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Heritage Patterns

Representative Models

Edited by

Éva Lovra

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Heritage Patterns—Representative Models

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Editor

Éva Lovra

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Editor
Éva Lovra
University of Debrecen
Hungary

Editorial Office
MDPI
St. Alban-Anlage 66
4052 Basel, Switzerland

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About the Editor

Éva Lovra , Ph. D. (1984) has a M. Sc. in Civil Engineering, M. Sc. in Urban Engineering and a Ph. D. in Architectural Sciences (with a focus on urban morphology and history of urban planning). She continued her postdoctoral research at the Space Syntax Lab of The Bartlett School of Architecture, University College London, and at the University of Novi Sad. She is a senior lecturer/adjunct professor at the Department of Civil Engineering, University of Debrecen, senior lecturer in the English language through Urban Systems Engineering MSc program, and a lecturer and doctoral supervisor at the UD Doctoral School of Earth Sciences. She is a former researcher at the Slovak Academy of Sciences, carried out her research fellowships in Prague, Zagreb and Bratislava, and gave lectures at the Technical University of Košice, La Sapienza and Roma Tre Universities in Rome. She is a permanent invited member of the Standing Committee on Urban Science of the Hungarian Academy of Sciences, a member of the Hungarian National Committee of ICOMOS, and an appointed member of the Cultural-Art Consultative Board of the Hungarian National Council (Vojvodina). Her main research interests are urban morphology (typo-morphology), urban planning theory, micro-urbanism, comparative analysis of urban structure configurations, and Space Syntax. Her most recent scientific monograph, *Towns in the Austro-Hungarian Monarchy. Urban Tissue Typology and Urban Typology 1867–1918*. (TERC Kft., 2019) won the Publication Award of the University of Debrecen (2020).

Preface to ”Heritage Patterns—Representative Models”

Special Issue on Heritage Patterns—Representative Models

Tangible heritage, whether universal or local, has numerous layers and perspectives regarding its nature, as well as how it is approached and interpreted. To understand the universal value of tangible heritage, we must seek its underlying principles, rules, and patterns, involving disciplines that are not directly connected to the phenomenon of tangible heritage: urban morphology, space syntax, and generative design, in addition to the traditional ones such as archaeology, art and architecture history, and heritage preservation.

The Special Issue of the journal *Heritage*, entitled *Heritage Patterns—Representative Models*, aims to research the patterns in heritage and the underlying rules that define tangible heritage as a universal value in spatial coexistence, economics, urban life, and design via case studies and theoretical proposals that could be implemented in the future. The pattern language and the heritage phenomenon could act as a base of observation to deduct logic and create generative algorithms (generative design); to understand the importance of spatial connection with tangible heritage and urban forms (space syntax, urban morphology, urban morphometrics) and its visibility; as well as archaeological, architectural, and urban heritage. Based on the UNESCO-ICOMOS doctrines and the examination of morphological regions, urban morphological research and its different layers (urban forms, structural components, built environment, urban tissue and their interaction) act as a background and foundation for general urban heritage conservation and protection proposals, and also as the base of specific interventions in the built environment caused by natural disasters.

The *Heritage Patterns—Representative Models* issue of *Heritage* welcomed twelve articles that discussed traditional and contemporary methodologies and scholars from different backgrounds who intended to look for patterns of tangible heritage and its underlying principles to understand the diversity of heritage approaches.

The collections of papers include theoretical and case studies and a combination of the two:

The article *Town-Plan as Built Heritage* argues for the consideration of the town plan in frameworks of conservation and heritage, together with the building fabric. After more general considerations, the study widens the scope of the built environment (building fabric) from singular buildings (monuments) to public buildings or built areas (mainly residential) that occurred after the mid-twentieth century. The paper emphasises the conservation of the town plan and built-in areas from the past to provide a basis for more accessible, dense, and continuous contemporary design.

Visibility Model of Tangible Heritage. Visualization of the Urban Heritage Environment with Spatial Analysis Methods provides a theoretical study on the topic (visibility, isovist analyses, and space syntax analysis) and a case study of the Sulukule neighbourhood as proof of concept of the proposed innovative, yet adaptive approach (combined methodology) to defining and preserving heritage sites and their elements by linking the perceptual behaviour with the information of the built environment.

Patterns of the Expanding City: An Algorithmic Interpretation of Otto Wagner's Work discusses Otto Wagner's 'Großstadt' vision, his rules about the future of the evolution of cities from 1911. Based on the formulated rules about the sustainable expansion of Vienna in a controlled manner, the author of the article systematised these rules of inherited patterns and turned them into recursive algorithms to simulate urban growth. The resulting patterns of two case studies, Vienna (Austria) and Miskolc (Hungary) are presented in 2D and 3D as proof of Wagner's concept and the recursive algorithms created by the author.

The Spatial Morphology of Community in Chipping Barnet c.1800–2015: An Historical Dialogue of Tangible and Intangible Heritages "presents a case study of the London suburb of Chipping Barnet to show how a spatial-morphological approach to tangible heritage challenges its archetypal image as an affluent commuter suburb by highlighting its resilience as a generative patterning of social space that has weathered successive phases of social change."[1] The authors analysed the historical maps using space syntax to indicate the street network as a dialogue of both the tangible and intangible heritages of Barnet.

Lines of Settlement: Lost Landscapes within Maps for Future Morphologies discusses the multiple values and purposes of archival documents beyond their original determination, as they can provide integrity for new lines of heritage analysis. The paper identifies the cultural and urban heritage significance of the cartographic representation of 'lost landscapes'. Moreover, urban and landscape design can reflect on these landscapes and discuss new forms of interpretation through design reconciliation.

Sustaining Heritage Patterns in Mining Towns of the North American West: A Historico–Geographical Approach discusses the application of the historico–geographical approach to study heritage patterns in 19th century mining towns located in mountainous regions of the western United States in order to inform the design and revitalization processes of architects, planners and community stakeholders in the territory. The author proved that "The historico-geographical approach is particularly helpful for interpreting formative and transformative processes and for identifying key elements that define the physical structure of historic contexts at a town or neighbourhood scale". [2]

A Preliminary Study on Industrial Landscape Planning and Spatial Layout in Belgium defines the concept of industrial landscape planning via the main categories, industrial heritage landscape and industrial tourism landscape. The authors studied the industrial landscape planning to identify the features of industrial heritage spatial layout in Belgium using the ArcGIS spatial analysis tool and kernel density calculations.

Urban Morphology of Zagreb in the Second Half of the 19th Century—Landmarks Guiding the Reconstruction of the Town and the Preservation of Identity after the 2020 Earthquake is an urban morphological study of the Upper (medieval) and Lower Town. The study emphasizes the Lower Town, built mainly in the second half of the 19th century, where the most significant damage was caused by the earthquake on 22 March 2020. The discussed and identified urban patterns, such as the orthogonal street grid, public parks and squares and public buildings, and the urban identity factors are the markers for new architectural and urban interventions as parts of the post-earthquake reconstruction.

Functional and Morphological Transformations of the Urban Block—Contribution to the Expected Modernization of Zagreb's Historical Core discusses the possibilities of the structural and functional transformation of urban blocks in the Lower Town of Zagreb as a part of the modernization of decaying areas and/or those that were damaged during the earthquakes in 2020. The authors provided a detailed analysis of the structural–functional changes and proposed urban reconstruction models for three selected urban blocks. Preservation and improvement of the local urban identity, urban green infrastructure, and the new role of the street in sustainable urban renewal are the leading concepts of the proposed urban regeneration solutions in the historical environment of Zagreb's downtown.

The two abovementioned studies are related and complement each other. It is recommended to read these articles together to gain broader knowledge about the history and urban-heritage-friendly regeneration of the Croatian capital after the earthquake in 2020.

Urban Morphometrics and the Intangible Uniqueness of Tangible Heritage. An Evidence-Based

Generative Design Experiment in Historical Kochi (IN) represents the application of the Urban MorphoMetrics (UMM) methodology to the historical town in India and identifies respective urban types with unique morphological features. UMM is a rather new methodology in the field of urban (quantitative) analyses and the outcome aligned with the urban character of the respective types of the study areas while allowing distinct design expressions. It shows that the combination of the proposed approach, as the combination of morphometric analysis and workflow for a figure-ground generation, has the potential to contribute to the production of context-based design in historical/heritage sites.

Safe Haven—Bath House and Library by the Burmese Border gives an overview of the contemporary vernacular tendencies in Thai architecture rooted in inherited traditions. The article provides examples of community-building "healing architecture" that can provide cultural continuity as a significant factor for the organic evaluation of regional architecture.

Spatial Distribution Characteristics and Influencing Factors of the World Architectural Heritage studies the World Heritage List established by UNESCO to analyse its spatial distribution characteristics (ArcGIS spatial analysis, space–time statistical method) and influencing factors (geographical environment, historical evolution, economic strength and discourse power, international heritage protection situation, and registration policy) at the global and regional level. As its main findings suggest, this study provides a scientific basis for further architectural heritage protection.

The Heritage Patterns—Representative Models is dedicated to the late Christopher Alexander (1936–2022), the late Jeremy Whitehand (1938–2021) and the late Bill Hillier (1937–2019), who established the disciplines which form the basis of this Special Issue of *Heritage*.

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Éva Lovra
Editor

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Article

The Town-Plan as Built Heritage

Vítor Oliveira

CITTA Research Centre for Territory Transports and Environment, Rua Roberto Frias s/n, 4200-465 Porto, Portugal; vitorm@fe.up.pt

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Abstract: The physical form of cities is exposed to conflicting forces of change and conservation. In the conservation field, despite the advances achieved over the last decades changing the paradigm from historical monuments to urban landscapes, the focus tends to be on the building fabric and the main three-dimensional characteristics of buildings. This paper proposes a complementary emphasis for conservation—the town-plan, meaning the different patterns of combination of streets, plots, and block-plans of buildings (building footprints). Preserving the town-plan of urban areas built in the past, means bringing to the present significant parts of urban history, assuring diversity (a key characteristic for sustainable, resilient, and safe cities), and providing a basis for the design of new areas more accessible, dense, and continuous. This argument is illustrated in the Chelsea district in New York at two different scales.

Keywords: conservation; heritage; urban morphology; urban form; town-plan; streets; plots; block-plans of buildings; New York

1. Introduction

Cities are amazing places. Since Humankind started living in cities (the word is used in a wide sense), almost 6000 years ago, these have always been at the centre of evolution [1–3]. From Ur to Rome, from Constantinople (Istanbul) to Baghdad and Chang'an, and from these to London, New York, or Tokyo, the history of cities is, indeed, the history of Humankind. Over this long period, cities have been places of learning, places where men and women have addressed and overcome major challenges and problems that were sometimes raised by the very fact of living and working together in increasingly larger settlements. In the past, present, and future, cities seem to offer the most efficient stage for social interaction and economic development, fostering the creation of enterprises and jobs. It is also expected that cities can lead the way in addressing the fundamental environmental challenges of our time.

