has been originally planned, does not carry this potential today. This result can be explained by the representation of three centres belonging to the city as shown in Figure 2: the functional centre where business and service activities are concentrated; the demographic centre that minimizes the distances of the city; the morphological centre, which is topologically the most accessible area of the city. As a result of the study, it is mathematically observed that Brasilia's main city axis and specific urban centres are in changing conditions.

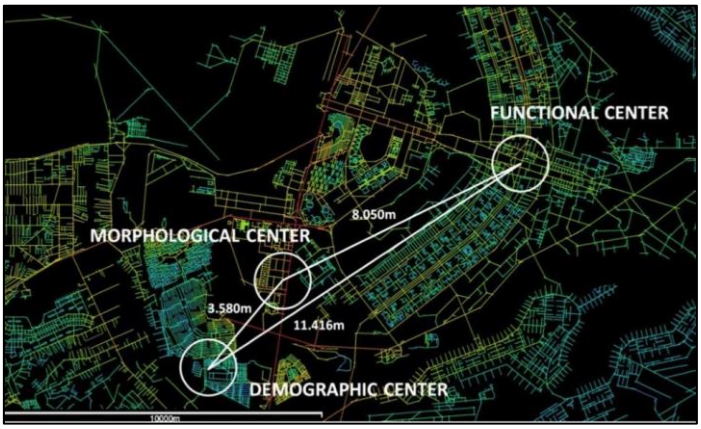

Figure 2 Deformation of Brasilia's city centres obtained by Space Syntax analysis (Holanda et al., 2015).

In this context, Turkey's capital city Ankara has a unique meaning by carrying the effects of the special historical, cultural and political process, especially from the Country's Republican Period of 1923 to today. In the light of the previous studies, this research analyses Ankara's changing urban structure and morphology.

3. Methodology

Analysing a city's physical structure using a holistic approach brings an evaluation of all the interacting elements within the city (Herbert & Thomas, 2013). Kropf (2017) defines urban morphology as a representation of researching, studying, and thinking tools to understand and interpret the urban environment. Examining the morphological changing process of a capital city presents a perspective to evaluate the conditions of its historical periods.

The research proposes using Space Syntax as a tool to evaluate the planning periods affecting the historical development of Ankara. This special morphological theory—developed by Bill Hiller

and Julienne Hanson and colleagues at UCL—provides a demonstrable frame to understand the urban system and its physical evolution (Kubat, 1999). The aim behind this technique is to explain the connection between the society and urban environment (Kubat, 1997). Space Syntax allows us to understand social relations and their reflections on the morphological structure (Hillier, Hanson & Graham, 1987). By presenting a quantitative view to the analysis of the changing conditions of cities, Space Syntax is a frequently used research method (Hillier & Hanson, 1984).

Space Syntax contributes a morphological approach to analyse the physical conditions of the city while evaluating the relationships between society and urban structure. In this study, the physical analysis of the city has been started by considering historical periods. The capital city's historical plans and documents of each determined period are converted into axial maps. Additionally, these maps, which are an axial representation of each determined historical period of the city, are converted into segment maps to analyse the city's morphological structure more accurately. These maps created from the historical plans are analysed in the Depthmap programme which allows the interpretion of the changing structure of the city with tables and graphics. Space Syntax measures the connectivity, integration, and choice values of the historical periods evaluated in the research. Thus, a comparative framework on mathematical data is presented by using various parameters in the analyses. The urban system and its spatial relations can be reached in a more understandable frame through these measurements (Hillier & Hanson, 1984). By evaluating local (R:400, 800) and global (R:n) radii, Ankara's historical and planning periods can be observed through a comparative perspective morphologically at the city scale.

4. Findings of the Morphological Change of Ankara

Turkey's capital city Ankara was born in Anatolia, known as a place like a steppe (Işın, 2009, p. 11). Ankara is a special city representing the Republican period, and a cultural transmission belongs to this unique process.

The Declaration of the Turkish Republic reflects a significant period that shaped the urban character of Ankara as the capital city. Most of the studies about the capital city Ankara define the Republican period as a symbol of national identity (Bayraktar, 2016; Işın, 2009; Cengizkan, 2009) and representation of modernism. This study considers the special period as a breaking point for the evolution of Ankara's morphological structure (Figure 3). The historical periods analysed by the study have been shaped around this perspective. Therefore, both the urban system before the declaration of the Republic and the planning periods created after that time and the current city situation are analysed in this research.

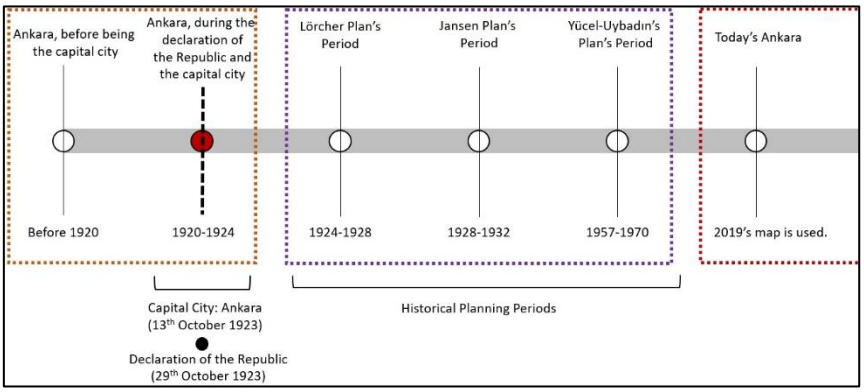

Figure 3 The historical periods examined by the study with Space Syntax method.

The data evaluated within the scope of the study are the plans of the Lörcher period (1924-28), Jansen period (1928-32), and Yücel-Uybadın Period (1957-70), the three main planning periods that affect the urban development of Ankara, and the map reflecting its current condition. Additionally, the 1839 map, which reflects the urban structure of Ankara before it became the capital, and the 1923-24 map, which represents the period when the Republic was declared, and the city was the

capital, are analysed with their axial maps (Figure 4). In determining the maps of the mentioned periods, the reachable data is a limitation of the study. The implementation process of the study is based on the analysis of these six periods with the designed methodological frame shaped by Space Syntax (Figure 5).

Figure 4 The axial maps of the analysed historical periods (a. 1839 map; b. 1924 map; c. Lörcher Plan; d. Jansen Plan; e. Yucel-Uybadin Plan; f. Today Ankara).

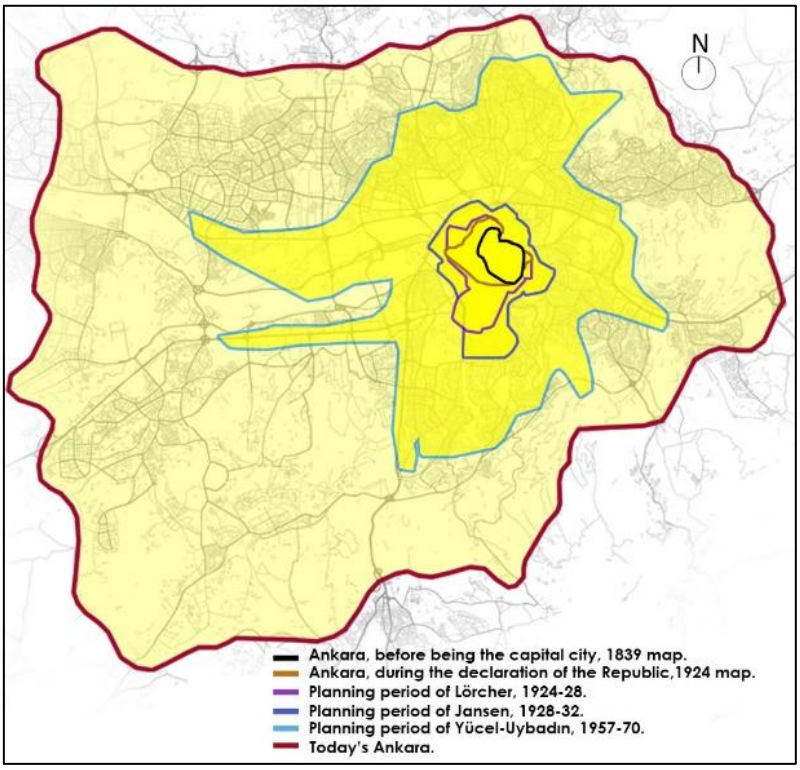

Figure 5 The city boundaries of the six periods analysed.

4.1. Historical periods

The first map evaluated within the analysis of the study belongs to the year 1839 and has a critical role in that it reflects the first known borders of Ankara (Cengizkan, 2009). This historical map contains the first traces of Ankara's macro form shaped by its geomorphological urban structure. When this map is analysed spatially, Ankara is surrounded by castle walls in the historical period before it became the capital city, and an organic pattern of structure is observed (Figure 6). The settlement was shaped around the Ankara Castle, and the circulation in the city can be described with thin and long roads.

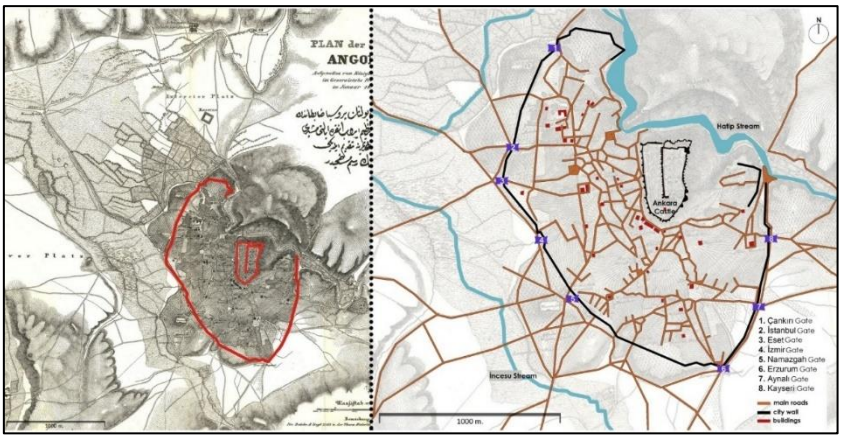

Figure 6 The 1839 map & its spatial analysis.

By the 1920s, the process of Ankara being the capital city and the declaration of the Turkish Republic brought about the necessity of phases to be taken for the physical condition of the city and planning decisions. The first preparation in this period was to develop the city's growth opportunities with the Ankara Castle and its surroundings, which represent the city's historical centre. The 1924 map has a significant role in reflecting the urban system as a map during the period when Ankara was the capital city. It is an inevitable process that the effects of the developing new administrative period will directly reflect on the morphological structure of the city. This map's spatial analysis provides information about the growth directions of the city and the traces of the new representation spaces reflecting the Republican period (Figure 7). In the 1924 map, a representative urban axis can be observed. This unique axis is Atatürk Boulevard (known as Bankalar Street in that year), connects the old and new city and reflects the Republican period (Keskinok, 2009). In these years, the city needs to experience development on the axis of Atatürk Boulevard, especially while the location selections for the new buildings relating to the Republican period were made. This unique urban axis is essential in connecting the old and new centres of the city. Additionally, it has a significant role in reflecting the capital city's economic, social, cultural, and historical transformation. Atatürk Boulevard is evaluated as a strategically important city axis for this research.

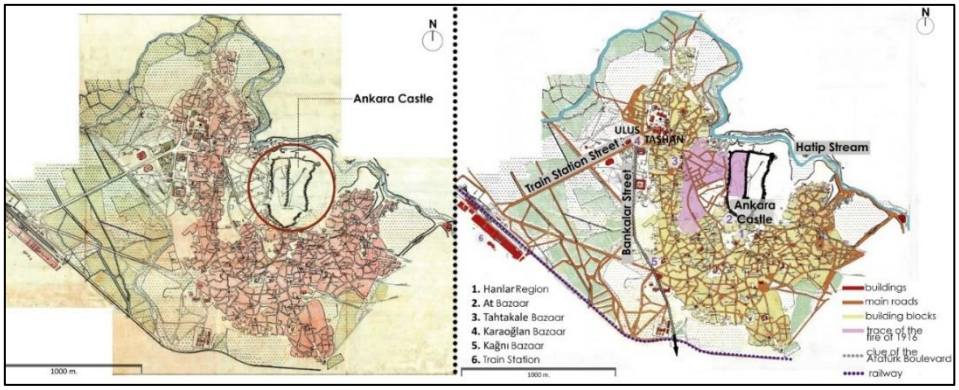

Figure 7 The 1924 map & its spatial analysis.

Lörcher's Planning period (1924-28) shows the first planning decisions of the capital city Ankara. This plan's decisions include growth strategies in the south of the city, Ulus representing the old city, and Kızılay representing the new city in the direction of growth emphasised (Figure 8). In these planning decisions, historical buildings reflecting the Republican period have been located in Ulus, while the Kızılay region houses the administrative units. The urban element that provides a strong connection between these two city centres is Atatürk Boulevard. In this period, the city's morphology was formed by the streets, squares, and regions around the boulevard.