Cities are made of people. They are made of men and women, families, people of different ages, individuals living at shorter or longer distances, people of different races, religions, and sexual orientations, and citizens with different educational backgrounds. This intricate social fabric is matched by a complex economic tissue made of different companies and workers. However, cities are also physical constructions. They are made of streets and infrastructures, squares, gardens, and parks, street blocks, plots, special buildings (mostly institutional), and ordinary buildings (mainly residential), to name the most important [4]. While acknowledging the crucial importance of the social, economic, and environmental dimensions of cities, the paper focuses on their physical form.

The physical form of a city is a complex process in time, gathering the action of many different agents, many times with conflicting views [5]. In different parts of the city, from the historical kernel to the peripheral areas, urban form results from the overlap of distinct layers created by different societies and economies in various periods of time. If it is acknowledged that for humankind to have a future, it should have a past and a memory [6], it might be expected that a culture of respect for this built heritage would be developed and even institutionalized. However, cities are in constant transformation, which raises a major challenge: under this cultural umbrella, what is to be conserved (in these inherited urban landscapes) and what is to be changed [7,8]? It is important to consider that conservation should not be exclusive of historical areas and transformation must not be limited to peripheral areas. On the contrary, the tension between conservation and transformation is present in each part of the city. Historical areas must admit selective transformation and peripheral zones should maintain certain elements of urban form. It is also important to bear in mind that the debate on urban form should not be closed. This means that form is important not only because of itself (including built heritage or architectural quality issues) but because of its relationships with other fundamental aspects of cities [9]. Indeed, as societies and economies are the main drivers in shaping the physical form of cities, it might be expected that the later has an influence on the first.

Urban conservation is an idea of modern times, developed after the French Revolution. Over the nineteenth and twentieth centuries, with variations in different geographical contexts, historic monuments were the focus of conservation. While promoting the preservation of these special buildings, this conservation approach allowed, and in some cases supported, the destruction of significant parts of urban landscapes based, for instance, on health, security, and aesthetic considerations. Whilst we can go back to the famous action of Haussmann in Paris in the mid-nineteenth century, this approach can also be found in Moses's intervention in New York one century later. In parallel to this dominant approach, new perspectives on conservation emphasizing the role of the urban landscape started to emerge in the early twentieth century, inspired by works of Sitte, Geddes, and Giovannoni [10–12]. In the 1960s and 1970s, there were important advances, including the preparation of the Venice Charter, the creation of the International Council on Monuments and Sites/ICOMOS (and the subsequent realization of the 'Convention concerning the protection of world cultural and natural heritage' and establishment of the 'World Heritage List') and the making of the first planning documents centred on conservation—notably, the Bologna plan coordinated by Cervelatti. Present debate on urban conservation includes the tension between narrow architectural perspectives (including facadism and pastiche) and a comprehensive understanding of heritage (such as the historic urban landscape approach [13]), the synergies and tensions with planning [14], the importance of cultural tourism in the economy and the pressure of tourists [15], and the contradiction between places that were areas of production in the past and are centres of consumption in the present, to name some of the most important. Debate also reflects the specificities of different geographical and cultural contexts, from China [16] to the United States [17,18]. In the US, historic preservation activities related to the main street and downtown development, promoted by the National Trust for Historic Preservation since the late 1970s, are of particular interest. The way how communities have been implementing this perspective, including four main issues—organization, promotion, design, and economic restructuring – has been explored in literature [19]. This focus on the main street can also be framed by research on streetscapes, encompassing different characteristics of urban form, land use, ownership, social capital, local identity and belonging, to name just a few [20–22].

While the usual focus of conservation trends is the building fabric (the three-dimensional characteristics of buildings), this paper proposes a distinct emphasis—the town-plan, meaning the different patterns of combination of streets, plots, and block-plans of buildings. Preserving the town-plan of urban areas that were built in the past means bringing to the present and future some key characteristics that can contribute to make our cities more inclusive, safe, resilient, and sustainable. When considering the preservation of the street system, in opposition to individual buildings or spaces, Karimi argues for the conservation of the 'spatial spirit' of the place [23]. Reproducing this town-plan (and not the building fabric) in the design of new areas would offer the ground for constructing more accessible, dense, diverse, and continuous urban landscapes. The next section offers a review of how the town-plan has been addressed in literature over the last decades, paying particular attention to the historico-geographical approach in urban morphology. Against this background the paper proposes the use of the town-plan as a unifying element—between the past, present, and future—that should be preserved. This proposal is explored in the Chelsea district, New York. The application into this case study offers the stage for a wider debate, making evident the contribution of this paper to heritage conservation.

2. The Town-Plan

The notable study on Alnwick, Northumberland, developed by German geographer M. R. G. Conzen, is probably the first utilization of the town-plan as it is considered in this paper. Conzen has defined the town-plan as the topographical arrangement of an urban built-up area in all its human-made features. The town-plan contains three distinct complexes of plan elements: (i) streets and their arrangement in a street system; (ii) plots and their aggregation into street blocks; and (iii) buildings or, more precisely, their block-plans (building footprints). Together, the town-plan, the building fabric (three-dimensional characteristics), and the land and building utilization constitute the tripartite division of the urban landscape [24].

Over the last decades both the concept and the method of town-plan analysis have been widely used to describe and explain the physical form of cities. Conzen M. P. offers a remarkable synthesis of the concept and method [25]. Researchers working under the historico-geographical approach [26,27], when addressing the complex processes of urban development, have frequently associated the town-plan framework with other concepts, notably the fringe belt [28,29] and the morphological region [30,31].

In the Alnwick study, Conzen defines the fringe-belt as a belt-like zone originating from the temporarily stationary or slowly advancing fringe of a town and composed of a characteristic mixture of land use units initially seeking peripheral location. Conzen M. R. G. takes the concept proposed by Louis giving it an important role in his morphological theory [32]. Since the late 1960s, Whitehand has progressively extended the scope of the concept, exploring new aspects of its spatial dimension—from city to conurbation, from static to dynamic [33]—adding it an economic [34], an agency, and a planning perspective [35], and confirming its validity in different geographical contexts. The detailed understanding of fringe-belt formation and modification and the economic perspective has been subsequently taken up by Barke [36,37].

A morphological region is an area that has unity in respect of its form that distinguishes it from surrounding areas, based on a combination of town-plan, building fabric, and land and building utilization. The concept of plan unit, considering only the town-plan, was first applied by Conzen in Alnwick. The concept of morphological region would be then developed in Ludlow, where Conzen considers not only the town-plan but the three form complexes. Additionally, he offers a first systematization of the method [38,39]. The purpose of making the method more explicit was developed by Baker and Slater, Barrett, and Bienstman [40–42]. It is also important to mention the first applications of the concept and method into planning practice, particularly in the production of a zoning map and its regulations in Mennecy and Barnt Green [43,44].

Considering the three elements constituting the town-plan, streets (and all other parts of the system of public space) have a higher permanence in time, as they represent the most significant economic effort of a society in the process of city-building. The layout of streets can last for centuries, even surviving natural catastrophes and human-made disasters. Streets support the different flows of a city, allowing access to the different plots, buildings, and activities of the urban system. Shape, length, and width are important characteristics of each street. Yet, research shows that the main variations of the street system are justified by variations in its density, or more specifically, in the density of its nodes and segments [45]. Considering nodes implies considering access to other segments. In this sense, each street would be important by itself and by its relationships with other streets, both in the immediate surroundings and in the whole urban system [46–48]. More specifically, two areas with distinct density in terms of streets nodes and segments at a neighbourhood scale or with distinct accessibility at a city scale would have different potentials of flows. The most expressive differences between different areas seem to be related to the time of their construction. When studying Portuguese cities, Monteiro and Pinho, and Oliveira et al. found that the density of street nodes and segments and of street blocks is higher in areas of the city built until the mid-twentieth century than in those built after that date [49,50]. This means that, in general, streets and street-blocks created after the mid-twentieth century are less connected (to the neighbourhood and to the whole system) and larger, respectively, than those created before the mid-twentieth century. On the other hand, the analysis of the other part of the timeframe (the older part), reveals three situations. Before the nineteenth century, streets had a high connectivity, balancing the presence of three-way and four-way nodes (X and T nodes), and street-blocks were small. In the nineteenth century, streets had a high connectivity. They have become more regular and their length and width have increased, enabling connectivity with streets in a wider metric range (three-way nodes have decreased, while four-way nodes have increased). The size of street blocks has slightly increased. In the first half of the twentieth century, street length and the size of street blocks has decreased. Due to the decrease in street length, the relation of each street with streets in a wider range has also decreased.

In general, the second of the three town-plan elements with higher permanence in time is the plot. The intensity of transformation—amalgamation or subdivision processes—depends on the dynamics of change, and the social and economic needs and aspirations of the city and neighborhood. Plots represent the structure of property, the land division and distinction between public and private, and the division between different private owners. The higher the number of plots in a street-block, the greater the possibility of having a higher number of owners and, as such, of getting different strategies for the development of that part of the city. Marcus calls it spatial capital [51]. When considering plots, although size and shape matter, perhaps the most important characteristic is the frontage width. Again, looking at urban form evolution in Portugal, in general, the density of plots was high in medieval times and in the nineteenth century, but then it started progressively decreasing over the twentieth century. This means that, in general, urban landscapes created in the last decades have less plots per street block and, as such, have potentially less agents and urban strategies. Bobkova et al. and Fleischmann et al. are two examples of on-going lines of quantitative research on plots, using large datasets and, in the second case, a high degree of simplification [52,53].

The third element of the town-plan is the block-plans of buildings. Two important aspects when considering this element are density and position. The density of buildings is intimately related to the density of plots. Today, in many countries, the position of each building within the plot is frequently defined by plan regulations. As such, setbacks can be discouraged or promoted by planning. The position of building expresses the relationship between interior and exterior space (building coverage). Certain positions are more effective that others in terms of space organization. More important, this position translates a specific relation between building and street. One of the major changes that has occurred in the urban landscape in the twentieth century was the setback of buildings. While in most buildings erected until the end of the nineteenth century the facade was coincident with plot frontage, in areas developed in the twentieth century, building and plot frontages started to be non-coincident [54]. While setbacks have been originally developed to protect health, offering light and air to buildings and its residents, they have helped greatly to destroy the street as a social space [55,56]. Taking the building facade from the plot frontage to an interior position means removing the doors and windows of the building from the plot frontage, transforming the action of walking in the street into a less desirable experience, as many elements of interest are removed.

What is the heritage value of the town-plan? For thousands of years humankind has been living in cities. It has been a long process, involving some ruptures but mainly a continuous improvement of urban forms towards the effective adaptation to human needs. It is remarkable how the main elements of urban form and fundamental patterns of combination that have structured the first cities of Mesopotamia were the same as those of late-nineteenth century, including the major cities of London and New York. Then something happened which started to radically transform the dominant processes of city building. Due to a combination of different drivers, including demographic increase, real estate emergence, new patterns of mobility, and new planning theories (mainly the garden-city and the modernist models), some elements of urban form (mainly streets and plots) lost their importance, in theory and in practice, and new urban landscapes started to emerge. These were, and still are, landscapes of low accessibility, density, diversity, and continuity. While acknowledging a few positive aspects in twentieth century processes of city building, this paper argues for a recovery of the structural elements of this six-millennium legacy that were lost in the twentieth century. The preservation of town-plans created before this major rupture of the early twentieth century, as well as the re-creation of these town-plans (controlling streets, plots, and the block-plans of buildings) in the design of new urban areas, while allowing more flexibility in the three-dimensional characteristics of buildings and land uses can contribute to make cities more accessible, dense, diverse, and continuous.