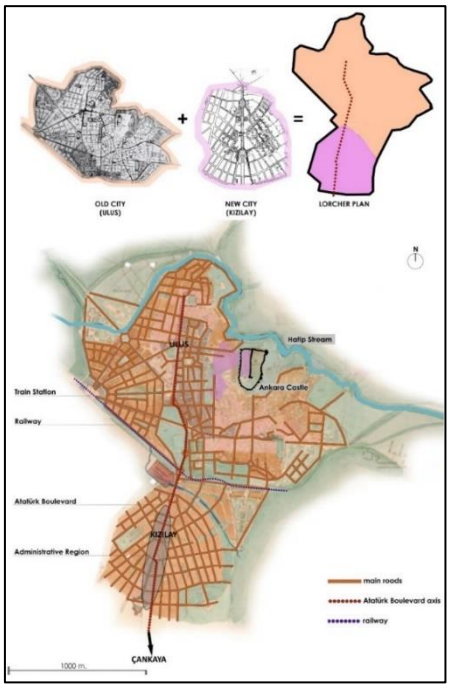

Figure 8 Lörcher's Planning Period (1924-28) & spatial analysis.

Jansen Planning decisions (1928-32), which continue the traces of the Lörcher Plan, were put into practice with international competition. This period proposes the strategy of zoning in the city regions. Jansen's planning approach concentrates on the idea of the development of the urban system on Atatürk Boulevard. The role of Atatürk Boulevard as a bridge between the old and the new city centres became more striking in this period. Also, the cultural, educational, and administrative buildings were located on this monumental axis. Considering the spatial analysis of this period, Ankara's main growth direction has been determined towards Çankaya in the south. However, Ankara Castle has been used as a representation symbol in the Ulus region, the old city centre, and new constructions have been settled there (Figure 9). Jansen's emphasis on preserving the traditional pattern of the city by considering the old and new city centres together in the urban planning decisions also carries clues about which processes play a role in the change of the morphological structure of the capital city. In this context, the monumental Atatürk Boulevard axis had a strategic position. In contrast, the core regions of the city have been extended from Ankara Castle to Çankaya direction with a preservative approach for this period.

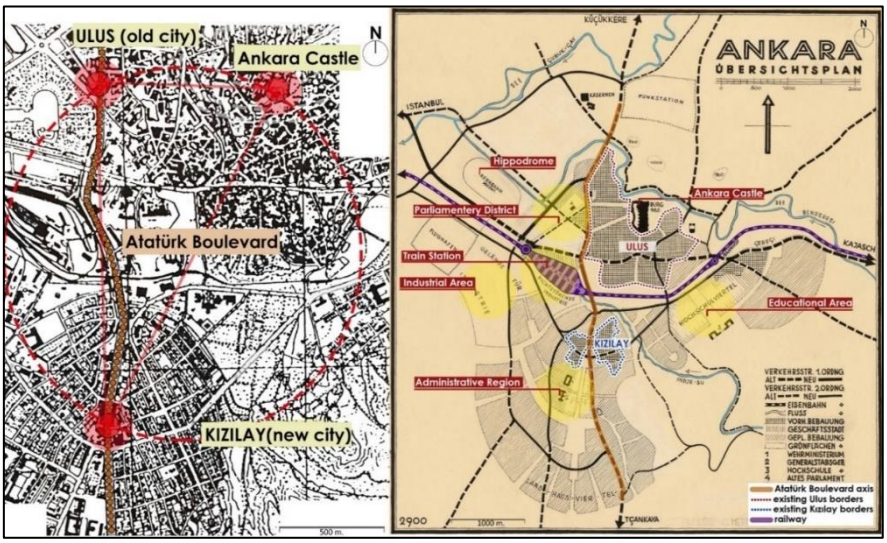

Figure 9 Jansen's Planning Period (1928-32) & spatial analysis.

Yücel-Uybadın Plan (1957-70) has been implemented as a result of an international competition at a time when the population of the capital city increased considerably. This period aimed to prevent urban sprawl with this plan, which was created to control the increasing population (AMM, 2006). However, the unpredictable population growth led to illegal buildings in the city (Figure 10). This planning period had been created when the rate of urban development and the increasing population was high and became a period when the number of buildings and parcels increased throughout the city compared to the previous Jansen period. Because of this condition, the number of buildings and parcels has increased throughout the whole city compared to the previous Jansen period. Günay (2006) states that this period did not have the form-seeking approach of the Jansen and Lörcher planning periods. It is generally thought that this period had not strategically directed the development of a capital city.

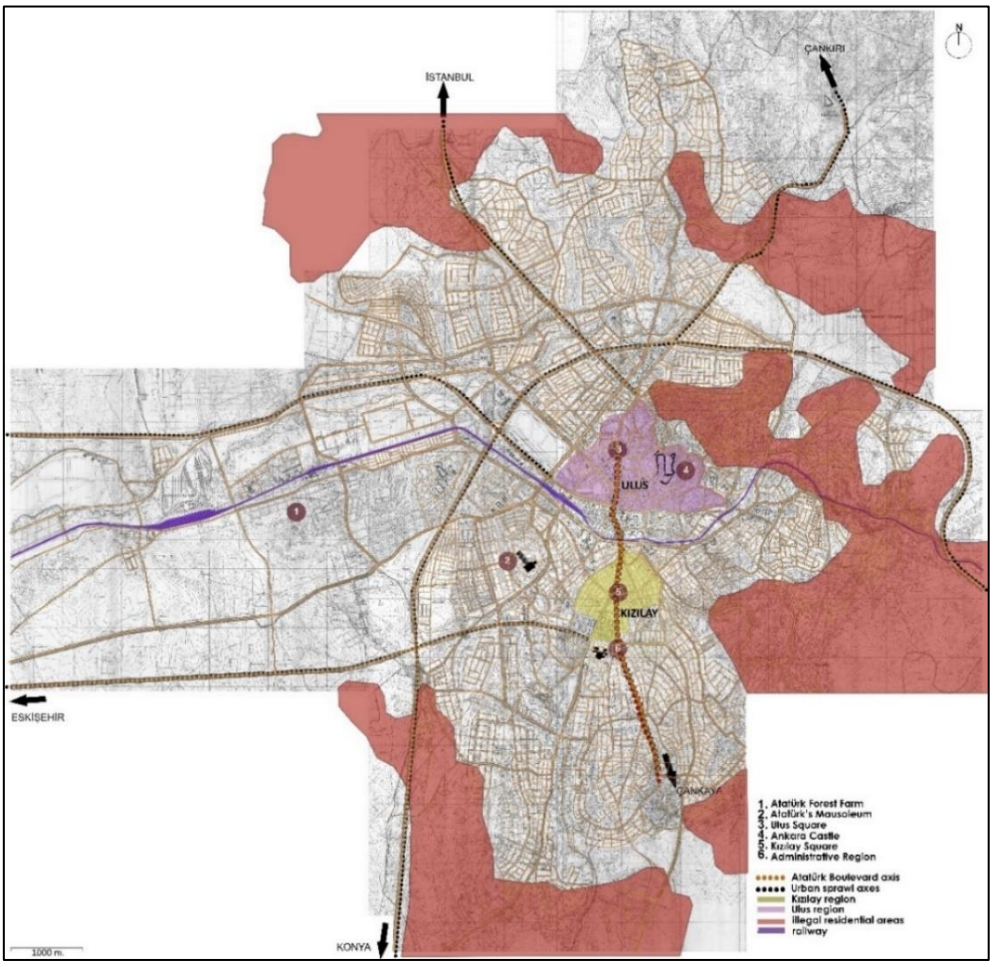

Figure 10 Yücel-Uybadın's Planning Period (1957-70) & spatial analysis.

Since the 1970s, the development in the urban model has affected the city as an uncontrolled growth process. Essentially, since the Jansen Plan, the need for a comprehensive master plan has been emphasised (Günay, 2006). For this purpose, the 1990 master plan has been developed, which has the effects of the current urban system of Ankara (Figure 11). An increased urban circulation axis and many interaction arteries are observed in current Ankara's urban morphology. It can be concluded that the effective potentials of the old city centres Ulus and Kızılay have decreased when today's condition is evaluated within the uncontrolled growth process of the city (Figure 12). Especially since the 2000s, increasing shopping malls, high-rise offices, and residential blocks and the problem of scale disorder in the city have become factors affecting the morphological structure of the city.

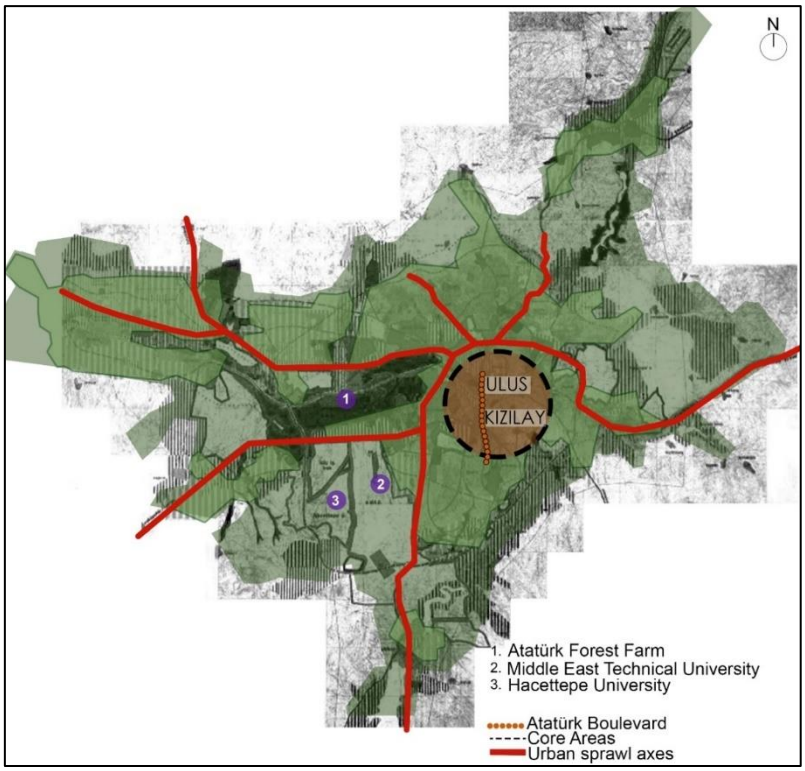

Figure 11 1990 Master Plan.

By evaluating the distinctive planning decisions and historical periods of the capital city Ankara, the morphological structure of the city's changing process is observed with historical maps and images. As a result of these observations, it is deduced that Ankara's urban system is shaped by the effect of its geomorphological features, and the central core areas emphasise its capital city character. Atatürk Boulevard, which is the main urban element in the capital city, has shown its potential throughout all periods as a monumental city axis. However, it is concluded that the existence of this axis in the historical periods has gradually lost its strong character due to the appearance of different city axes. The most critical milestones of examined different periods are explained in Figure 13.

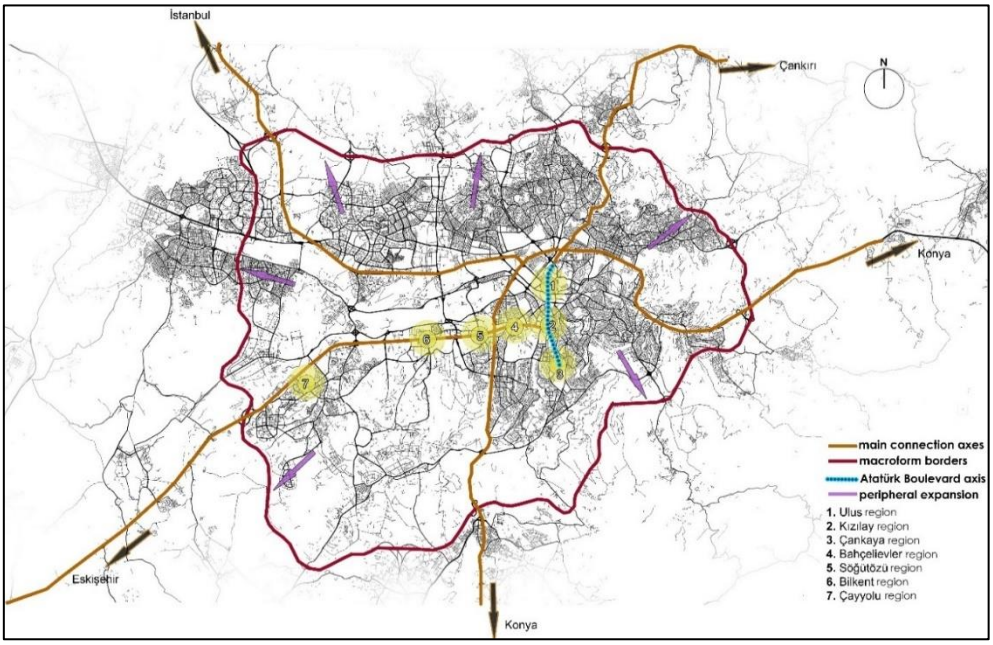

Figure 12 Today Ankara & spatial analysis.

	Before being the capital city (1839 Map)	During the declaration of the Republic (1924 Map)	Planning Period of Lörcher (1924 - 28)	Planning Period of Jansen (1928 -32)	Planning Period of Yucel-Uybadin (1957 - 70)	Today Ankara
Spatial Inferences	• city walls • commercial areas • organic pattern • Ankara Castle • Ulus region as symbolized core area	• Ankara Castle • Train Station • commercial areas • Atatürk Boulevard traces (known as Bankalar Street) • traces of the new direction to the south	• old city: Ulus new city: Kızılay • connection between the old and the new city (Atatürk Boulevard) • railway	• zoning decisions • city triangle = Ulus (old city) - Kızılay (new city) - Ankara Castle • Atatürk Boulevard as a bridge between old and new city	• urban sprawl • decreasing potential of the Atatürk Boulevard • new city directions mostly to the west • increasing buildings and parcels	• growing macroform • new city centres • decreasing potential of the Atatürk Boulevard • strengthening of the west axis

Figure 13 The spatial effects of the examined periods on the city.

4.2. Application of the method

Space Syntax analyses aim to explain the urban change affected by the planning decisions and historical periods in the capital city's morphology with an analytical approach. Axial maps are created of all examined periods, and then each period is evaluated comparatively with mathematical parameters to explain the changing process of Ankara.

While the total number of axes is 364 in the 1839 map representing Ankara before it became the capital city, the total number of axes is 613 in the 1924 map reflecting the period when Ankara was declared the capital city. In both maps, it can be observed that the city has been formed on the same axis. On the 1839 Map, the longest axis in the city is 726.66 m., and it was the connection that provided access to the Namazgah Gate, which is located outside the city wall. On the 1924 map, the longest axis in Ankara is 1731.86 m. It has been determined that it connects the city to the train station and the surrounding city. In the Lörcher Period (1924-28), the first planning experience of the city and the connection of the old centre to the new centre has been put forward; the total number of axes was 380. According to the 1924 Map, the value of almost half has a striking result. This decrease is the many organic streets in the 1924 Map, especially around the Ankara Castle, and the planning of the street layouts in the city with longer viewing distances. However, during the Lörcher Plan Period, the longest axis was 1399.54 m. It is observed that Atatürk Boulevard stands out as the connection line of the old and new city with its syntactic value. During the Jansen Plan Period (1928-32), the total number of axes increased to 830, and the longest axis was 2630.43 m. It was the line designed as one of the leading transportation links descending from the outer periphery of the city to Ulus. The existence of Atatürk Boulevard in this period is still remarkable, but it did not show the feature of being the longest line due to the interruption of the axis on the connection points between the viewing distances. In the Yücel-Uybadın Period, when the urban growth rate increased, the total number of axes was 3928, and today it has reached 23177. These values are shown in Table 1.

Table 1 Quantitative analysis of axis, segment and connectivity.

	Ankara, Before being the capital city (1839 Map)	**Ankara, During the declaration of the Republic** (1924 Map)	**Planning Period of Lörcher** (1924 - 28)	**Planning Period of Jansen** (1928 -32)	**Planning Period of Yucel-Uybadin** (1957 - 70)	**Today Ankara**
Total number of axial lines	64	613	380	830	3928	23177
Min. (m)	21.21	15.46	21.43	16.75	25.43	10
Mean (m)	149.06	106.23	227.73	234.56	261.85	590.02
Max. (m)	726.66	1731.86	1399.54	2630.43	6019.74	9339.85
Total number of segments	809	1518	1236	1792	10234	55272
Mean (m)	58.48	37.48	63.55	99.36	89.49	65.96
Mean Connectivity	3.71	3.89	4.35	3.68	4.06	2.93

By focusing on the connectivity values, which are used to measure the degree of connection of each line with others from the axial maps, it is observed that the streets with the lowest connection are located in Ulus, which represents the historical city (Figure 14). On the other hand, Atatürk Boulevard has maintained its potential by having the highest degree of connectivity in all periods. This considerable result strengthens the role of Atatürk Boulevard as the city's main artery. However, the connectivity values of the central points located on the monumental axis Atatürk Boulevard have lost their strong character today.

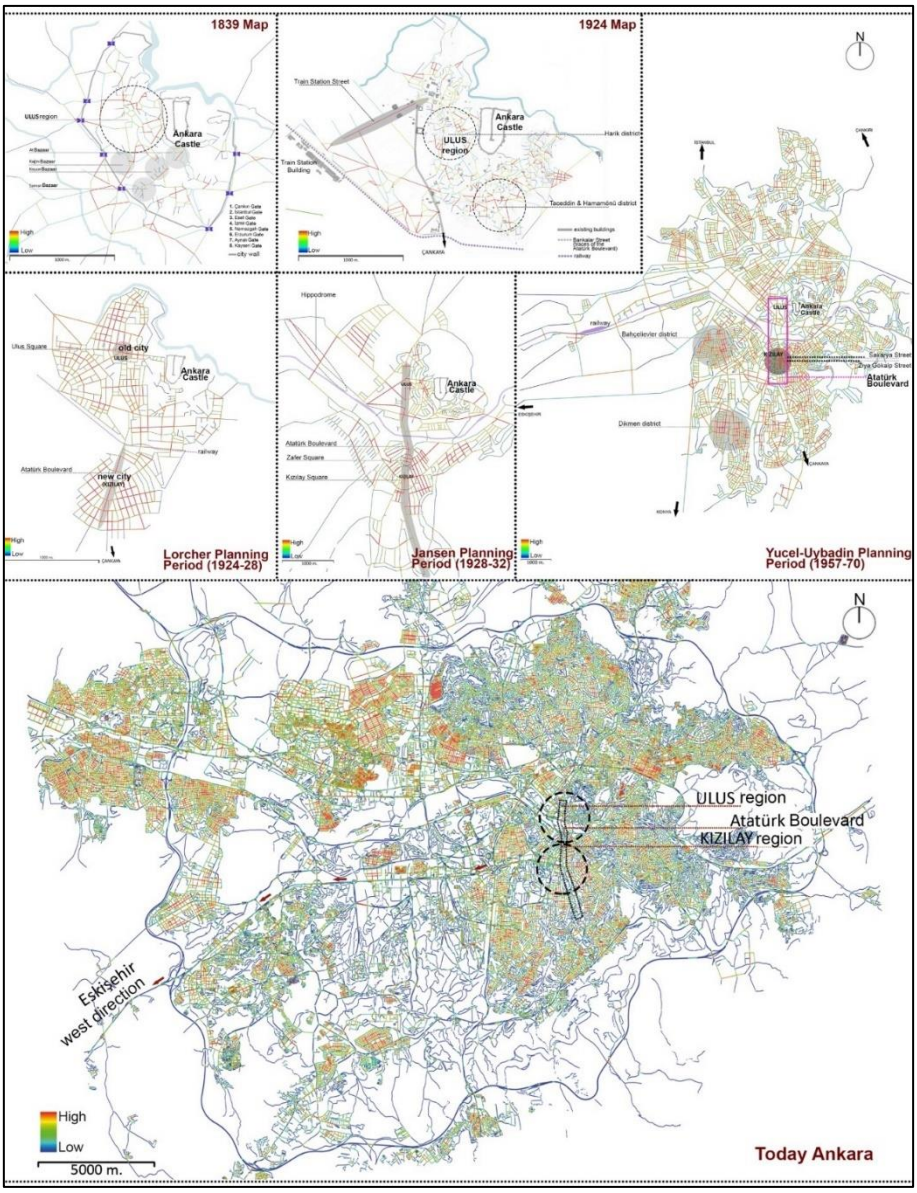

Figure 14 Connectivity maps.

The integration measurements of the examined periods from the segment maps, global and local values that give information about the accessibility values of each network at different scales have been examined (Table 2). In global integration (Rn) analysis, a high value means high accessibility, while in local measurement, the accessibility values of walking distances are reached (Al_Sayed et al., 2014). It is observed in the analysis of global integration values that as the city has growth points, the values of Ankara Castle and its surroundings in Ulus, which represents the old city, decrease. This situation gives clues about the morphological development process of the capital city. As shown in Figure 15, it is determined that Atatürk Boulevard continued its strong role until the Yucel-Uybadın Plan Period, but in this period, there is a decrease in its potential with the

existence of the western corridor, which is a new transportation axis. It is determined that the integration values of the central cores of the city have decreased as it came to today's condition at both the global and local scales.

Table 2 Global and local integration values of the historical periods.

		Ankara, Before being the capital city (1839 Map)	Ankara, During the declaration of the Republic (1924 Map)	Planning Period of Lörcher (1924 - 28)	Planning Period of Jansen (1928 -32)	Planning Period of Yucel-Uybadin (1957 - 70)	Today Ankara
Global Integration (Rn)	**Min.**	0.29	0.38	0.46	0.31	0.46	0.2
	Mean	0.61	0.64	1.03	0.85	0.9	0.77
	Max.	1.5	1.03	1.57	1.37	1.39	1.2
Local Integration (R400)	**Min.**	0.53	0.53	0.51	0.39	0.54	0.35
	Mean	1.22	1.02	1.03	1.31	1.33	1.19
	Max.	2.66	2.35	2.08	3.42	3.04	3.07
Local Integration (R800)	**Min.**	0.32	0.43	0.43	0.26	0.44	0.35
	Mean	0.95	0.82	1.27	1.09	1.17	1.04
	Max.	1.75	1.9	2.04	2.86	2.5	2.89

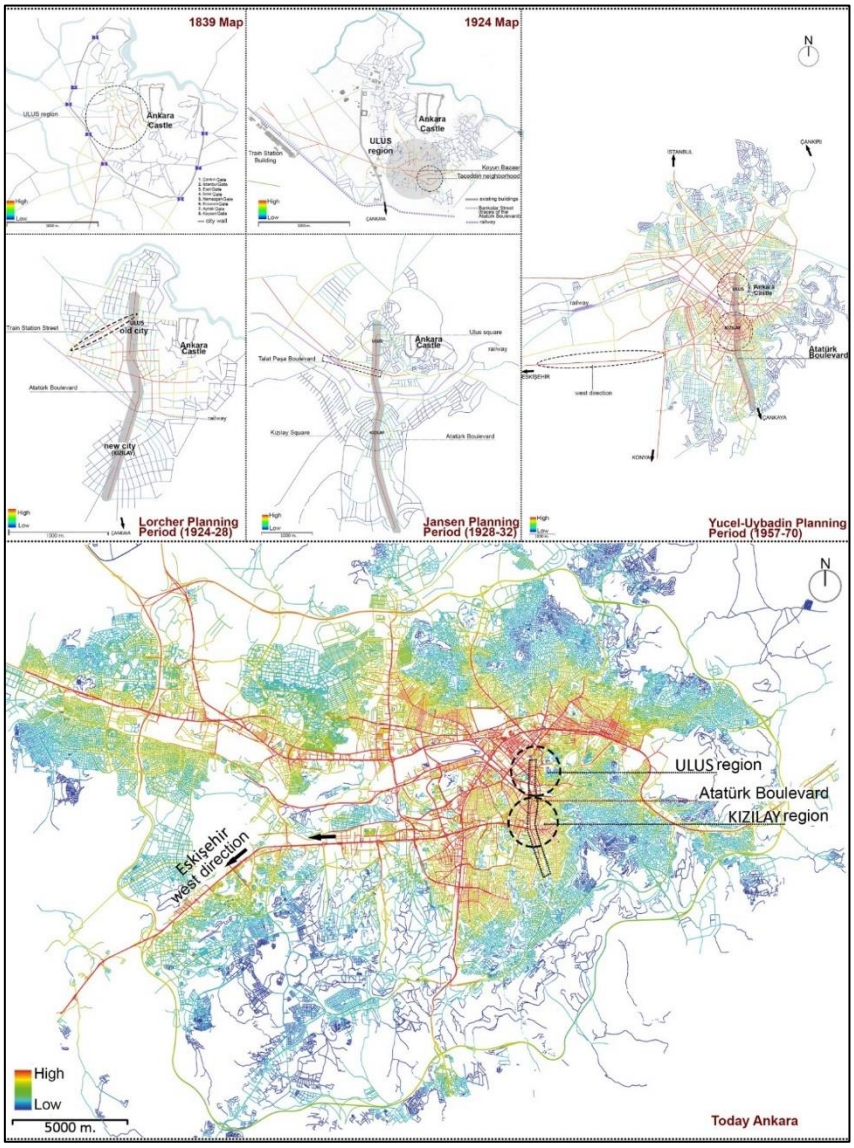

Figure 15 Global Integration (Rn) maps.

For the six evaluated historical periods, the choice parameter, which investigates the preferability level of the street networks in the urban system, has also been analysed at global (Rn)

and local scales (R400 and R800) (Table 3). In the 1924 map, when Ankara was declared the capital city, the area with the highest global choice value is in Ulus. As the periods progressed, it is determined that the choice level of Ulus was replaced by Kızılay (Figure 16). A significant result observed here is that the global choice level of the western corridor, which is the new axis showing its existence in the Yucel-Uybadin Plan Period, has a low result. This striking result showed itself with the same findings at local scales. In line with this result, the western artery does not have the same potential as the monumental Atatürk Boulevard in terms of its structural components and connection to the city.