3. Chelsea, New York

The last section has reviewed the advances in the town-plan concept. The goal of this paper is to extend this concept, proposing it as unifying framework that must be preserved, and that can bring together the past, present, and future of cities. To illustrate this perspective, the paper focuses on a small area in Chelsea, New York: the street blocks set between the 19th and 24th streets, and the 8th and 10th avenues. These ten street blocks are in the south part of Manhattan Community District 4 (MCD4)—Chelsea, Clinton, and Hudson Yards. MCD4 had 103,000 residents in 2010, meaning an increase of almost 20% since 2000 (Table 1). Of these 103,000 residents, 52.4% are male and 47.6% are female; 30% of residents are foreign-born; 59% of residents are White, 17% are Asian, 16% are Hispanic, and 5% are Black. Eight percent of residents are under the age of 18, and 13% are age 65 and over. There is a strong presence of the LGBTQI+ community. Educational attainment is significantly higher in this district than in Manhattan and New York City. Unemployment and the so-called poverty measure are also higher. Finally, the rent burden and the mean commute to work are more reduced in MCD4.

Table 1. Indicators for MCD4, Manhattan and New York City.

	MCD4	Manhattan	New York City
Population, 2010	103,245	1,585,873	8,175,133
Population increase, 2000–2010 (%)	18	3	2
Educational attainment (%) (>25 y with, at least, a bachelor's degree)	74	61	37
Unemployment (%)	3.7	4.2	4.9
NYC gov. Poverty measure (%) (residents with incomes below poverty threshold)	11	14	20
Rent burden (%) (households spend > 35% of income on rent)	34	37	45
Mean commute to work (minutes)	27	32	41

Figure 1 is a reproduction of the 'Map of property belonging to C. C. Moore at Chelsea' prepared in 1835, presenting the streets, street blocks and plots of this area in the mid-1830s. Figure 2 presents the current pattern of streets, streets blocks, and plots of the same area. The town-plan of Chelsea, as of a substantial part of Manhattan, was laid down by New York's 1811 plan, designed by Simeon De Witt, Gouverneur Morris, and John Rutherfurd, assisted by surveyor John Randel. The plan proposed the structure for the future development of the city, designing a street system made of 12 avenues and 155 streets, almost 2000 street blocks, a plot structure for each street block, and basic guidance on building alignments and heights [57]. This is a clear example of a town-plan that must be preserved. Figure 1 maps the ground of Chelsea two decades after the design of the plan. The street system fully conforms to the plan. Avenues are 30 m width and streets are 18 m width (except for 23rd Street, 30 m width). Street blocks are 60 m width and about 240 m long.

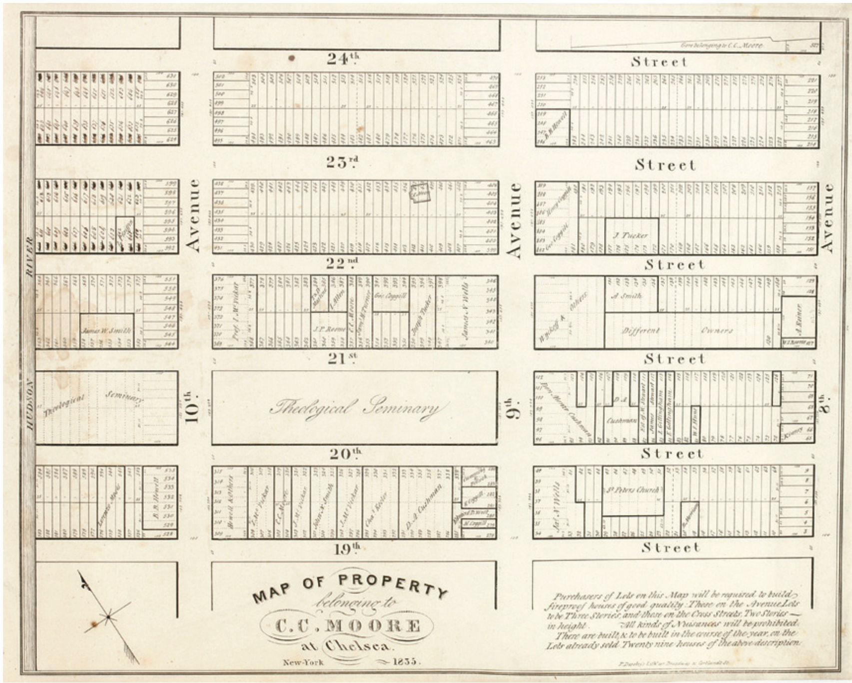

Figure 1. Reproduction of the 'Map of property belonging to C. C. Moore at Chelsea', New York, 1835 (source: public domain).

Figure 2. Streets and plots, 2021 (source: New York City's Zoning & Land Use Map).

Two of the street blocks (on the top left of the figure—street blocks 8 and 10 in Figure 2) largely conform to the initial layout of the plan, while in the other eight several plots have already been bought by the same agent. Each of these two street blocks is made of 64 plots (16 facing the avenues and 48 facing the streets)—Table 2. Each plot is about 7.5 m width and 30 m long. In the other eight blocks, there have been many processes of plot amalgamation—from two plots to a whole street block (street block 4, owned by the Theological Seminar). Street block 2 is a good example of the flexibility of the grid and of how different agents have developed different ownership strategies. In the mid-1830s, the street block was made of 62 plots. Twelve agents owned 60 of these plots (one of the agents had 12 plots), while two of the plots were not sold yet. These 10 street blocks included 561 plots. In the bottom of the 1835 map, it is written that the avenue's plots would have three-story houses and the streets' plots would have two-story houses.

Table 2. Town-plan evolution in ten street blocks, Chelsea (1835–2021).

	1835	2021	
	Plots	**Plots**	**Buildings**
Street block 1	62	52	56
Street block 2	62	40	44
Street block 3	62	45	48
Street block 4	1	7	10
Street block 5	60	55	55
Street block 6	59	61	64
Street block 7	63	48	50
Street block 8	64	62	67
Street block 9	64	2	4
Street block 10	64	3	16
Total	561	375	414

The implementation of the street system proposed by the 1811 plan was a long process—it took about 60 years for the grid to be built up to 155th Street. The process included some changes: (i) the maintenance of Broadway; (ii) the construction of two new avenues (Lexington and Madison); (iii) the creation of new open spaces—neighbourhood parks and squares (from Union Square to Bryant Park) in a first stage and Central Park in a second stage; (iv) the enlargement of some axes (Park Avenue, Lenon Avenue, Adam Clayton Powell Boulevard, and 17 of the east–west streets). Another important change, in the twentieth century, was the incorporation of 'superblocks' into the grid, erasing some street sections. While some were formed for monumental buildings (New York Public Library, Grand Central Terminal), others contained monumental ensembles (Columbia University, Rockefeller Center, Lincoln Center). From the 1930s through the middle of the century, some sections of the grid were obliterated to create large housing projects. The study area includes one of these changes in the street system—a housing project, between 24th and 28th streets, developed in the early 1960s. While the ten street blocks had 561 plots in 1835, they have 375 plots in 2021. This represents a loss of 1/3 of plots. Yet, it also reveals how resilient this design of the ground proposed by the plan 200 years ago was, in a city as dynamic as New York, growing from about 100,000 to more than 8,000,000 inhabitants. Remarkably, two of the ten street-blocks have increased the number of plots over the two last centuries. Although the ground of Manhattan has been planned, the narrow and deep plot that characterizes this vast urban area is a key element of urban landscapes, non-planned, of medieval and nineteenth century origin in other parts of the world. These 375 plots include 414 buildings. While in eight street blocks (1 to 8) the building and plot frontages are mostly coincident, in two street blocks (9 and 10) the building and plot frontages are mostly non-coincident.

Figures 3 and 4, and Tables 3 and 4 focus on street block 6 offering a more detailed view of the case study area. Of the 61 plots in this street block, 85% have a 4 to 8 m width, and 55% of the total still falls in the plot width type proposed by the 1811 plan. Clement Clarke Moore Park, plot 33 in the corner of 10th Avenue and 22nd Street, is an exceptionally large plot in the street block, with a 64.7 m width. Other large plots are plot 51 (36.4 m) containing four buildings, and probably resulting from plot amalgamation in the 1960s; and plots 13 (25.8 m) and 10 (19.8 m) containing the largest block-plans of buildings in the street block, and were most likely subject to plot amalgamation in the 1930s.

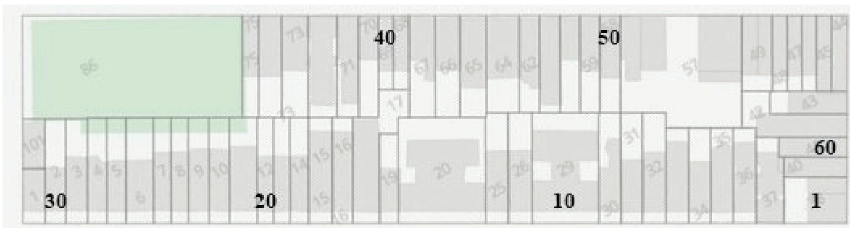

Figure 3. Street block 6, 2021 (source: New York City's Zoning & Land Use Map).

Table 3. Street block 6, 21st Street and 10th Avenue (source: New York City's Zoning & Land Use Map).

Plot Number and Location	Plot		Building		Utilization	Owner
	Area (m^2)	Frontage (m)	Year Original, Alteration	Floors		
1—Corner	810.7	13.5	1910	2	MRC (1)	J. Steven Shore
2—21st St	640.0	8.2	1889	5	RMF—10	-
3—21st St	603.5	6.7	1853 (1976)	4	RMF—12	-
4—21st St	603.5	6.7	1853	4	RSF	Lubica Mason
5—21st St	603.5	6.7	1853 (1962)	5	RMF—5	Chelsea Square North Inc
6—21st St	603.5	6.7	1853 (1962, 2009)	5	RMF—5	Chelsea Square North Inc
7—21st St	700.7	6.7	1843 (1983, 2008)	4	RSF	Maryam Banikarim
8—21st St	700.7	6.7	1843 (2000, 2006)	3	RSF	The J. R. Walsh R. Trust
9—21st St	700.7	6.7	1843 (1993, 2017)	3	RMF—3	Samuel M. Bisbee
10—21st St	2057.4	19.8	1938 (1989)	6	RMF—36	421 West 21st Street LLC
11—21st St	697.3	6.7	1853 (2009)	6	RMF—5	George Fares
12—21st St	716.2	6.9	1853 (2016)	4	RMF—5	427 W21 St CP
13—21st St	2554.5	25.8	1930 (1988)	13	RMF—69	433 West Associates
14—21st St	480.6	5.7	1853 (2009)	4	RMF—8	High Line 21 Corporation
15—21st St	1089.6	7.6	1854 (1999, 2006)	5	RMF—3	E Griswold Morgan
16—21st St	594.3	6.0	1854 (1999)	3	RSF	Mack Joshua L
17—21st St	772.3	7.8	1898	5	RMF—10	Jundi Hada
18—21st St	501.7	5.0	1857 (1999)	4	RSF	P. John Murrin
19—21st St	501.7	5.0	1857 (1982, 2013)	5	RSF	E F Baker Tobin
20—21st St	501.7	5.0	1857	4	RSF	DGT Chelsea Holdings LLC
21—21st St	753.4	7.6	1853 (1954)	4	RMF—5	453W 21St LLC
22—21st St	601.9	6.0	1854	4	RMF—4	C A Pallange Howell
23—21st St	601.9	6.0	1854	5	RMF—10	The George C Cabell
24—21st St	526.6	5.3	1854 (1964, 1999)	4	RSF	John K L Bortwick
25—21st St	526.6	5.3	1854 (1963)	4	RMF—4	Jackalope East LLC
26—21st St	752.2	7.6	1836 (1972)	4	RMF—6	463 West 21St INC
27—21st St	601.9	6.0	1853	3	RTF	29 Chelsea Square North LP
28—21st St	601.9	6.0	1853	3	RSF	Anne E Delaney
29—21st St	592.8	6.0	1853	3	RSF	Chenzhou Family LLC
30—21st St	592.8	6.0	1853 (2000)	3	RTF	Adam H Seessel
31—Corner	322.4	6.0	1853 (1999, 2012)	3	RSF	Robert S Bailin
32—10th Av	269.1	6.0	1891	3	MRC (1)	188 Tenth Av Corporation
33—Corner	6493.1	64.7	-	-	OS	NYC D Parks Recreation

Notes: CO—Commercial and Office, MRC—Mixed Residential and Commercial, OS—Open Space, PF—Public Facilities, RMF—Residential Multi-Family, RTF—Residential Two-Family, RSF—Residential Single-Family.

Table 4. Street block 6, 22nd Street and 9th Avenue (source: New York City's Zoning & Land Use Map).

Plot Number and Location	Plot		Building		Utilization	Owner
	Area (m^2)	Frontage (m)	Year Original, Alteration	Floors		
34—22nd St	481.5	4.8	1854 (1989, 2013)	4	RSF	DRGB y Asociados LLC
35—22nd St	647.0	6.5	1854	4	RMF—5	Finn G Isdahl
36—22nd St	750.4	7.6	1839	4	RMF—15	456 W 22nd St Part 1 LLC
37—22nd St	865.3	8.7	1897 (1987)	5	RMF—16	456 W 22nd St Part 1 LLC
38—22nd St	639.4	6.4	1835	4	RMF—15	Chelsea Equities LLC
39—22nd St	601.9	6.0	1835	2	RTF	Joanne Downes
40—22nd St	329.1	4.5	1854 (1999, 2009)	4	RTF	David Vence
41—22nd St	329.1	4.5	1854 (2005)	4	RTF	446 W 22nd Street LLC
42—22nd St	752.5	7.6	1836	3	RMF—3	444 W 22nd Street LLC
43—22nd St	750.4	7.6	1847	4	RMF—24	Chelsea 442 LLC
44—22nd St	752.5	7.6	1836	3	RMF—6	The Michael Minick LLC
45—22nd St	940.6	10.0	1900 (1984)	3	RMF—6	Jeffrey Preston
46—22nd St	567.8	6.0	1900	3	RMF—4	Jeffrey Preston
47—22nd St	553.2	5.9	1843 (2000, 2017)	3	RMF—3	The Weinberg 2011 Trust
48—22nd St	543.7	5.8	1843 (2015)	3	RTF	Padukone Maitreya
49—22nd St	555.0	5.9	1843	2	RTF	Carolyn N R Meinhardt
50—22nd St	552.6	5.9	1843 (1984)	3	RMF—3	426 W 22nd Associates LLC
51—22nd St	3723.1	36.4	1960	4	RMF—20	414–424 W 22nd Street LLC
52—22nd St	624.8	8.6	1856	4	RMF—12	410 Holdings, LLC
53—22nd St	312.7	4.3	1856 (1986)	4	MRC (6)	Katie D Wong
54—22nd St	312.7	4.3	1856 (1959)	4	RMF—10	London Apartments LLC
55—22nd St	312.7	4.3	1856 (1966)	4	RMF—5	404 Manhattan Reality
56—22nd St	312.7	4.3	1856	4	RMF—7	Sullkor Reality Chelsea LLC
57—Corner	312.7	4.3	1856 (1984)	4	MRC (5)	400 West 22nd Street
58—9th Av	473.6	6.4	1858 (1964)	5	PF	Div of Adm Revenue MGT
59—9th Av	835.7	7.0	1856	4	MRC (4)	Terri Zimmerman
60—9th Av	368.1	5.6	1868	2	CO	Langer 189 LLC
61—9th Av	339.8	5.6	1868	2	CO	Yamco II, LLC

Notes: CO—Commercial and Office, MRC—Mixed Residential and Commercial, OS—Open Space, PF—Public Facilities, RMF—Residential Multi-Family, RTF—Residential Two-Family, RSF—Residential Single-Family.

More than half of the buildings in this street block have been erected in the 1850s. Almost one-fourth of these buildings were built in the 1830s and 1840s. Only 10% of the buildings have been erected in the twentieth century. More than half of the building have been altered over the last seven decades, with no significant alterations in the facades. Almost half of the buildings have four stories and one-fourth of them have three stories (one building has 13 stories).

More than half of the buildings are residential and multi-family (most with less than 10 dwellings); 20% are single-family, and around 10% are two-family buildings. Almost 10% are mixed residential and commercial buildings. There are two buildings for commerce and office, one public facility, and one green area.

There is a high diversity of agency in the street block. Only three agents own more than one plot (two plots): 'Chelsea Square North Inc' (plots 5 and 6), '456 W 22nd St Part 1 LLC' (plots 36 and 37), and Jeffrey Preston (45 and 46). The plots and buildings owned by these three agents are not very different—the plot width is 6.0 to 10.0m, and the building height is three to five stories. The number of dwellings in plots 36 and 37 is the triple of dwellings in the other plots. Ownership data for two of the 61 plots is not available.

Figure 4. Street block 6: 21st Street looking west (including the 13-story building in plot 13), 9th Avenue facing north, and 22nd Street looking west (Clement Clarke Moore Park in the south corner) (source: Google Maps).

4. Discussion

The importance of the town-plan in urban landscape—as a combination of streets, plots, and the block-plans of buildings—has been debated in literature, particularly in urban morphology. This paper argues for its consideration in frameworks of conservation and heritage, together with the building fabric. This is so important as the widening of scope from singular buildings (monuments) to common buildings or built areas (mostly residential) that occurred after the mid-twentieth century.

Manhattan is a notable example of the persistence of a town-plan over time. The orthogonal pattern of streets and avenues, the rectangular street blocks (60 m width and variable length, decreasing from centre to the margins of the island), the narrow and long plots (6 to 7.5 m width, 30 m long), and the general guidance on buildings (position in plots, different heights according to avenues or streets) offered the physical support for two centuries of urban history of one of the two first megacities in the world.

If diversity is acknowledged as a fundamental characteristic of cities, the town-plan can offer a profound contribution for its achievement and development. A town-plan made of accessible streets, small to medium-size street blocks, a high density of plots and a high coincidence of building and plot frontages will contribute for the presence of distinct agents, different utilizations (including several types of residential uses), and different buildings' heights and ages—and, as such, of residents with different socioeconomic backgrounds. The Chelsea case study clearly illustrates this statement.

Manhattan's town-plan, while being the most stable element of urban form, has been able to accommodate change over the last 210 years. While it does not fit into the scope of this paper, focused on the long-term change, future research should address recent dynamics (such as the High Line project), in order to explore additional elements to reinforce the main argument of the paper. It is argued that analysis of the transformations carried out over the last two centuries can offer guidance for future change and the design of new urban forms. While the 1835 map, prepared two decades after the 1811 plan, already registered different possibilities of plot amalgamation (from two plots only to more than 60 plots constituting street block 4), the different buildings erected in the following decades can illustrate how the town-plan has combined permanence (of the most structural elements) and change (of the most ephemeral elements, such as architectural styles and building heights). Our case study, made of 10 street blocks, offers two interesting examples.

The first is 433 West 21 Street (plot 13, street block 6)—Figures 3 and 4, top. The 26 m-width plot probably results from the amalgamation of four plots. The building, erected in 1930, conserves the dominant alignment (a slight setback from the street) and one of the dominant building materials, bricks. While the architectural style was new in the street, it did establish a careful relation in terms of the facade design. On the contrary, change is clear in building height. It is a 13-story building in a street dominated by four- or three-story buildings. Another important difference is that this building is made of 69 dwellings, while most of the other buildings have less than 10 dwellings.

While the former illustrates the insertion of a large residential building into an extant residential frontage, erected one century earlier, Public School 11 (315 West 20 Street—street block 3; Figure 2) is an example of the construction of an institutional building in the mid-1920s. The plot, also facing 21st Street, probably results from the amalgamation of 12 plots (six in each street). While the peripheral areas of the building are aligned with the surrounding buildings, its central parts setback form the street. Building height fits the surrounding building fabric. As most institutional buildings, the school has a large block-plan—that is the only major change it introduces in this urban landscape.

At the city scale, Columbia University, in Manhattan Community District 9, stands out as another remarkable case of relationship between institutional buildings and the 1811 town-plan (the basic plot metric is for residential buildings). Columbia occupies six street blocks (the major change), between 114th and 120th streets, and 10th and 11th avenues, plus surrounding extensions. The construction of the notable complex of buildings started in 1900. While interrupting some streets, the complex allows the continuation of others as paths within the open space of the institution. Building and plot frontages coincide. All this contributes to establishing a profound physical continuity with the surrounding urban landscape.

Clement Clarke Moore Park is an example of the inclusion of a green area into the corner of a street block (plot 33, street block 6, Figure 3). Throughout the last two centuries, many other examples of green areas, of very different size, that were not in the 1811 plan, have been created in Manhattan—from Bryant Park (part of two street blocks) and Union Square (part of three street blocks) to the Central Park (occupying 153 street blocks).

5. Conclusions

This paper argued for a change of paradigm in conservation debate and policy—giving the town-plan a similar role as the building fabric. Based on recent advances of scientific knowledge on the town-plan, and to some extent on the exploratory case study, the paper offered three main reasons for this change of paradigm. Firstly, preserving the town-plan of an urban area built in the past, as Chelsea, means bringing to the present significant parts of its urban history. Each street and avenue, each plot and each block-plan of building created in these two centuries is part of New York urban history. Secondly, preserving a town-plan created in a period former to the main ruptures introduced in cities over the twentieth century is a contribution to assuring diversity. The detailed analysis of street block 6 made evident the diversity of agents, land and building utilization, and buildings, with a high potential for attracting people with diverse socioeconomic backgrounds. Thirdly, preserving such a town-plan provides the basis for the design of new areas (made of new buildings) more accessible, dense, and continuous, recovering the fundamental strengths of the urban landscapes created before the twentieth century.