Table 3 Global and local choice values of the historical periods.

		Ankara, Before being the capital city (1839 Map)	Ankara, During the declaration of the Republic (1924 Map)	Planning Period of Lörcher (1924 - 28)	Planning Period of Jansen (1928 -32)	Planning Period of Yucel-Uybadin (1957 - 70)	Today Ankara
Global Choice (Rn)	**Min.**	0.001	0.001	0.001	0.001	0.001	0.001
	Mean	0.86	0.85	0.95	0.89	0.9	0.86
	Max.	1.52	1.52	1.57	1.56	1.53	1.53
Local Choice (R400)	**Min.**	0.001	0.001	0.001	0.001	0.001	0.001
	Mean	0.86	0.92	0.97	0.85	0.94	0.92
	Max.	1.52	1.44	1.45	1.87	1.48	1.62
Local Choice (R800)	**Min.**	0.001	0.001	0.001	0.001	0.001	0.001
	Mean	0.89	0.9	1.01	0.93	0.99	0.94
	Max.	1.52	1.41	1.43	1.73	1.56	1.67

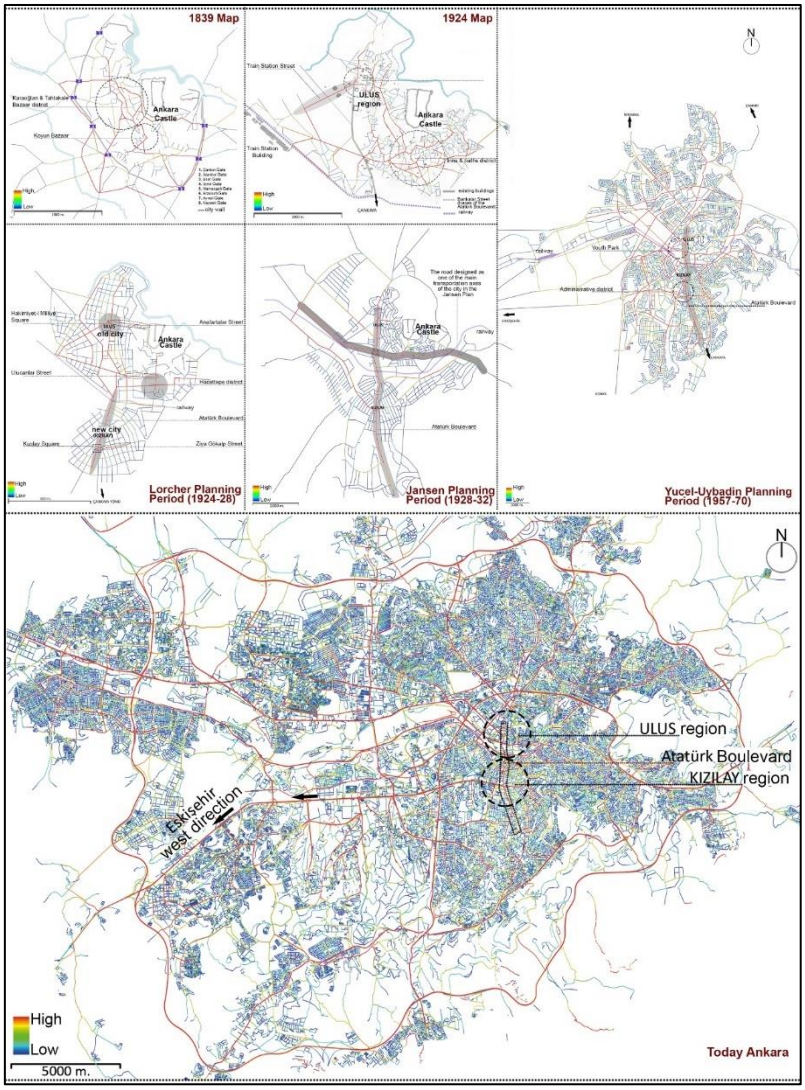

Figure 16 Global Choice (Rn) maps.

In the Space Syntax analysis, historical periods are examined, and the places that gave Ankara the role of being the capital city are determined in a quantitative framework. When the city is evaluated holistically, the historical core areas located on the monumental Atatürk Boulevard axis still have potential for Ankara. However, as the city grew and developed, the growth direction of the city changed, and new spatial constructs emerged in the westerly direction (Figure 17).

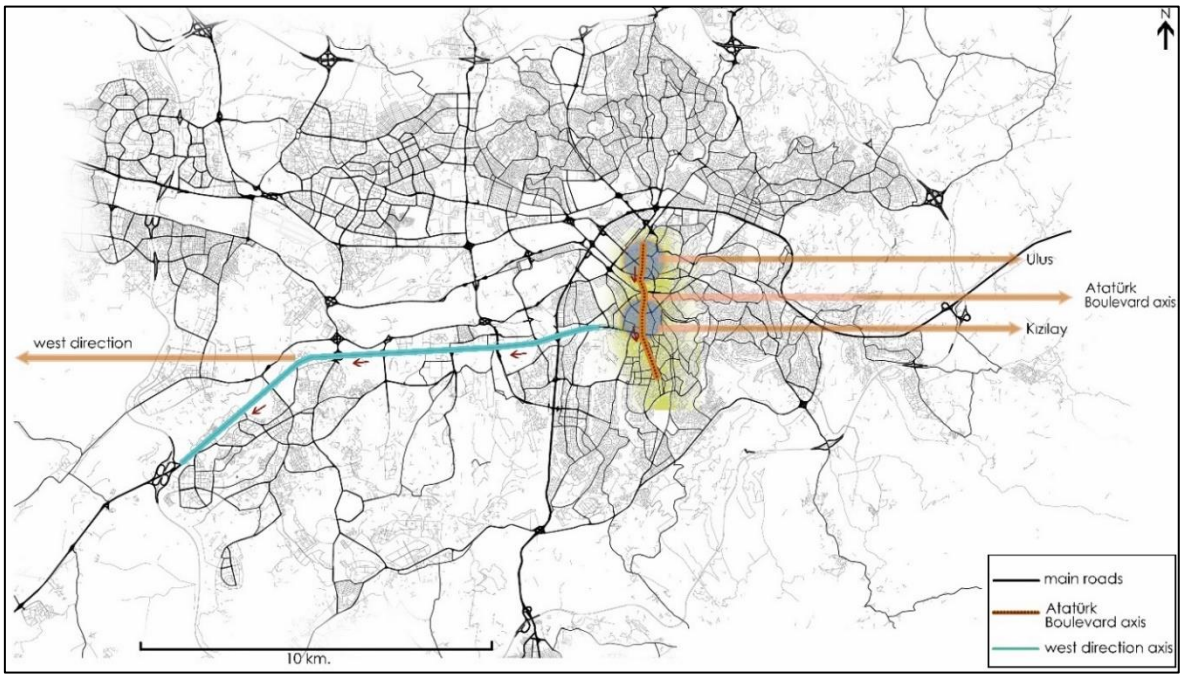

Figure 17 The evaluation of Ankara's current condition.

According to the analysis of the periods affecting the city, it can be concluded that the effectiveness of the symbolic areas of Ankara is decreasing when it comes to the present day. Although each period has main effective characteristic areas, these definitions differ as the periods progress. Space Syntax analyses have greatly contributed to distinguishing this observation. The physical reflections of the examined periods, which affect the morphological structure of the city, as a result of overall findings obtained from Space Syntax analysis are shown in Figure 18.

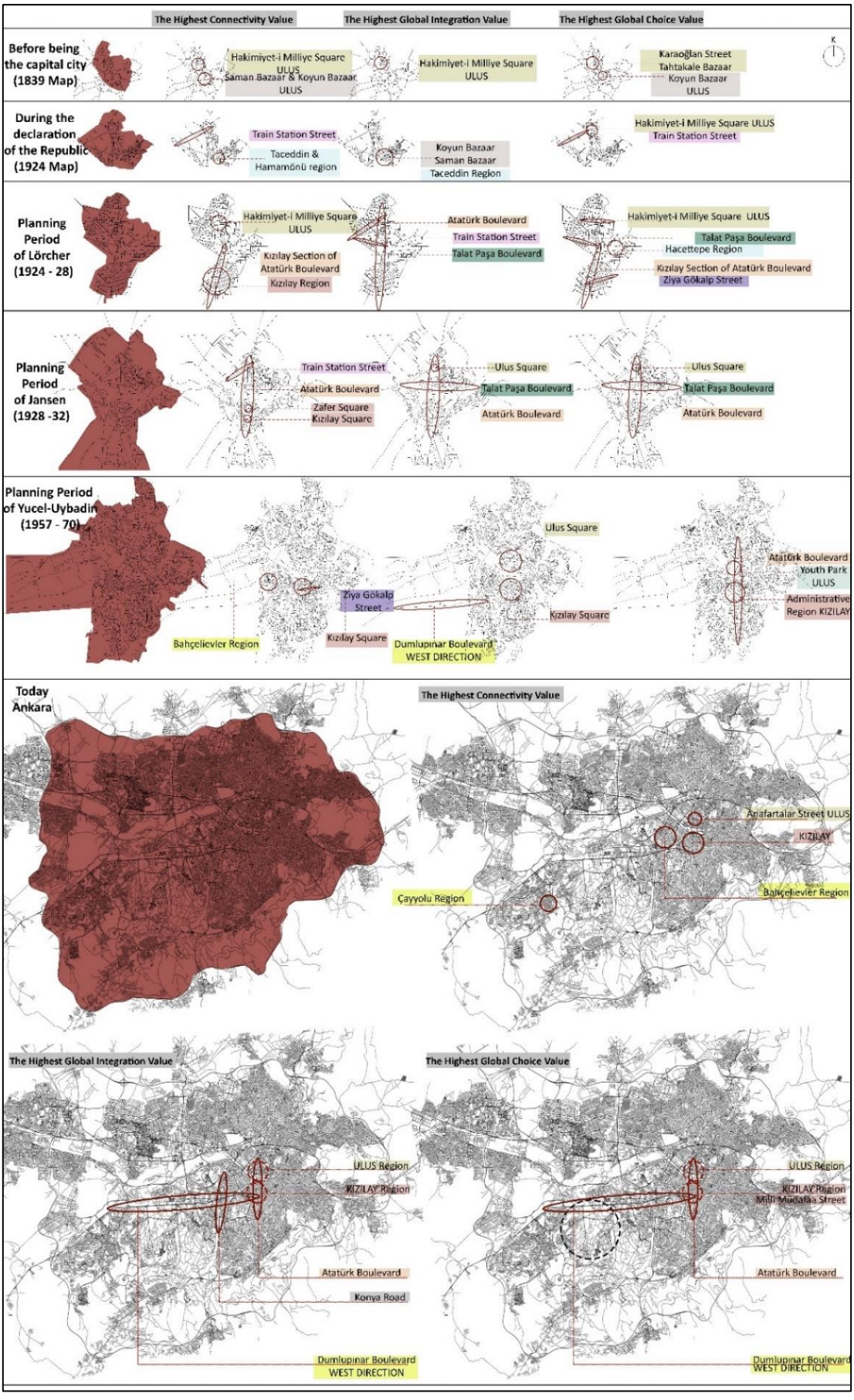

Figure 18 Space Syntax findings on the urban structure of Ankara.

5. Conclusion

The morphological analysis of the periods affecting a capital city's urban structure is the main consideration for this paper. By focusing on the physical evaluation of the periods that affect the city's urban development in light of a mathematical method, this research aimed to define the change in the urban system.

Using Space Syntax in the analysis of Ankara's—Turkey's capital city—changing urban system contributes a striking observation about where the planning decisions in the historical process affect the city, where they continue their existence in the city, and where they have entirely disappeared. Thus, obtained results from the mathematical approach provide a distinctive determination of the strategically spatial elements or places that have a major role in being a capital city. The inferences reached from the Space Syntax analysis are shown in Figure 19. As can be seen from this inference regarding the differentiation of Ankara's physical urban system, and confirmed by Space Syntax analysis, the potential of the historical core areas of the city has shifted towards the newly developing city axis today (Figure 20).