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heritage

Article

Visibility Model of Tangible Heritage. Visualization of the Urban Heritage Environment with Spatial Analysis Methods

Elif Sarihan

Department of Civil Engineering, University of Debrecen, 4028 Debrecen, Hungary;
elifsarihan@mailbox.unideb.hu

Abstract: The methodological approach of the study proposes an innovative yet adaptive way to define and preserve heritage sites and their elements. In the case study, the proposed methodology guides the design/planning research of heritage sites by linking the perceptual behaviour with the information of the built environment. Visibility is the tool to measure the level of exposure of specific urban elements from a particular perspective. While isovist analyses define visibility in the built environment, fields of view from the periphery of heritage sites are applied to calculate visible or invisible areas by the observer. The purpose of the current study is the evaluation of the identification of the elements to be protected, by modelling both the heritage environment and the heritage elements according to the visibility criteria. For this purpose, I illustrate my approach by using visibility analyses and Space syntax analysis in the case of the Sulukule neighbourhood, the leading renewal project, in Istanbul. This area used to have notably cultural–historical assets–historic land walls, the lifestyle of Roma people—but now the renovation works carried out in the Sulukule case study site have affected the identity of the "visible" and "known" space of the historic quarter.

Keywords: visibility analysis; isovist; field of view; urban heritage; built environment; Istanbul

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1. Introduction

The concept of heritage derives from the fact that humans create urban environments and form urban patterns as they bring together components, constantly changing their surroundings [1]. Throughout history, people have marked the places where they live with distinctive features that contain/carry information. These are the tangible patterns, such as architectural and urban heritage, and physical and historical remains as architectural and historic values [2]; or intangible patterns, such as language, belief, and traditional forms of expression of these places and given to the objects that shape contemporary historic urban landscapes [3]. Therefore, historical cities have become important places where the collective values of tangible and intangible heritage can be found and represented. Heritage sites continue to exist in the complexity of contemporary cities as remembrances of the past [4]; as part of the present urban fabric, they will persist in the future.

Spatial–temporal and natural, cultural, and social processes construct the historical urban landscape. As a result, the concept of the historical urban landscape provides a mindset to understand the urban context. The concept is related to the built environment and cultural values, as they cover local knowledge such as physical layers, intangible cultural heritage and value perception, building practices, conservation, and management, which have symbolic significance [5].

According to the definition of historic urban landscapes, the protection of cultural heritage sites plays an essential role in preserving the built environment of these areas [6]. Thus, the perceptions of urban complexity are brought together holistically, combining the tangible and intangible patterns of heritage with the layers of the built environment. Increasing unprecedented urbanization and structural transformations have profoundly created more pressure over the past decades, not only on suburban outskirts and the inner core of the cities [7], but on societies, also affecting natural, historical, cultural, and archaeological heritage sites.

The concept of urban heritage has a global reach, with numerous definitions and contexts to which it relates. According to Olsson [8], urban heritage does not only subsume designated protected areas or heritage monuments and areas. However, it is a system set in which these values are defined in the broader environment and describe the interaction between the parts of a system where the urban landscape is described as heritage. Therefore, urban heritage should be evaluated within the system of both intangible and tangible characters. In this context, urban heritage should include tangible characters (physical remains) and less tangible characters (human beings as significant factors for the articulation of the heritage space and the built environment) [2]. Blake [9] defined it in the context of these two features, as cultural heritage brings together elements of seemingly ordinary characters, such as features of the natural and cultural landscape.

Even preservation and development of cultural heritage are target areas of international urban planning policies, but there is an emerging need for planning studies of heritage protection areas that will predetermine the results of planning stages and predetermine the solutions that will preserve heritage. These are becoming more and more important in the lines of heritage conservation and development of heritage sites. In contrast, various obstacles [9,10] prevent the visible scene of such heritage sites in the historic urban landscape. These obstacles could be the increases of newly added buildings, and the deficiencies of the spatial configurations and designs.

The current research methods offer directions to define the heritage surroundings quantitatively in historical landscape areas preserved in urban settings. Based on traditional urban morphological approaches (Conzenian [11], Caniggian [12], Gordon Cullen-Townscape [13]), the researchers created comparative urban analyses using the areas' landscape units or character zones, in combination with photos and sketches, to determine the historicity of the urban landscape. Despite that, human perception is the fundamental link between human and built environment [14]. These tangible patterns of the environment are defined by perceptual features and manipulate themselves.

The listed buildings or heritage environments are attractions of human interest because their views, meanings, and patterns reflect their cultural and historic natures [15]. However, this phenomenon is related to the visibility/perceptual conditions of these elements in the environment. The idea, generated from the research of Michael Batty [16], is related to our perception, based on the geometrical properties of different urban spaces. In terms of visual representation, it is about creating a visual field derived from any viewpoint of an observer and based on the extensive geometric properties of the environment. Batty offered an isovist analysis method to present space with spatial and statistical value. The isovist (fields of view) obtained by making use of the properties of the form or (urban and geographical) morphology [16]. Michael L. Benedikt defined isovist as "The set of all points visible from a given vantage point in space and with respect to an environment" [17] (p. 47). Based on this definition, it is possible to generate a defined visual field of the spaces and features from an observer's point of view in different points in space. The isovist and isovist fields reveal the meaning of clarity, preservation, specialist, dynamics, or complexity by human behaviour and human cognition [17]. David O'Sullivan and Alasdair Turner [18] generated the reciprocal visibility of a series of isovists from different positions and aimed to derive a general visibility graph in the space. The holistic approach, a graph-based analysis produced locally and globally, presents a methodology for defining the configuration based on accessibility and visibility [18].

Hillier and Hanson [19] used spatial analysis methods to examine how spatial structure promotes human behaviour, coexistence, and contact with humans in culturally diverse built environments and various historic environments. Analytical tools that seek to explore the visual qualities of three-dimensional space have begun to emerge in recent years [20]. Current studies on the urban environment focus on problems related to the visibility of landmarks and heritage sites within urban systems. Phil Bartie [21] studied the visibility of landmarks within heritage systems throughout a series of visual metrics. André Soares Lopes et al. [22] studied the elements of the urban landscape that appear together as an overview of visibility analysis. They analysed the other elements that are co-visible in the visible scene by focusing on the visibility of heritage elements.

The research problem is how to visualize the outputs of the elements related to the perception and clarity of heritage sites within complex systems, and how the spatial configurations of the buildings of the heritage sites must be controlled and designed so as to define the performance of the urban elements holistically. It is significant to decide on the components integrated with heritage, or which factors are not well determined in terms of preservation of the heritage settings.

The current methods of spatial analyses lead towards understanding the urban landscape as a whole by using urban geometry as data, defining and reflecting all elements visually. The methodologies provide the adaptation of deep learning of the two-dimensional spaces to evaluate the elements that must to be protected or included in the heritage sites.

This paper offers a spatial analysis method to overcome spatial configuration problems of heritage sites with urban systems. Most importantly, the method provides a way to connect the results of integrated visible models of the urban landscape—created by multiple isovists—by learning from the characteristics of the heritage environment. Thus, while defining heritage pertinence targets within the built environment, urban designs and projects can be implemented in heritage areas with a more holistic approach.

2. Background

According to Athos Agapiou et al., there is a need to track innovative ways and analyse new and practical approaches to urban heritage sites away from the archaeological approach [23]. For this purpose, this research represents a method for establishing interoperability and a methodology to reduce the obstacle elements of heritage visibility. The combined approach is based on integrated visibility analysis to determine traceable results of the compositions of urban heritage settings.

Visibility is an analysis tool that provides a significant advantage in visualizing the integration of the urban environment based on visible data of fields and objects through a point of view and isovists at a particular location [24]. Developments in computer science have allowed visibility analysis to become a widely used research method today [25], including GIS-based view analyses, ArcGIS, and 3D Analyst; or spatial analysis techniques such as the space syntax based on Social Logic of Space [19]; or isovist analysis [17] used for evaluating urban or architectural spatial scenarios.

The current research aims to demonstrate the spatial compositions of the heritage environment and the different visual elements of its configurations. It includes space syntax analysis to reveal a range of people's visual directions about the landscape [26] and the complexity of various factors.

The integration of the visual analysis methods creates a more holistic approach to the representation of heritage sites. space syntax focuses graphically on the spatial arrangement of buildings and cities and how human movements affect their social and environmental consequences [27], whilst isovist analysis tends to focus on people's social experiences and perceptions in space and determine the scope of vision in the built environment [28].

The difficulty in perceiving urban space depends on the variation of shaping elements of the built environment and the isovist behaviour (an observer makes the decision). Urban spatial research must include both analyses of visibility and permeable visibility. Thus, in this way, it can be decided which spatial configurations inhibit urban elements to consider or ignore [29], and the changes of visual permeability will reveal the heritage elements.

In the current research, the focal point is on the deep/comprehensive visibility analysis. Both demonstrate the visibility character of heritage sites, enable their integration to other urban spaces, and reveal the geometry/layout of the urban heritage environment. Deep spatial learning is limited to the neighbourhood level in which the heritage environment is located. Isovist analysis is successfully used in two-dimensional spatial computing at the neighbourhood scale. It is beneficial in analysing the degree of visibility of landmarks (heritage sites, listed buildings, monuments) or the panoptic appearance of these areas as they move through space and determine how urban interventions will affect these elements [30]. The visibility of the observed area and the amount of appearance vary concerning the diversity of the area around the space [31]. According to Y. Kim and S. K. Jung [32], the isometric measurement approximates the amount of visual information at a given point, and the isovist field reflects the amount of visual designated field from observation points. Visible areas inside or the Field of View (FOV) may not be visible outside of the space due to the permeability of the geometry. In the historical landscape of heritage sites as the effective environment with visible elements, we should consider all the elements that can be seen simultaneously with historical elements from all possible points of view. The space establishing elements are distributed in different positions and combinations based on the observer in a given point of view and a given horizontal Line of Sight [33] (Figure 1). Therefore, we must decide which elements can be sequenced in the formation of visible areas. While it is difficult to isolate what will be preserved (buildings, urban ensembles) in such complex systems [34], it is clear that the unique identity of the heritage environments must be maintained.

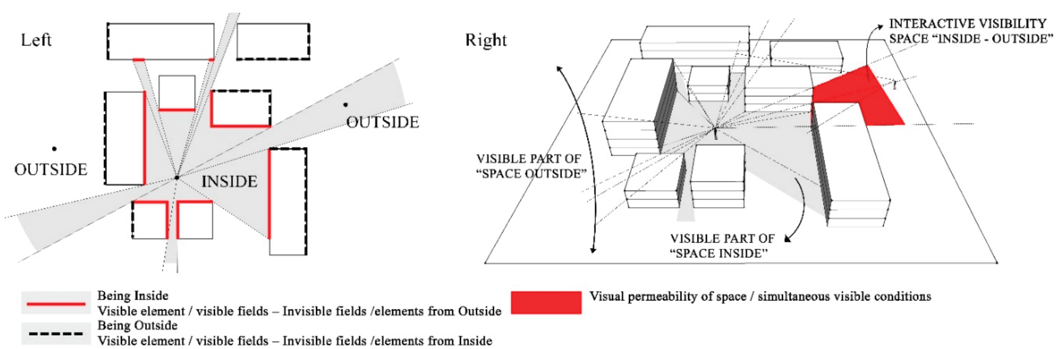

Figure 1. The different visibility conditions based on the position of the observer, inspired by Philip Thiel [33] (pp. 222–224). Left is a space bounded with physical boundaries; Right is a visual environment in Left; re-illustration by the Author.

The Field of View (FOV) in landscape architecture is a concept dating from about the 1960s and has been adopted by many disciplines. It displays the areas visible from a single point of view by measuring the Lines of Sight (LOSs) from that point to all other localities in the working area [35]. According to Phil Bartie, the Field of View (FOV) is measured as the most large-scale observable horizontal angle among targets in the most certain Field of Interest (FOI) created from a given viewpoint. It derived from object size and orientation measures but does not determine the angle vision that may be obstructed from the inside of the FOI [21]. The front area is often measured by placing the apparent scope under each target, taking the unknown obstacle areas between the observer and the target into account (Figure 2).

The main purpose of the current research is to evaluate the various methods of visibility analyses combining the constituent elements of heritage sites, and possible/already established design and planning indicators in their integration with the built environment to provide a framework based on visibility analysis on the visual preservation of heritage.

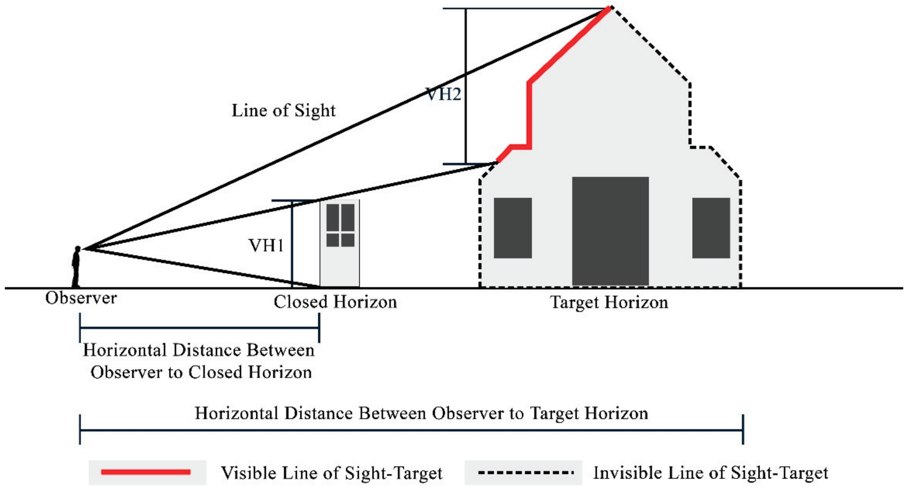

Figure 2. Visual representation of LOS. Closed horizon location indicates the level of visibility on the target horizon; inspired by Bartie et al. [35]; re-illustrated by the Author.

3. Materials and Methods

For seeing perceptual patterns in heritage sites through the generation from any point where an observer establishes a different visible field (isovist), the research combined different approaches.

Firstly, to generate the visible field, we had to determine the phenomena, namely an outline of the spaces/nature of the isovist boundaries and points of view. The isovist analysis was applied according to Benedikt [17]. The shape and size of the isovist are determined based on the environment's geometry; for this purpose, Batty's research [16] was considered, and the research used the methods of Bartie et al. [21] and Lopes et al. [22] to determine the object or size that obstructed the visibility conditions of the field of interest (heritage target).

Lastly, to evaluate the mutual visibility of heritage elements and the built elements of their surrounding built elements, visibility graph analysis was conducted for each selected heritage site, according to Turner et al.'s research [29].

3.1. Methodology Overview

The methodological approach proposed a new and general way of defining the heritage site and preserving heritage elements. In the case study, the methodology guided the design/planning study of heritage sites by linking the perceptual behaviour in the heritage space with the information and attention of the urban heritage environment. The types of information about the visual experiences of the space, generated with the visibility analysis, are based on the observer's point of view. Physical information/tangible data (such as location, boundaries, or dimensions of the heritage site) are real life data and do not allow any judgment about their existence or nature. Intangible data are flexible and allow for some value judgments and are related to the are non-quantitative cognitive and perceptual aspects of space and properties of objects.

Therefore, a distinction of interest had to made between these two elements in the current research. Each heritage site shows diversity and different physical patterns that have different information [36].

The framework stage used for the case studies is presented in Figure 3 and includes an outline of the data, separating the data of the sites, and moving towards the more detailed resolution, step by step. It starts with the identification of real data followed by the selection of a set of isovists that generates the spatial system with all its elements. The final step is to evaluate all visibility conditions with graph analysis (Figure 3).

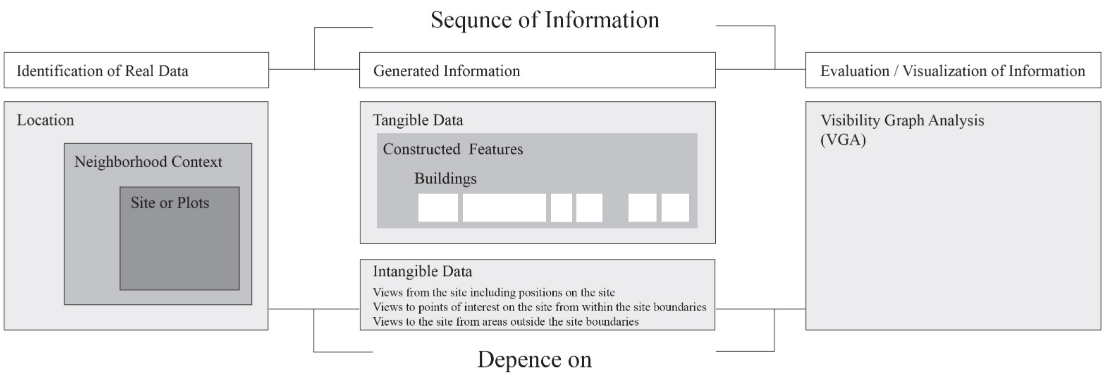

Figure 3. The framework of the proposed stages.

3.2. Identification of Real Data

The first stage of the identification part of the model (A) involves mapping the heritage site's location with respect to the city as a whole. This type of mapping method allows planners or decision-makers to understand the heritage space or to create information-containing elements. The neighbourhood context (B) represents the immediate surroundings of heritage sites beyond one or two blocks away. Thus, all conditions that may affect the heritage site can be evaluated and displayed together. In heritage sites, we need to determine the "outline of the spaces"/"nature of the isovist boundaries" (C) in order to create isovists (visible area) in the generation of perceptual information from any point where an observer will create a different visible area (isovist) (Figure 4).

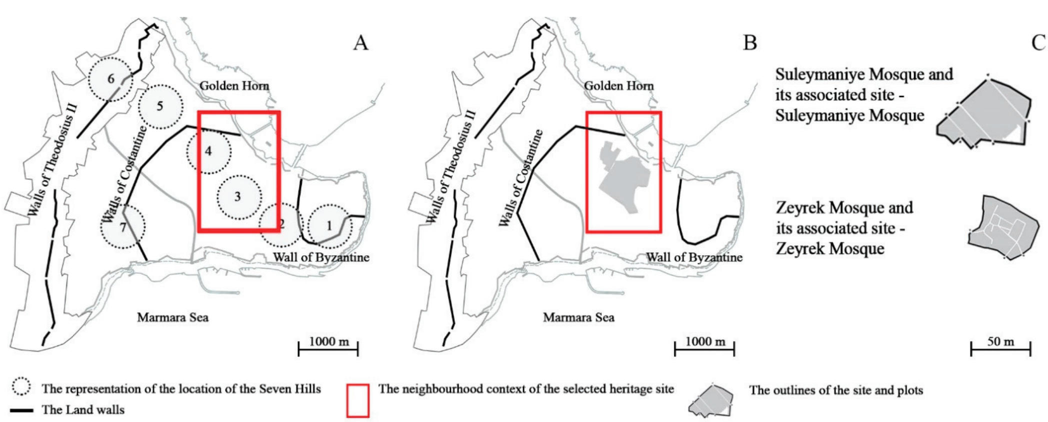

Figure 4. Mapping real time data for identification of heritage sites and immediate surroundings is based on OpenStreetMap and created by the Author.

Tangible patterns add more meaning to the appearance of heritage, thus making it possible to make more detailed inferences to perceptual attributes on the spatial level.

3.3. Generated Information

3.3.1. Constructed Features

Tangible elements of heritage sites are created by revealing blocks and primary building volumes. Assets of all urban components are determined by evaluating the heritage sites' tangible data. Due to the lack of information visually presented by the two-dimensional analysis, three-dimensional forms create [37] the existing perceptions of the spaces at this methodological stage. They also contribute to the analysis of the dominant current architectural character surrounding the heritage sites. According to Lopes et al [22] the mapping method of tangible patterns shown in the methodology allows planners or decision-makers to understand the three-dimensional approach (e.g., 3D landscapes, visibility analysis, and eye ray tracking analysis) or focus on the two-dimensional analyses (complementary analysis and visibility measures) of the spatial attributes of heritage sites and complementary interpretations about visual features (Figure 5).

Figure 5. The constructed features of heritage sites and existing architectural monumental buildings that characterize their surroundings; based on OpenStreetMap; illustrated by the Author.

3.3.2. Intangible Data

This stage identifies the points in the heritage sites where the observer's field of view is closed/blocked or open. These obstacles are buildings, blocks, or walls according to the tangible pattern of the urban environment defined above. Visible fields or visibility conditions of the heritage surroundings cognitively describe the space. Therefore, it is possible to predict human perception and behaviour (intangible). Isovists take the shape of the environment or geometry of space. Thus, our way of experiencing a field and our visual perceptions are related to the isovists.

Since the purpose of this stage is to identify intangible patterns of the environment of the heritage sites, it should reveal the meaningful features of the environment related to human perception, although intangible heritage should be defined as spaces that are used and perceived by individuals.

In this stage, we generate the point of view from outside the boundaries of these elements, even including components of the urban surroundings of the heritage site. Thus, all possible combinations can be determined regarding visibility conditions within the visible cluster, visible angles, visible permeabilities, the most dramatic/less visible positions, or highly visible areas of the heritage surroundings.

The solution is the chosen perspectives or points where the targeted heritage buildings are visible/or not visible.

The number of visible rays in each sight frame varies according to the perceived distance, size, and form of the obstacles. For this reason, viewpoints were obtained from the periphery of the heritage site. The effects of the urban elements on the visibility of the target and the visibility behaviour of the distance were determined (Figure 6).