AREAS	Before being the capital city (1839 Map)	During the declaration of the Republic (1924 Map)	Planning Period of Lörcher (1924 - 28)	Planning Period of Jansen (1928 -32)	Planning Period of Yucel-Uybadin (1957 - 70)	Today Ankara
The highest connectivity value	Hakimiyet-i Milliye Square ULUS	Train Station Street ULUS	Hakimiyet-i Milliye Square ULUS	Train Station Street ULUS	Ziya Gökalp Street KIZILAY	Anafartalar Street ULUS
				Atatürk Boulevard ULUS + KIZILAY		Atatürk Boulevard KIZILAY
	Saman Bazaar Koyun Bazaar ULUS	Taceddin & Hamamönü Region ULUS	Atatürk Boulevard KIZILAY	Zafer Square Kızılay Square KIZILAY	Bahçelievler Region WEST DIRECTION	Bahçelievler WEST
						Çayyolu WEST
The highest global integration value	Hakimiyet-i Milliye Square ULUS	Saman Bazaar Koyun Bazaar ULUS	Atatürk Boulevard ULUS + KIZILAY	Ulus Square ULUS	Ulus Square ULUS	Atatürk Boulevard ULUS + KIZILAY
		Taceddin Region ULUS	Train Station Street ULUS	Talat Paşa Boulevard ULUS	Kızılay Square KIZILAY	Konya Road SOUTH DIRECTION
			Talat Paşa Boulevard ULUS	Atatürk Boulevard ULUS + KIZILAY	Dumlupınar Boulevard WEST DIRECTION	Dumlupınar Boulevard WEST DIRECTION
The highest global choice value	Karaoğlan Street Tahtakale Bazaar ULUS	Hakimiyet-i Milliye Square ULUS	Hakimiyet-i Milliye Square ULUS	Ulus Square ULUS	Youth Park ULUS	Ulus Square ULUS
			Hacettepe Region ULUS	Talat Paşa Boulevard ULUS	Atatürk Boulevard KIZILAY	Atatürk Boulevard ULUS + KIZILAY
			Talat Paşa Boulevard ULUS			Kızılay Square Milli Müdafaa St. KIZILAY
	Koyun Bazaar ULUS	Train Station Street ULUS	Atatürk Boulevard KIZILAY	Atatürk Boulevard ULUS + KIZILAY	Administrative Region KIZILAY	Dumlupınar Boulevard WEST DIRECTION
			Ziya Gökalp Street KIZILAY			

Figure 19 Space Syntax findings of the examined different periods.

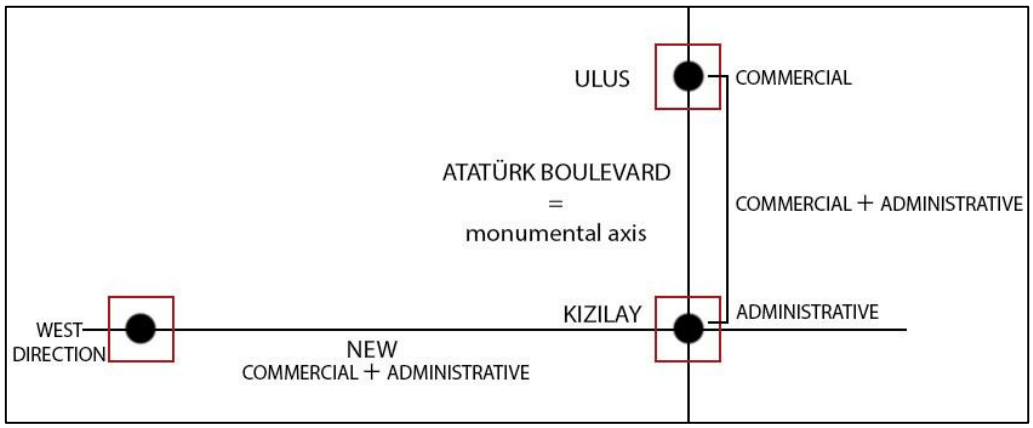

Figure 20 The schematic concluded inference about differentiated Ankara.

Economic, social, cultural, and political processes have remarkable reflections on Ankara's historical periods. By evaluating the capital city's urban system through Space Syntax, the changes caused by the mentioned effects on the morphology of Ankara are presented from a quantitative point of view. The differences between each examined period have considerable effects on the city's urban morphology and the concluded points are evaluated demonstrably. Regarding the change of the characteristics that give Ankara the role of being a capital:

- The city is in a changing condition, and it reflects the consequences of the process on its urban form.
- Atatürk Boulevard, which formed the administrative and monumental axis of Ankara from the declaration of the Republic, came to the forefront through syntactic values in historical periods at the findings of the Space Syntax analysis. However, this special axis has lost its characteristic feature of being the main city axis today. It still exists, but the western artery of the city has strengthened its potential due to the developing political and economic demands in the new period.
- The historical core centres of the city are still carrying the potential as observed in the quantitative analysis. It is significant to preserve and move them to the future by reflecting the importance of architectural, historical, and morphological characters.

The changes in the city from historical periods to today have affected the areas that shape Ankara's urban character. This research contributes to understanding a capital city's urban development process from comparative and quantitative perspectives. By analysing the changing structure of the city analytically, the importance of morphological evaluation is highlighted in the paper.

In this study, the changing morphological structure of the capital city has been demonstrated by Space Syntax analysis. Another phase of the study has been developed through a typo-morphological approach from an architectural perspective, in which the differentiation in terms of the characteristics, building materials, and heights of the buildings on the Atatürk Boulevard, which reflects the historical city, and the western direction, which reflects the new city, have been analysed. Thus, the formation and development process of a capital city is analysed on both a city and architectural scale using two different morphological methods. However, in this research, the changing process of Ankara is emphasised from a city scale using Space Syntax.

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Resume

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Mural as public art in urban fabric: An attempt to link configurational approach to perceptual morphology

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Olgu Çalışkan**

Abstract

The intrinsic relationship between art and the public has changed as public art has greater visibility in contemporary urban space. Especially following the growing interest in placemaking in spatial planning and design, many cities in different countries tend to experience an unprecedented transformation of urban space displaying various modes of artistic performances open for the public. As a visual art, the mural could be considered one of the leading creative activities in the cities' public domain. The ever-increasing popularity of murals as public artwork made the local governments tend to introduce some programs to steer the performance of the art within the very spatial condition of the city fabric. Along with its vivid cosmopolitan culture, Istanbul has performed as the cultural hub of the contemporary arts located both indoor (the various size of galleries) and the city's outdoor spaces. As one of the central neighborhoods in Kadıköy district in İstanbul, Yeldeğirmeni, represents a very relevant context to investigate the issue public art in urban space. Having accommodated an international mural festival in 2012, the district has turned into an experimental site for various mural practices. The extent of the art in the urban space calls for morphological research to test the perceptual performance of the artwork in terms of the characteristics of the physical fabric in which the murals locate. The paper, in this context, conducts a spatial analysis focusing on network integration, visibility, and townscape characteristics of the neighborhood fabric. The research findings are correlated with the level of recognition of the murals by the public to reveal the conditional relationship between the spatial morphology and the perceptional capacity of the murals as public art.

Keywords: public art, mural, perception, urban morphology, townscape

1. Introduction

The ways of reproduction of social life, which has been culturally transformed in urban societies, parallel the subtle transformation of the public space. With the advancement of social communication networks through intensive digitalization, human experience in physical urban space (i.e., activity, mobility, and perception) tends to change radically. Inclusivity of the public sphere is the historical character that has been formed and evolved by the mutual interaction of the free individuals (Habermas, 1997); therefore, it is characterized by the politics of democratic accessibility to the public space mainly through 'social expression' of the body (Negt and Kluge,

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1993). Since the Ancient Greek period, when the definition of the citizen was rather exclusionary (for women and slaves), the modern understanding of the public sphere has evolved through the multiple and pluralistic notion of the socio-space through different forms and practices (Arendt, 1958). At this point, art as one of the most vital expressions of human imagination and mind in the public domain represents a critical position for the future transformation of the democratic public space.

From that perspective, supporting the artistic creativity of the individuals and the right to self-expression has turned out to be critical strategies for the current urban policies aiming for sustainable transformation of public spaces in the cities (Landry, 2020; Hall and Robertson, 2001). In the recreational spaces and various programmatic spaces (i.e., educational, medical), urbanites of different ages are encouraged to experience the art and the artistic performance (Remesar 2005; Lovell, 2020). With its unique character, even a temporary artwork installed in a public space can positively impact the collective memories within common spaces of everyday life. Reshaping our imagination, public art is considered a kind of social practice that conditions the spatial memory of the city (Lovell, 2020). The public art forms which have a relatively shorter lifespan, such as graffiti and mural, mostly have no existence other than the memories of those who encounter and experience them in space (Erdoğan, 2014). Considering the conditional relationship between the patterns of perception and experience and urban space (Bosselmann, 1998), one could argue the critical role of urban design in the perceptional quality of the public works of art. As Phillips (1988) discussed, the publicness of art in space is highly dependent on the capacity of the artwork to be accessible by the public (Phillips, 1988: 97 cited in Ercan, 2013: 226). Therefore, it is necessary to carefully establish an effective relationship between the artwork and the urban space for better communication between the arts and the people. The desired accessibility condition, in this regard, could be set both visual and physical manner.

In that framework, following a brief discussion on public art and the city, the paper will problematize murals in the urban fabric regarding the issues of perception, morphological and townscape characteristics of urban form and structure. Recognition of the mural in the urban fabric as the perceptual performance of the public art is discussed via a set of spatial analyses conducted on the actual case of Yeldeğirmeni Neighborhood, Istanbul, Turkey. As one of the experimental areas of public art since the Mural Festival in 2012, the neighborhood suggests a relevant spatial setting to discuss the issue on a morphological basis. In the specified context, aiming to delineate the key spatial factors that influence the level of visual recognition of public art in a dense urban fabric, the research, initially, utilizes the configurational analyses of Space Syntax and Isovist. While the former set of analyses measures the physical accessibility of the murals, the latter considers visual accessibility as the fundamental condition of the perceivable presence of the artwork in space. Then investigating the perceptional capacity of urban space regarding public art will be elaborated with the townscape analysis. Here, the basic argument of the paper is that high public recognition of the artworks in space could be ensured not only by the spatial and visible accessibility but also through some supporting townscape characteristics of the built environment.

Developing some ‘complementary models’ combining the different methodological approaches represents one of the most up-to-date research questions in the field of urban morphology. The recent attempts to suggest a composite view on alternative methods, in this regard, tend to suggest the integrated model frameworks relating the configurational approach (of Space Syntax, in most cases) to the historico-geographical school of morphology (Griffiths et al., 2010; Li and Zhang, 2020; Allahmoradi and Cömert, 2021), spatial analytical approach (Oliveira and Medeiros, 2015) or all the others -historico-geographical, typological, and spatial analytical- (Oliveira et al., 2014; Monteiro and Pinho, 2021). Within this context, the configurational approach has yet to be integrated with the perceptional dimension of urban form, in other words, the so-called ‘perceptual morphology’ initially delineated by the conceptual and analytical framework by Cullen (1961).

2. Public art and the city

In every period of history, the common space has reproduced itself with the representational power of public art, commonly as the symbolic expression of the political power of the authority. Since the ancient periods, monumental works have been installed in the city's sacred and symbolically representational spaces (Januchta- Szostak, 2010). Positioned as a powerful tool in constructing a shared identity, public art has been frequently used by the political authority in principal spaces during the periods when social life and political structure underwent some ideological transformations. For instance, with the proclamation of the Republic of Turkey, the new public spaces of the modern regime were created by the state along with the aestheticization of the new national identity and the powerful image of its founder (Yaman, 2011), (Figure 1).

Figure 1 Monuments marking the public space of modern Turkey: public art to aestheticize the national identity in the making (Source: URL-1, URL-2).

In that view, one could consider the monumental works of art contributing to the construction of national pride and secular citizenship in the early republican period, the first systematic approach to public art in urban space in Turkey. These monuments making a historical contact with the present by representing the past establish a sort of temporal linkage with the space (Miles, 1997: 37). That implies the ideological reproduction of the state power via public artworks.

Following the development of the art industry as privately sponsored curatorship and collection programs, the critical movement against the production of the so-called 'high-art was to emerge in Europe and the States in the 1960s. Accordingly, the critical interpretation of public art was manifested as a radical discourse of the avant-garde movement that claimed public space as an alternative to the institutional reproduction of the art within galleries having limited accessibility by the public (Januchta-Szostak, 2010). The artist, within that view, is envisioned as the one putting their artistic performance, not in the art studio but urban space (or nature) by using alternative materials (i.e., waste), emphasizing some socio-political issues such as ecology and modern industrial society (Lacy, 1995). Thus, the dominant domain of public art would be more public, and respectively, political. The artists who question the fashion of performing the art through exhibitions, galleries, and museums believed that publicity would provide free expression with its social or political meanings, which cannot be revealed simply by the notion of open access (Hein, 1996). In this regard, the perception of art was to transform from a kind of individual practice that revolved within the specialized institutional bodies to something more integrated into daily life through the subtle transformation of society (Kortbek, 2018). The conception of art as the medium of social expression gave way to the 'New Genre Public Art' performing outside the institutional frameworks by calling artists for direct engagement with the audience while addressing socio-politics (Lacy, 1995). All those might suggest that behind the prevalence of modern art in the public space, a particular political motivation tends to make the artistic experience, somehow, a part of the people's practice of every life.

Murals, in this context, could be considered one of the powerful representation techniques regarding the accessibility of a politically symbolic or pure abstract expression of the artist to the public. One of the most striking examples of the new genre of public art is 'Mexican muralism.' Having started in the 1920s, just after the Mexican Revolution, the promoted act of mural painting conveyed the 'visible' message of the nationalist and socialist ideology on public buildings. As a kind of artistic movement, Mexican muralism strengthened the relationship between society and revolution while the artists had an extensive chance to express themselves in the public domain (Baca, 2013).

As argued by (Phillips, 1988), the idea of 'public' has a volatile and somewhat blurred conceptual ground since it has a psychological construct (pp. 93). Therefore, the common consent of the public on the aesthetics of the work of art in the public domain, in some contexts, emerges as a conflicting issue. For instance, Richard Serra's Tilted Arc sculpture placed in Foley Federal Plaza in Manhattan, NY, in 1981 was not accepted by the public who were using the place. Then, it was removed by the court decision (Miles, 1997). Likewise, John Ahearn's sculptures in South Bronx, NY represented the common profile of the neighborhood's social structure and stories. They could only remain for five days on the pedestals in public space following the protests by some residents who found what was represented by the artist inappropriate (Kwon, 1997). In this regard, the visibility of the public artwork in urban space turns out to be a critical factor for the performance of the art in the public domain regarding the profile of the people that the artwork aims to communicate.

Similarly, along with the so-called counter-cultural hegemony that the political authority tends to establish for the last twenty years, the issue of public art in space has been subject to discussion within many cities in Turkey. The mainstream populist tendencies in central and local governments have resulted in a series of implementations of the artworks in public space, mainly in the form of sculptures as the pure representation of local identity and cultural figures without any abstract quality involved. The current political authority, in this sense, performs in subtle reaction against the abstract representation of modern art to be visible in the public space in Turkey. Having started with harsh criticism against a sculpture, which the previous social-democrat municipality had installed, as one of the examples of abstract art (Figure 2, left), the 'counter-anesthetization' of the populist government goes on with various applications engaged with the ideological symbolism of the ruling ideology in a very figurative style (Figure 2, right).

Figure 2 Sculpture as the prevalent type of public art in Turkey: the abstract versus figurative representation as a tool for cultural politics reflected on space. (Source: URL-4, URL-5)

Nevertheless, especially in the metropolitan cities in Turkey, there has been a solid tendency to integrate art into the public space initiated by civil society and the new local governments aiming to revitalize the public space and create a vibrant image of public life in space. In this regard, it is possible to observe many programs and organizations which systematically involve the art and artistic performances in public space as a tool for community development and placemaking (Figure 3).

Figure 3 Istanbul Comics & Art Festival provided some experimentation platforms (i.e., outdoor workshops and exhibitions) in public space (left), and the graffiti artists drawing under the gaze of people on the street (Source: URL-6; personal archive, 2017).

In this context, it is quite possible to argue a subtle transformation in the common perception of public art in Turkey. While it used to be dominantly performed with the initiative of central governmental authority before, the public art in Turkey is in the way of the self-performance of the art by the society in close relation to the local governments. Such emerging dynamism essentially acts as a factor that tends to socialize public art phenomena collaboratively. In this sense, the increasing number of experiments in various public spaces and living environments in Turkey make us revisit the issue from a social and spatial perspective as an alternative to politics.

As commonly accepted in the literature, integrated with the environment, public art plays an essential role in strengthening local identity by creating a sense of place with all the other spatial properties of a given context (Selwood, 1994; McCharty, 2006). Art potentially transmits the local histories and unknown stories of the space and presents a collective image to the society (Porch, 2000; Kwon, 2002; McCarthy, 2006). Moreover, it has an intrinsic power to support cultural diversity through encouraging the integration of marginalized groups into the larger society by including them in the processes of cultural representation (Hall and Smith, 2005: 176). In the contexts where it has a solid social basis, public art could be considered a means of reproducing society within the domain of the cultural public (Selwood, 1994). The emotions aroused by the art in the public domain revive awareness and relate people to the space (Hall and Robertson, 2001), transforming the space into a meaningful environment.

In terms of the collective perception of urban space, public art has a subtle function supporting the construction of the urban image continuously mapped out by the urbanites. Differentiating from its surrounding environment, a public artwork potentially performs as the focus of spatial perception, a landmark that is one of the fundamental elements of the image of collective urban form. Therefore, public art elements could improve the legibility of cities from a perceptional point of view (Porch, 2000; McCarthy, 2006). Public art, in this sense, is an active agent that supports the vitality of the public spaces, increases its use value and performance. Therefore, it appears as one of the critical issues within design policy frameworks of contemporary urbanism.

3. Murals in urban fabric

Mural painting can be considered a branch of graffiti, the drawings or writings made on a wall or other surfaces in the city fabric. It is usually practiced without official permission. Due to its

anonymous and unauthorized performance, graffiti is classified as a marginal art. Located on the less important but the most visible facades, graffiti appropriates both the architectural elements (i.e., staircase, windows) and personifies the public space (Rey, 2019). Considered either as a form of vandalism, art, politics, or advertisement (Dovey, 2016: 201), graffiti writing has a prevalent practice in the modern city. Performed in the forgotten spaces, it is an informal form of placemaking that revitalizes urbanity through the fabric of the city (Halsey and Pederick, 2010: 96 cited in Dovey, 2016: 208).

Figure 4 With the theme of 'la Hermandad' (brotherhood), Colombian graffiti artists painted Yaşar Kemal and Gabriel Marcia Marquez on the wall of a Çankaya Municipality building in 2019 in Ankara (Source: URL-7).

Like graffiti, murals are in public view, usually applied on larger surfaces mainly through the legal permissions, within the knowledge of the owner(s) of the buildings. Murals require more comprehensive processes than graffiti or other surface applications such as stencil or tag applied to larger surfaces. It can also be applied to public buildings to provide social awareness (Figure 4).

Figure 5 Some applications within the neighborhood fabrics of Ankara (Source: C.G. Yaşar's personal archive, 2021).

In addition to its application on public buildings, utilizing the facades of the ordinary buildings within the neighborhood fabric has become common in Turkey's metropolitan cities. (Figure 5) Such a trend goes along with the socio-political tendencies as stated above. Unlike the advertisements, which require high accessibility positions and large building surfaces, the main reason why the mural applications are more frequent within the city's living quarters than in the central areas is that location-choice is more affordable to artists to hire facades for their temporary art performance in the neighborhoods. The emerging tendency towards the residential fabrics could be considered a positive factor that increases the quality of public space within the living fabric of the cities.

Murals' production time depends on many variables such as weather conditions and the number of the artists involved -up to 5 people depending on the coverage area of the façade- (Kramer, 2016: 117). In some contexts, they have to compete with the advertising signs that catch people's eye in daily life as the prominent element of the modern urban image (Toy & Görgülü, 2018: 1153). To Remesar (2005), as 'ideological advertisements', murals demand the passer-by's attention in the public space (p. 7). That means it requires a particular aesthetic dialogue with the people encountering the artwork in space. Making a kind of exceptional aesthetic statement within its spatial context, murals could perform better in the old urban patterns in which the sensation of the users is relatively settled. As J. Jacobs once argued, "*new ideas must use old buildings*" (Jacobs, 1961: 188).

Like all other types of artworks, murals need to pursue a certain level of perceptional capacity within their environment. This point gets critical especially considering the positioning of the artwork within the dense urban fabric, which suggests various perceptional conditions through its form and structure. That indicates a perspective to consider the mural as a spatial art. Therefore, one could argue that the aesthetic experience offered by the mural has to be revealed and enhanced spatially concerning the relations between the artwork and the townscape elements surrounding the artistic experience itself.

4. Spatial perception and townscape

The perception of urban space starts with collecting information primarily through the senses, albeit accompanied by many factors. The process includes collecting, organizing, and making sense of spatial information (Carmona et al. I., 2010: 87). Ittelson (1978) associated the concept of environmental perception with cognitive, imaginal, affective, and value aspects. At this point, the idea of 'image' comes forth. The image is then reproduced version of sight through the filter of mind (Berger, 1972: p. 9.). Despite being experienced in the same environmental context, different people can construct other images with subtle similarities (Rapaport, 1977). The image construction can be shaped according to the needs and motivations of the people in the move (Ittelson, 1978). For this reason, perception of space and image construction could be characterized as an intersubjective phenomenon.

In this context, Lynch (1960) defines the essential elements of the urban image (*i.e., edge, node, district, path, and landmark*) and describes the act of environmental perception within a rational framework. Lynch (1960) explains the relative existence of different urban landscape elements as follows: "*A great landmark may dwarf and throw out of scale a small region at its base. Properly located, another landmark may fix and strengthen a core; placed off-center, it may only mislead*." (pp. 84). Accordingly, visual perception is considered as a process of making sense that is realized with the close relationships between the elements, which, in turn, characterizes a specific spatial pattern.

G. Cullen (1961) introduced a similar perceptual approach in his seminal work, 'The Concise Townscape'. Cullen (1961) argues that a temple can be defined by itself with all its qualities. Still, it can be shifted to a completely different level of perception with relatively small buildings located

next to it (p.10). That goes parallel to the relational nature of the elements of the urban image indicated by Lynch (1960). Then, the relational position of an urban component within the larger environmental context essentially conditions the internal quality perceived by people. In other words, we can conclude that the visual awareness of new elements placed in the urban fabric could be ensured by considering their environmental characteristics.

As Arnheim (1969) states, the human mind is evolutionarily susceptible to changes in appearance (pp. 36). Considering that the perception of urban space is mainly experienced by the pedestrian or driver in motion, one could also argue that the holistic visual perception of the city is primarily characterized by the spaces of mobility, the so-called *motionscape* (Çalışkan, 2011). In other words, "*the moving view is the primary way in which we experience our environment today*" (Lynch, 1972: 185). Spatial perception processes based on movement are experienced within specific sequences. In this regard, the more continuous relations between the townscape elements sequentially perceived by the mobile observer, the more coherent image of the space would be constructed by perception. Therefore, it is possible to assume a strong relationship between movement and vision. Cullen (1961), in this regard, developed a coding system of visual documentation by experiencing spatial perception from the human eye. The proposed model called 'serial vision' is used for examining the entire perception of space in motion, all along with the changing townscape qualities during the movement. The method has gained wide acceptance within morphological studies based on urban perception.

The imageability of physical objects, which implies the availability of a strong image in mind, is delivered by the condition of visibility. The imageability of urban elements increases the probability of being noticed and remembered within their spatial context. Accordingly, Appleyard (1969) defines the act of recall on four building attributes: *imageability, visibility, its role as a setting for personal activities and use, and its cultural significance to the population at large*. (pp. 134).

Imageability of a physical environment, the capacity of space to enable people to construct a holistic image on that spatial setting, highly depends on the spatial form that suggests a legible structure through its perception. A clear characteristic relationship between the spatial elements (i.e., buildings, spaces, and landscape features), in this sense, does steer not only a total image of the spatial pattern but also a specific recognition of the particular elements within the complex environmental setting, as well. What we can see in Appleyard's (1969) conceptualization of the 'imageability' of a building is the distinctiveness in its physical form conditioned by both the singular attributes (i.e., contour, size, shape, surface) and the relational properties (i.e., signs around the building). In this regard, the perceptional capacity of an urban element (including a public artwork) should not be simply considered with its superiority over the other elements in the same setting. It needs to be revealed contextually and relationally. That leads us to a morphological framework dwelling on the characteristic relationships between the form elements in an urban fabric. Such a perspective would suggest a relevant basis for investigating the public arts' perceptional quality in the urban fabric.

As part of the domain of morphological research, 'perceptual morphology' concerning the built environment with a direct reference to the sensational experience of man in space (Carmona et al., 2010: 111), in this framework, could be considered an essential layer of analysis. Finding its theoretical basis in Porteous (1977), perceptual morphology assumes the cognitive capacity of the human mind, which interconnects, structuralizes, and processes the environmental stimuli received from the built fabric. Considering the public artworks as an integral part of the townscape concerning their potentiality in the collective imagination of space, one could set the systemic relationship between the townscape elements and the artworks in public space regarding the imageability of the public art. Therefore, in that paper, the authors introduce townscape as one of the significant layers of analysis in recognizing artwork (i.e., murals) in the urban fabric.

5. Recognition of the mural in the urban fabric: A morphological analysis

To elaborate on the conditional (if not causal) relationship between the public art and the spatial quality of urban form, which provides peculiar accessibility structure and volumetric 'stage' on/in which the artistic performance/artwork locates is to be studied on an analytical basis. To that end, the paper suggests a framework that involves configurational and townscape characteristics of the urban form concerning the location and spatial setting of the murals in the urban fabric. For that purpose, Yeldeğirmeni, a central neighborhood in İstanbul, Turkey, has been selected for the analysis. Following a brief information about the site, the findings of Space Syntax, visibility, and townscape analyses will be presented, respectively. Via the matrix involving the results of analyses, the critical morphological aspects to ensure the perceptional capacity of the murals will be discussed.