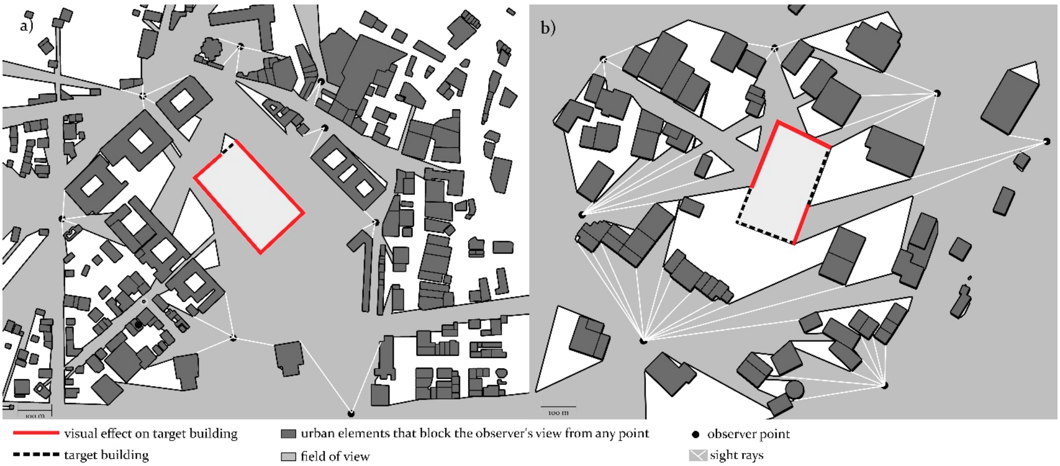

Figure 6. The isovist rays respond to the visibility conditions of the surrounding heritage and visual permeability from inside and outside of the space. The perimeter of the historical building targeted/point of interest as the Süleymaniye Mosque in (**a**) was determined by 2D analysis. The historical building environment targeted/point of interest as the Zeyrek Mosque in (**b**) was defined by 2D analysis, generated on the isovist platform [28] by the Author.

3.4. Evaluation/Visualization of Information

Visibility analysis tools determine the perceptual qualities of architecture or the built environment and characterize different urban system types as a whole [16] based on matching multiple visible criteria.

Heritage areas, especially cultural heritage sites, can be evaluated by the spatial-based framework, by combining it with its cultural and social framework [18]. In the consideration and evaluation of heritage, it is important to combine the interaction between traditional land use, relevant social characteristics, mobility, and interests.

4. Case Study

Istanbul's Historical Peninsula served as the capital city of several civilizations, such as the Roman, Byzantine, and Ottoman Empires. It hosts the oldest settlement in Istanbul. It was the capital of the Byzantine Empire for 1058 years, and then the Ottoman Empire conquered the city and hosted the Ottoman Empire as its capital for 469 years. Istanbul is situated on the northern part of the Marmara Sea between the Bosphorus and the Golden Horn natural harbour. Its topography consists of hills overlooking the water (Seven Hill Istanbul), slopes, and valleys heading to the shores and valleys. Located on the first hill overlooking the Golden Horn, the Acropolis was fortified with the Sur-i Sultani, after the Ottoman Empire came under sovereignty, and Topkapı Palace (New Palace), allocated to the state administration under this inner castle, was established and has been the administrative centre of the Ottoman Empire for centuries. An understanding of urban zoning in the Ottoman Period, considering the topography, aims to position the wide range of service structures (complexes) on the hills to reflect in the view the hierarchy between these buildings, and at the same time to point out the centres of the sub-regions/districts of the city and to provide an understanding and orientation of the city in today's words. The outstanding universal value of Istanbul reflects the unique incorporation of culture and characteristics of several civilizations experienced in the city, overlapped on the city, and shaped with its unique silhouette the social and physical patterns visible today [38].

In the Historical Peninsula, the historical strata are multi-layered within the contemporary urban structure [39]. The monumental structures, existing in the same urban areas of the Historical Peninsula conservation site, reflect a transitional character in the urban fabric with the changing socio-cultural features. The backbone of the urban form was shaped according to the city's topography in specific periods. Important religious buildings or monuments developed and transformed [40], such as churches from the Byzantine period and mosques from the Ottoman period [41], and their symbolic meanings sustained. Over time, the Historical Peninsula partially lost its character. As an example of changes, the historic walls, which were the most important symbol of the Historical Peninsula, whose construction was started by Theodosius in the beginning of the fifth century, and the Topkapı region (included in the UNESCO World Heritage list) provided the defence function but also determined the size and development of the city. However, while some of the walls have survived until today, some have been demolished.

The Historical Peninsula has four areas that carry outstanding universal value, as one of the criteria to be listed on the UNESCO's World Heritage List (listed from 1985): the Archaeological Park at the tip of the Historical Peninsula; the Süleymaniye Quarter with the Süleymaniye Mosque complex, bazaars and vernacular settlement around it; the Zeyrek settlement area around the Zeyrek Mosque (the former church of the Pantocrator); and the area along both sides of the Theodosian land walls including remains of the former Blachernae Palace [42]. Monuments are known as unique architectural masterpieces of the Byzantine and Ottoman periods, such as the Süleymaniye Mosque designed by Mimar Sinan, the Hagia Sophia church, the presence of historical Byzantine walls, the mosaics of the palaces and churches of Constantinople influencing both Eastern and Western art, and the local residences around the important religious monuments in the neighbourhoods of Süleymaniye and Zeyrek. Elements such these that reflect the remains of the Ottoman urban texture have caused these four areas to be included in UNESCO's World Heritage list in 1985 [43]. The topography of the Historical Peninsula offers views of the city from many angles, including its seven hills; from the inner parts of the peninsula, it is possible to capture the scenery and even the sea. Those seven hills listed make it possible to see potential views that have overshadowed the city's skyline (Figure 7).

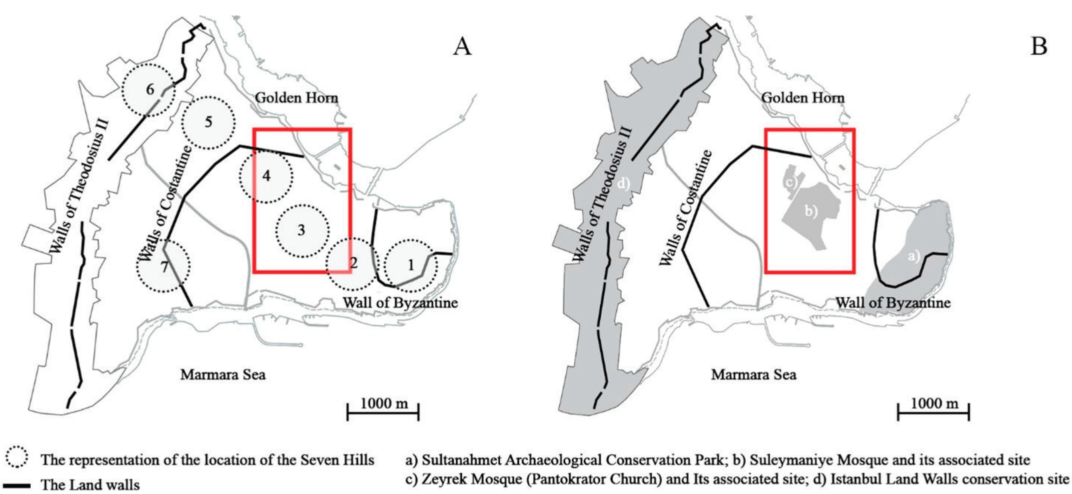

Figure 7. A representation of the seven hills of Istanbul (**A**) and the Historical Peninsula World Heritage sites (**B**): (b) Süleymaniye and (c) Zeyrek case studies map; map based on UNESCO [43,44]; re-illustration by the Author.

The Süleymaniye World Heritage case study site is situated on the third hill and continues towards the shores of the Golden Horn. The district shows the typical characteristics of the Ottoman Era settlement with its traditional houses and neighbourhoods formed by the streets, preserving their organic forms. The main element of the district is the Süleymaniye Mosque and the secular urban fabric around it.

The second case study is the Zeyrek Mosque World Heritage Site, located on the fourth hill and hillside of Istanbul, bordered by Atatürk Boulevard to the east. Atatürk Boulevard separates it from the Süleymaniye District (and the Süleymaniye Mosque and its Social Complex). The Zeyrek District is known as the fourth hill of Istanbul and was recognized as the monastery zone during the early Byzantine period [42]. Its traditional fabric is preserved, which consists of timber attached buildings that reflect the residential area's characteristics.

Zeyrek and Süleymaniye Mosques belong to different religions, cultures, and communities, located on two hills facing each other in the Historical Peninsula. From the Byzantine period to the Ottoman period, the two masterpieces positioned on these hills created a remarkable visual impact from many points in the cultural heritage site. Although these areas were designated as conservation areas from 1995, no conservation-oriented development plan was prepared for the Historical Peninsula until 2003. Since 2003, incomplete and inconsistent planning processes [45] caused the limited implementation of the conservation-oriented development plan. A comprehensive legislative structure (Law No. 5366) ("Law on conservation by renovation and use by revitalization of the deteriorated historical and cultural immovable property") [46] has been developed to undertake urban renewal initiatives in Istanbul's historic neighbourhoods. Istanbul's planning experts and scholars criticized the legislation for the social aspect of urban development, exclusion of residents, infringement of property rights, and negligence. Despite these objections, the Law entered into force. The legislation provided the basis for new urban renovation initiatives in the historic quarters of Istanbul. New legislation granted further responsibilities to municipalities for undertaking renovation programs in historic neighbourhoods. Therefore, World Heritage sites have been affected by urbanization processes due to their acceptability for investments in the tourism and housing sectors. Due to the limited intervention of UNESCO in these areas at the local level, the protection of historic neighbourhoods such as Zeyrek and Süleymaniye remains insufficient [47]. Furthermore, the poor design of the existing neighbourhoods and the construction of the densely built environment prevent a strong interaction of these Byzantine and Ottoman icons. Although they are close to each other, they are perceived far away and are disconnected by the human eye-level experience.

5. Implementation of the Method on the Renewal Areas

The purpose of the renovation zones declared per Law No. 5366 is to plan the neighbourhood where the historical–cultural heritage properties are concentrated. This policy has predominantly impacted Istanbul and its 47 historic districts. The leading examples of the renovation areas within the historical borders of the peninsula are the Süleymaniye, Sulukule, and Ayvansaray districts. These areas are occupied by middle-and low-income groups in the city centre. However, the planning decision aimed at improving the urban standards of selected regions with the physical renewal and quality of life of the settlers could not interfere with the accompanying social and economic processes. As a result, the former inhabitants had to migrate from their original settlements (gentrification) because they failed to adopt new economic and social conditions [48]. The investments focused on these renewal areas for economic development because these neighbourhoods had great opportunities to transform to satisfy the requirements of tourism, offices, and residences in heritage surroundings. Cultural heritage values understood as tangible and intangible features of heritage sites are significant elements of cities. Therefore, the protection of these elements should be taken into account when planning interventions in these areas. Now, with the renewal projects being carried out in leading historic communities like the Sulukule neighbourhood, attention is drawn to the importance given to those areas. The

Historical Peninsula has a multi-layered structure with historical changes and development. Among them, the Sulukule neighbourhood lies along the land walls of Istanbul, elements of the image of the city [49].