6. The spatial context

Having a very central location in Kadıköy, one of the oldest districts in Istanbul, Yeldeğirmeni is a mixed-use neighborhood composed of the dense fabric of the typical apartment buildings. Since it has proximity to various central areas of the city (Figure 6), the neighborhood's daytime population usually exceeds its settled population of 12 800 people (according to the Turkish Statistical Institute's 2020 census data). With a high level of accessibility, therefore, Yeldeğirmeni is one of the neighborhoods having strong recognition in the city. Such locational quality of Yeldeğirmeni has conditioned the recent transformation of the neighborhood in terms of public art, and therefore, presented a relevant context to be discussed within the current paper.

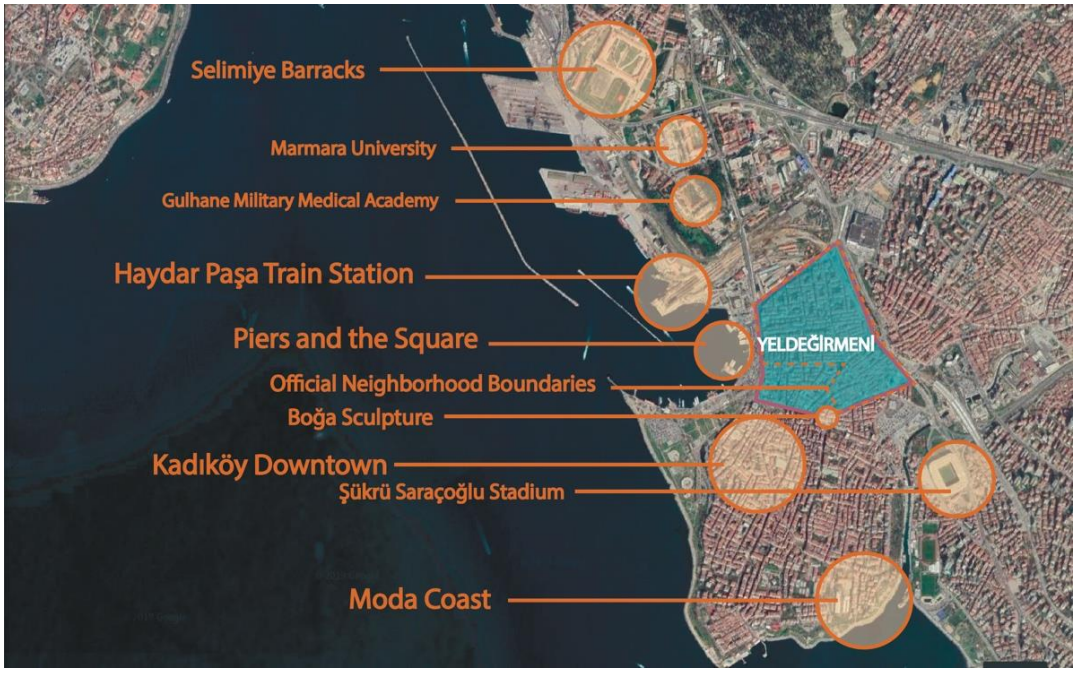


Figure 6 Location of the site in Kadıköy District, İstanbul, Turkey.

Having composed of derelict and unsafe public spaces with the lack of necessary social and physical infrastructure, Yeldeğirmeni used to have a negative reputation (mentioned as the 'back quarter' of Kadıköy) up until the early-2000s (Arısoy, 2014). Nonetheless, the multicultural community and the inherited building stock having many historic buildings were the opportunities for the future transformation of the area. In that context, the neighborhood became subject to a series of projects within the revitalization process executed by Kadıköy Municipality in cooperation with the Foundation for the Protection and Promotion of the Environment and Cultural Heritage (ÇEKÜL) in 2010.

Figure 7 Distribution of the murals made after the Mural Festival in Yeldeğirmeni in 2012.

In that process, the *Istanbul Mural Festival* has turned out to be the leading event supporting neighborhood revitalization. Having been introduced as one of the projects in 2012, the mural festival led the execution of 18 murals on the buildings' blind façades in different locations within the fabric. (Figure 7) Since its first application, the residents and venue users have highly appreciated the artwork, and the festival has turned into a regular event repeated every year.

Considering the perceptional capacity of the public art, the amount and extent of the application of the murals in Yeldeğirmeni suggest an appropriate basis for morphological research. With the analysis presented below, the authors tend to reveal the relative capacity of the murals accessed by the public. Then, the correlation between the level of recognition and the morphological attributes of the spaces in which the murals are located will be discussed.

7. Findings

To present a holistic view of perceptual morphology, the fabric is analyzed first concerning its configurational characteristics. At this stage, the axial integration pattern of the area is visualized by the Space Syntax analysis. That aims to see the relative positioning of the murals in terms of their centrality within the overall street pattern. Then, the same scalar framework is utilized to expose the visibility pattern of the urban fabric in which the buildings with murals are located. Thus, the compositional quality of the collective urban form is depicted concerning the visibility of the spaces.

Accordingly, the axial integration map shows that the area has higher centrality at its southern edge defined by the main street. In addition to that, the continuous axes with relatively high integration levels penetrate the core fabric and make the neighborhood accessible from the outside. (Figure 8, left) Then, the Isovist analysis represents the overall quality of inter-visibility of the spaces embedded in the fabric. As understood from the color-codes of the mapping (the bright

zones indicate the high visibility, as opposed to the dark-colored zones), the fabric is composed of a few 'hot spots in the form of junctions with higher visibility. (Figure 8, right) The murals located close to those junctions have a relatively higher potentiality to be perceived by the people walking on the street network.

Figure 8 Maps of axial integration analysis (left) and the visibility pattern by Isovist analysis (right)

Following the configurational analysis of the whole neighborhood fabric, the townscape analysis reveals the mezzo-scale morphology of the area regarding the perceived quality of the murals' close vicinity. Cullen's (1961) townscape method and terminology are utilized for the analysis. Accordingly, serial vision is employed as a technique in the cases of the murals' spaces where the perception is subject to change through the movement on the street. The townscape qualities are mapped out with illustrative photos taken at eye level. For the analysis, nine townscape features are specified as the key indicators of spatial perception of the murals in the urban fabric. While six concepts are borrowed from the existing literature provided by Cullen (1961), the authors suggest three of them from the same perspective.

Figure 9 The singular image represented in an exaggerated size creates a dramatic visual effect on the street (left), the detailed figure on the mural increases the grain of the perceived texture of the street.

The wall: As one of the main elements characterizing the image of a street, the blind façade is not only the vertical surface of a building but also a potential canvas on which the mural is applied. As Cullen (1961) discussed, the few blind facades that appear as empty vertical surfaces in the building fabric could suggest a distinctive 'wallscape' and might significantly differentiate the perception of the urban space (p. 155). In a dense urban fabric composed of buildings with articulated building facades, the cityscape is filled with many architectural details that make the overall perception of the environment much more intricate (Figure 9, right). As observed in the site, the magnitude of the distortion involved in the representation by the mural tends to create a dramatic effect in perception, and therefore, evokes a sense of surprise (Figure 9, left).

Figure 10 The staggered configuration of the street pattern generates the interrupted view that enables a better perception of the mural if it is located at the terminal point of the view corridor.

Closure: Cullen (1961) states that the closures created by the non-continuous segments of the street divide linear city systems into visually 'digestible' and consistent quantities (p.106). In this way, the sense of movement's progress would be preserved in the course of movement. The points of closure have a high perception level. In the dense urban texture, especially on narrow streets, it might be hard to visually capture the building facades entering in the view angle of the people on the street. Such spatial condition negatively affects the visibility of murals usually located on the flank fronts of the buildings. If the mural is situated in a closure point, it gains higher visibility within its fabric (Figure 10).

Figure 11 The serial vision on a selected street in the neighborhood exemplifies the change in the enclosure level and a perceived increase in the visual manifestation of the mural in the fabric.

Multiple enclosure: According to Cullen (1961), a space can exhibit *separate enclosures combined into one inter-penetrating whole* (pp. 30). The concept of 'multiple enclosure' could be observed in any street pattern on which the relationships between the buildings tend to differ. In this context, it is expected that the average view angle tends to decrease when the level of enclosure increases. In the street network, such an inverse relationship might change dynamically. That means with the changing level of enclosure, the visibility of the streetscape is transformed. While progressing on the street, the changing enclosure level stimulates or ceases the perception of the space. When the buildings define the space recess, the possibility of perceiving a larger surface of the environment visually increases. If the murals are located at the point of transition from enclosed to open space at the direction of the move, then it receives greater attention with increased visual recognition of the public art (Figure 11).

Figure 12 In the given context, the punctuation point implies a visual transition from commercial to residential fabric (below), and the changing spatial rhythm (above), accordingly.

Punctuation: To Cullen (1961), the built environment is articulated into identifiable parts which initiate the sense of here and there throughout the flow of the body in urban space. Such distinction is sometimes restricted by artificial elements such as narrows and closures (pp. 35, 182). Such an effect would also be generated by the visual aspects and the physical components of the built environment. Considering the typologies suggesting different building dimensions, we can specify the particular visual rhythms along with the street segments with distinct building typologies. Different articulations, even on the façades of the same building types, could create individual visual segmentations perceived through the movement in the network. Then, the changing points of the sequence of visual rhythms indicate a kind of punctuation, the terminal points that give way to another visual series. The spatial perception at those points raises significantly when the functional character of the street is also changed. Accordingly, as a space consists of similar images, any transition in the visual pattern during the movement stimulates the perception of the people experiencing the space. The murals coinciding with the so-called punctuation points have the higher potentiality to be perceived if they are visually accessible at a certain distance (Figure 12).

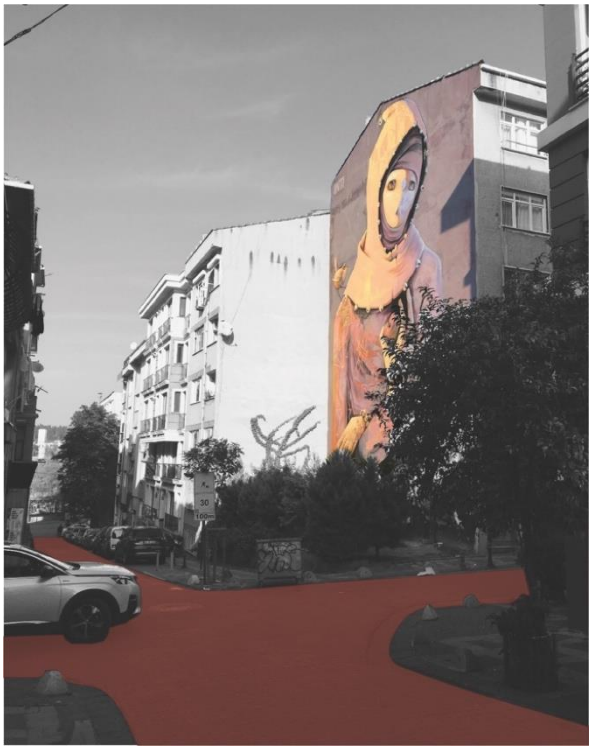


Figure 13 A street junction on which the mural is positioned with high perceptual capacity.

Focal point: Cullen (1961) identifies the 'focal point' as a vertical artifact -a *landmark* in Lynch's (1960: 78-83) term- coupled with the enclosure of a central space that pinpoints the spot of the common perception (pp. 26). Primarily located at the intersection of the streets as the node of the network, focal points could be considered the space terminating the flow and focusing the attention of the passenger inflow (Çalışkan, 2011: 330). Then, street junctions are unique points for the environmental perception in the cities. Due to the actual need to control both sides of the traffic flow in at least two street directions, the passengers are awakened at the time of crossing. At that stationary moment, the built-up elements could potentially have a higher chance of being noticed than what reside along the street. Moreover, the increased level of spaciousness makes the buildings around the junction more visible with a wider view-angle. (Figure 13) Creating a divided continuity along a single route, junctions determine a series of starts and end through the movement. This is what makes them perform as the focal point by which any possible presence of a mural makes it more perceivable.

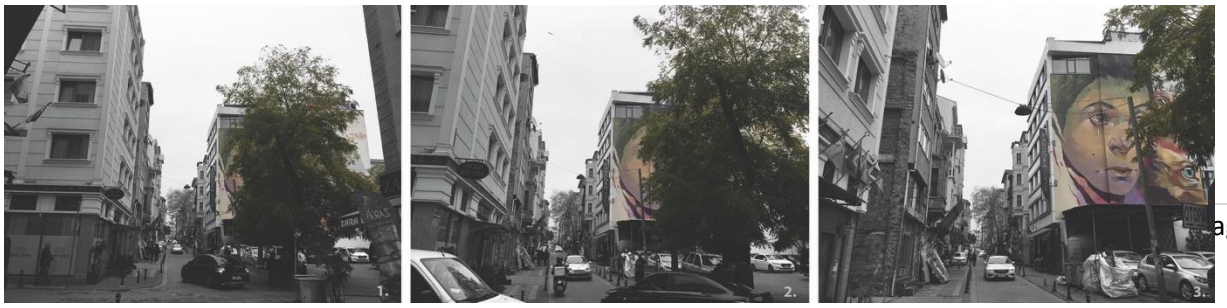


Figure 14 Within the serial vision, while the tree screens the mural standing behind from a distance, the successive change in the observer's position makes the mural visible without any barrier: The early stage, in which the mural is barely seen, stimulates the sense of anticipation, and makes the perception more effective.

Anticipation: The disorderly relationships between the townscape elements do not necessarily generate negative visual sensations in the urban environment. For instance, in the course of a movement in urban fabric, though a vertical element (i.e., a tree or a clocktower) disrupt the visibility of another townscape element from a certain distance when the proximity changes between the object and the observer, the changing view discloses the element behind another. During the approach to the piece behind, the observer would anticipate what is forthcoming. Explaining it regarding the barely observed facades of the buildings behind the other buildings in traditional fabric, Cullen (1961) describes the sense of curiosity as *anticipation* within space (pp. 49). In the context of the mural within a dense urban fabric, such dynamic visual relationship between the elements potentially enriches the aesthetic experience of the public art (Figure 14).

Figure 15 'Protrusion', a sudden change in the alignment of the frontal facades of the buildings, generates a highly perceived surface for the mural.

Protrusion: Within the traditional urban fabrics, the relationship between the building and the street is dynamic, and therefore, generates a rich visual setting. Admiring such visual complexity of the traditional urbanism, Cullen (1961) argues that "*any slightest deviation in alignment and quite small variations in projections and setbacks have a disproportionally powerful effect in the third dimension*" (pp. 17). This might also be the case within the planned urban fabrics subject to some incremental transformations. In townscape terms, the observed diversity in the positioning of the buildings characterizes the perceived continuity of the facades along the street. In this context, when a building overflows the common frontal setback within an urban block, or the adjacent building recesses its front façade after being redeveloped, then the lateral façade of the building would have a higher perceptional capacity. That makes the spot suitable for the murals aiming for high recognition by the public (Figure 15).

Figure 16 The blind facade of the building on a street wall creates a perceivable contrast within the streetscape. The nearby positioning of the mural takes advantage of that position for the desired perceptional capacity of the public art.

Juxtaposition: Cullen (1961) defines the state of a direct relationship between the contrasting visualities (i.e., urban vs. natural, pastoral vs. industrial) that could be found in and around the city fabric (pp. 60). The facades of the buildings involved in the formation of urban fabric expose different characteristics in terms of material, openings, layering, color, and articulation. The contrasting surface quality of the facades would be considered a common condition in the townscape of modern cities. When the distinction in single or multiple properties is high, such contrast causes either enrichment or disharmony within the urban environment, depending on the contrast level. In each case, the visual elements positioned between the contrasting facades tend to be more pronounced than any other location on the linear façade composition. That would be a desirable condition for applying a mural within the given fabric (Figure 16).

Figure 17 An observable match between the parking lots and the murals: such a coupling condition creates a characteristic setting.

Match: Some spatial settings condition the adaptation of various programs into the urban fabric. For instance, street corners invite corner shops or cafes; continuous facades could generate retail development, etc. Regarding the public art, the spatial voids that already exist in the city fabric provide a suitable condition for the murals to be applied on the aligned facade of the buildings. In the context of Yeldeğirmeni, the observed *match* between the parking lots and the murals signifies such a condition that increases the easy recognition of the artworks within the urban fabric (Figure 17).

8. Discussion

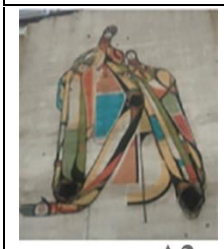
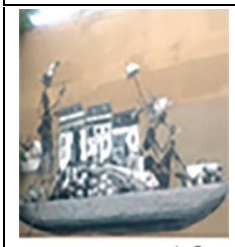
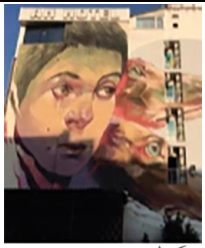
Following the morphological analyses to reveal the perceptional capacity of the spatial setting in terms of network integration, visibility, and townscape characteristics, a survey was conducted by questioning whether the participants have visually experienced the listed murals in the neighborhood. The survey involved 50 people who either live or work in the neighborhood. Within the survey, the pictures of each mural were shown, and the participant's responses on personal awareness were recorded. The main aim of the survey is to test the expected correlation between the spatial characteristics and the actual level of public recognition of the murals as public artworks.

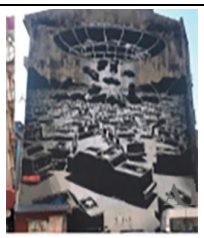
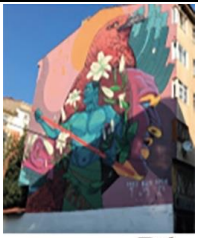
The area is divided into three-character areas with distinct functional and experiential qualities to encode the murals. (Figure 18) Accordingly, zone A, on the one hand, is characterized by heavy vehicular and pedestrian traffic along with a mixed land-use pattern due to its proximity to the urban waterfront and the pier. Therefore, the area has many open parking plots creating voids in the dense urban fabric. Along with the blind facades of the surrounding buildings, those unbuilt parcels generate a series of places affording high visibility for the murals. That's why; the highest number of murals are concentrated in this zone. On the other hand, zone B is characterized by the high-street backboning the area with all the recreational facilities (i.e., cafes and restaurants) concentered along the route. This essentially increases the use-value and the experiential capacity of the areas. Finally, zone C is a high-density residential area with few commercial functions and low traffic. Five murals in that zone are located close to each other.

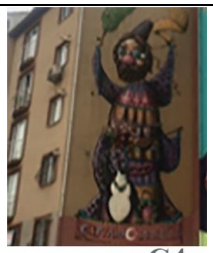
Figure 18 Character areas in Yeldeğirmeni Neighborhood and the location of the murals.

Accordingly, the survey results (the percentage of the people who responded positively on recognizing a given mural) are plotted in the matrix along with the analyses scores and the specified townscape characteristics of the spatial contexts (Table 1).

Table 1 The matrix showing the results of the spatial analyses and the survey results.

The murals	Axial integration value of the street on which the mural is located	Isovist value of the space in which the mural is located	Townscape characteristics of the spatial setting in which the mural is located	The percentage of the surveyed people who have encountered the mural in the neighborhood (%)
 A1	2.097	404	*focal point* *match*	48
 A2	2.094	163	*focal point* *match* *multiple enclosure*	28
 A3	2.094	141	*focal point* *match* *multiple enclosure*	30
 A4	1.732	161	*the wall* *match*	42
 A5	1.732	161	*focal point* *multiple enclosure* *juxtaposition* *match* *protrusion*	58
 A6	1.851	212	*anticipation* *match*	16

 A7	2.142	213	*match*	20
 B1	1.896	159	*punctuation* *juxtaposition* *anticipation*	50
 B2	1.684	454	*punctuation* *multiple enclosure*	50
 B3	1.725	380	*closure* *punctuation* *focal point* *match*	62
 B4	1.725	287	*focal point* *multiple enclosure* *match*	48
 B5	1.725	301	*focal point* *the wall*	42
 B6	1.851	130	*multiple enclosure* *punctuation*	16

 C1	1.645	172	*the wall* *focal point*	46
 C2	1.645	135	*multiple enclosure*	30
 C3	1.336	158	*the wall*	28
 C4	1.336	104	*protrusion*	24
 C5	1.384	171	*closure*	22

Low integration / visibility ---------- High integration / visibility

According to the survey results, the mural-B3 is scored with the highest level of recognition. The configurational analysis indicates the medium integration and a high Isovist value for the street and the space on/in which this mural is located. Examining the mural-B3's spatial context, we specify *closure, punctuation, focal point*, and *match* as the major townscape characteristics. Then, the survey results classify the mural-A5 as the public artwork revealing the second-highest recognition value. The mural is positioned on an axis with medium level of integration (like that of the mural-B3) in a dense traffic area along with the townscape features of *focal point, juxtaposition, match,* and *protrusion*. In this context, located near the parking space, *match* is the shared characteristics of the murals having maximum recognition. *Closure* could be considered one of the key features increasing the perceptional performance of the artwork, since it is observed only in the case of the mural-B3, the most recognized mural in the site. Likewise, revealed only in the context of A5 (along

with B1 as another well-recognized mural in the area), *juxtaposition* could be another feature providing a basis for high-level perception. Considering these two cases, one could argue that the townscape features strongly influence the perception of the murals compared to the configurational characteristics of urban spatial structure.

As seen in the table, both configurational values of the spaces in which the murals, A4, A5, and all the murals in the zone-C locate render below the average in the whole area. Then, some townscape qualities get critical since the recognition levels of A4, A5 and C1 are above the average. Shared by different couples of the murals, *match* and *focal point* stand out as the features that could ensure the high perceptional capacity of the artwork.

Among the first four murals having the highest axial integration values (A1, A2, A3, and A7), A2, A3, and A7 are in the lowest recognition group. Except for A1, the Isovist values of the former group are relatively lower within the larger group. That could imply that the high axial integration value per se does not guarantee the increased recognition of the murals. In addition, it is possible to state that A8, which is the least known mural within that group, has a kind of spatiality revealing an adverse *publicity* condition with the billboards visually screening the mural itself. That indicates that despite having high accessibility (in terms of axial integration) within their location, murals require supporting townscape qualities for increased recognition by the public.

When we look at the murals with high visibility, we could specify B2, A1, and B3 as the murals having greater Isovist values. Except for A1 considered above, B2 and B3 murals also reveal a high recognition level (clearly above the average –%36.6-). As expected, that indicates a positive correlation between the Isovist and the perceptual capacity. Then again, though the axial integration values of the mural-B2 and mural-B3 are below the average, the visibility factor supports their public recognition. In addition, the shared townscape feature of *punctuation* could be considered the critical positive factor for that score.

In this context, almost all the murals in area C, whose configurational values are below the average, reveal a low perceptional capacity in terms of the specified level of recognition. As an exception, the recognition level of the C1 mural is above the average despite the fabric's low spatial and visual accessibility. That would be explained by the locational townscape characteristics of the mural space as a ‘focal point’. Likewise, the murals, A6 and A7 exposing the lowest range of recognition, reveal the spatial accessibility just above the average integration value. That essentially demonstrates the significance of the adequate townscape quality characterizing the space and the fact that high level of network integration does not necessarily ensure the high public recognition of the artwork.

9. Conclusion

It might sound somehow tautological to state that public space is the basis of public art and its performance concerning the aesthetic experimentation of people. However, if it is installed in a public space in an outdoor setting, public artwork's spatiality necessitates considering the issue from a morphological perspective. The aesthetic experience of public art is conditioned not only by the art's internal quality as an object but also by the spatial framework that the figure interacts with. Such a synergetic relationship between the artwork and the space makes the issue a subject matter of the spatial research. The performance of public art is highly contingent upon the perceptual capacity of its spatial context to attract people’s movement and visual perception of itself. That also implies the procedural nature of the phenomenon in the name of ‘public process’, which is one of the basic features of public art. The sensory experience of public art is not limited to its actual location. It starts and unfolds through the movement towards its in situ visual presence. Such a kinesthetic experience involves the public art's close vicinity and its wider spatial setting within a contingent relationship between body and space. Then the aesthetic experience could be revealed through a series of morphological factors that condition the perceptional capacity of the public art. At that point, the authors argue that the integration of space, visibility, and townscape

characteristics could be considered the major spatial factors for the performative quality of public art in the city fabric.

To test that straightforward argument, following the spatial analyses of axial integration (Space Syntax), visibility (Isovist), and townscape, the authors conducted a survey that includes fifty people who regularly visit and use the site. The main intention behind the survey study was to collect information about the extent of people's recognition of each mural located in the neighborhood. In this way, the level of recognition could be correlated with the spatial characteristics of the particular locations where the different murals are positioned.

Theoretically, one could argue that the spaces with higher configurational capacity (in terms of integration and visual accessibility) have a higher degree of people's encounter with the public art if the space accommodates an artwork in its setting. The research reveals that despite being integrated and highly visible in a configurational manner, an urban space with poor townscape quality might suggest a low level of recognition of the artwork that the space exposes to the public. In other words, despite rendering relatively lower configurational capacities (of integration and visibility), the spaces that suggest certain townscape qualities would have higher potentiality to make the embedded artwork relatively more perceivable for the people. Such morphological indicators turn out to be the critical factor in increasing public art's desired performance. That indicates the necessity of an effective coalescence between the structural and townscape qualities of urban form, therefore, an integrative approach combining configurational and perceptual morphology.

In this context, urban design as an art of placemaking has a crucial role in empowering the sensory quality of urban form for a higher perceptional performance of the public art in our cities. Especially for the cities enacting the revitalization policies to promote the art in space, the design strategies enhancing the spatial setting towards more effective public art performances are essential. For that reason, better integration between morphological analyses, design frameworks, and the execution processes of public art should be constructed. The research, in this regard, could be considered an attempt to provide an analytical basis for a better practice.

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