If the cultural heritage concepts are not defined, the heritage of regions may face pressure because of new developments [50]. However, multi-layered heritage neighbourhoods and structures can be maintained and controlled through planning and design decisions. The renovation works carried out in the Sulukule case study site affected the identity of the "visible" and "known" spaces of the historic quarter. In this context, this study follows the examination of how the renewal process affects cultural–historical assets by using visibility analyses and space syntax analysis in the Sulukule example of a renewal area.

6. Results

6.1. Visibility Graph Analysis (VGA) Model—The Spatial Connection with Urban Environments

According to Turner [29], researchers, planners, or architects can analyse a visibility map for a spatial context by using some of the many metrics developed to examine graphic features across a spectrum of disciplines, thereby providing insight into the range of available measures.

The visibility graphs of the two case studies in the heritage sites were developed using isovist software. These are semi-local or relational measures that extend between local and global information: visibility, mean metric depth, mean visual depth, and integration. A planner's isovist field of visibility and accessibility created from a specific point to establish a network of all direct connections between nodes. The values of the visibility measurements in the analysis were represented using the colour scale in each analysis type. Furthermore, the extent of the analysis as well as the visibility of case studies in the heritage area, plotted using a scale from blue (minimum area) to red (maximum area) for a simple spatial configuration, was represented.

The red–blue colour spectrum visibility graph reflects how frequently a field falls into an isovist generated from within that area. Figure 8 shows a graphical comparison of the study areas based on the results of the space syntax analysis. According to the results of VGA, the first proposal indicates the most visually integrated, and the shallowest nodes on average are shown in red, while the least visually combined and deepest nodes on average are depicted in blue. The core of the two study areas and the part of the Atatürk Boulevard close to the cores are not visually integrated. The lack of circulation of pedestrian areas that would connect the Zeyrek Mosque and the Süleymaniye Mosque areas affect the integration in the region. It is clear how the importance of the correlation between visibility analysis and connectivity and integration provides clues to users in the entire spatial configuration [51].

The second proposal of visual metric depth analysis shows that the observer's location (point) in the historical site is the shortest metric distance from that point to a single global position. The red colour means that the metric depth is the longest path distance from a specific location of the observer to a global sample location. The third proposal of mean visual depth in the plane is presented for the illustrated number of visual measures from the point to all locations. The visual step depth determines the pedestrian flows between different routes in the spatial configuration and the quality of pedestrian accessibility and the accessibility to public spaces or public services [28].

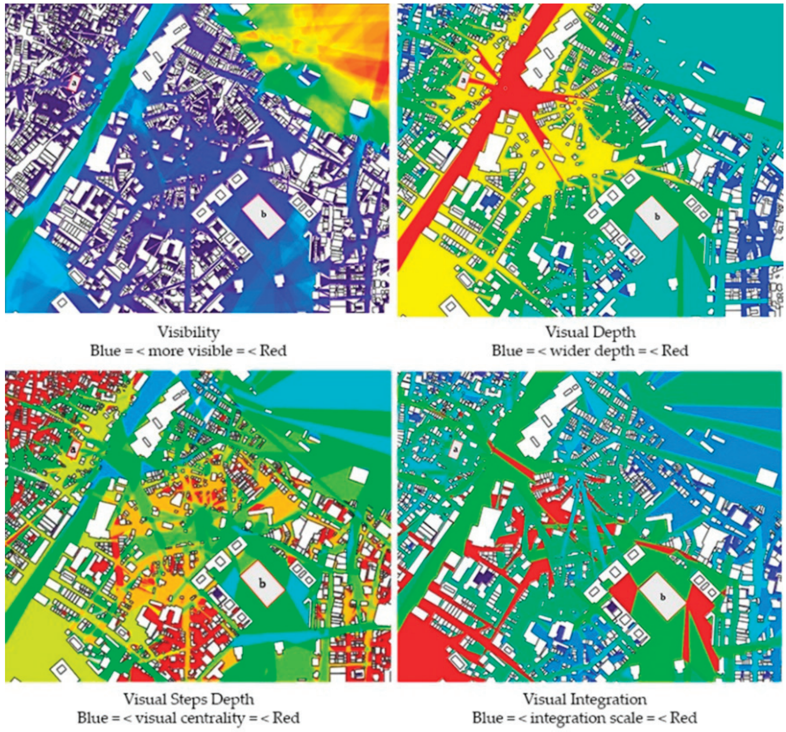

Figure 8. Visibility analysis results of the selected heritage sites, generated on the isovist platform [28] by Author.

In this context, the results obtained show that the visual step depth metrics were not sufficient for the accessibility of cultural heritage sites. The integration, which is proposed as last, is about the average number of lines required to go to all areas in the spatial system, not accessibility as a metric, but depth [52], and is used to show how far a particular area is from another area. In addition, integration is typically indicative of the number of people likely to be in a space [53]. In this context, red represents the most integrated spaces in the heritage site, while blue represents the least visually integrated areas from all other nodes. The result in the visual integration analysis is the integration surrounding in the core of two cultural heritage sites. It consists of the combination of primary and secondary integration areas and the central integration of the Atatürk Boulevard.

In this analysis, it was determined that the cultural heritage sites in urban areas and the spatial configuration of the heritage elements within them, land use compositions, and characteristics of the urban form affect the visibility and accessibility of the heritage site in many ways. Moreover, the variability of land uses around the cultural heritage site and the increased spatial intertwining between building densities indicate that space has a strong effect on regional accessibility behaviour.

6.2. Mapping the Visual Configurations of Spaces

These measurements, created by combining the GIS datasets of the Zeyrek and Süleymaniye study areas, can provide a user with the ability to be context-sensitive to the historical heritage area. When searching for spatial databases, visibility criteria can rank the results that show the most visible objects [35]. In navigating with visibility maps, visible field values (greyscale values) can guide the user to good viewpoints in the field. When an observer travelling from the settled field experiences visible field changes (corner to centre), the visible metric values change (light grey means a less visual distance to all other points), and the total duration of the trip increases (light grey means less metric distance). We can determine the measures of the visibility of the cultural heritage structures, regardless of the distance, and how many of them emerge or do not emerge as they move away from the structure.

Results can be derived from maps, for example, to perceive the target of the Zeyrek Mosque, and functions such as (1) which direction the observer should move, (2) visibility depths, (3) visible functions (visual connections, visual dominates), and (4) spatial integration can be calculated. However, as the observation distance increases, the perceived area decreases. This means that there is more exposure to a large (Süleymaniye) area and a small (Zeyrek) area than two equivalent areas. Even if the total area is equal, a large area and a small area may appear larger than two equal-sized areas [17]. According to Bill Hillier [20], human perception of space and time is positive in this sense. The Süleymaniye Mosque and the Zeyrek Mosque and the historic neighbourhood pattern that developed around them give heritage value to the cultural heritage site. However, in recent years, the World Heritage values in the Historical Peninsula have been negatively affected by the intense and linear housing pressure caused by rapid urbanization.

The perceived interest and visual impact of the Süleymaniye Mosque and the Zeyrek Mosque from many existing points has decreased. Figures 9 and 10 presents the findings of the visual perception analyses of the Süleymaniye and Zeyrek heritage sites. Results show that the fields of view around the mosque complexes have become relatively smaller. This is linked to the low amount of visually perceived dominance. In the analysis, visible metrics around the heritage buildings indicate that the visitor travelling in the cultural heritage sites experiences changes in visible areas, and the visible values of the heritage sites are decreasing.

In the Süleymaniye case, the light grey colour in the analysis indicates positive visibility (the historical buildings can be seen from that site). The dark colour in the first analysis represents that the visibility has decreased due to the small area occupied by the Zeyrek Mosque cultural heritage site and its intensely built environment. The placing of the urban blocks in the vicinity of the Zeyrek Mosque block the visibility of the heritage site.

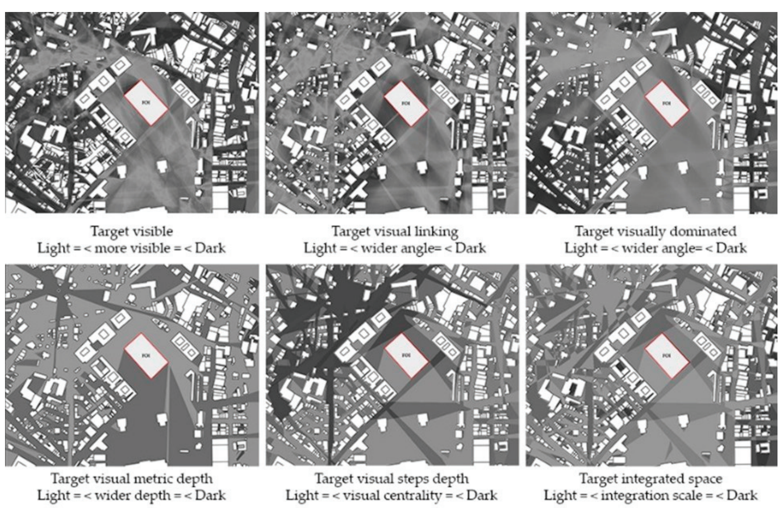

Figure 9. Maps of visual metrics of the Süleymaniye Mosque cultural heritage site, generated on the isovist platform [28] by the Author.

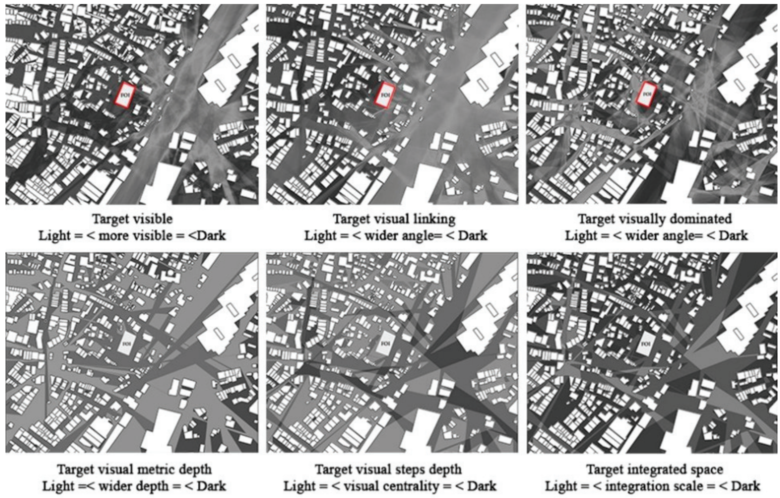

Figure 10. Maps of visual metrics of the Zeyrek Mosque cultural heritage site, generated on the isovist platform [28] by the Author.

6.3. Evaluation of the Visibility Analysis Method—Case Study of the Sulukule Renewal Area

Located along the Byzantine city walls of the Historical Peninsula, Sulukule is considered the first settlement of the Roma community (Figure 11). According to the information obtained from limited sources, the Roma people arrived from India in 1054 to this region [54].

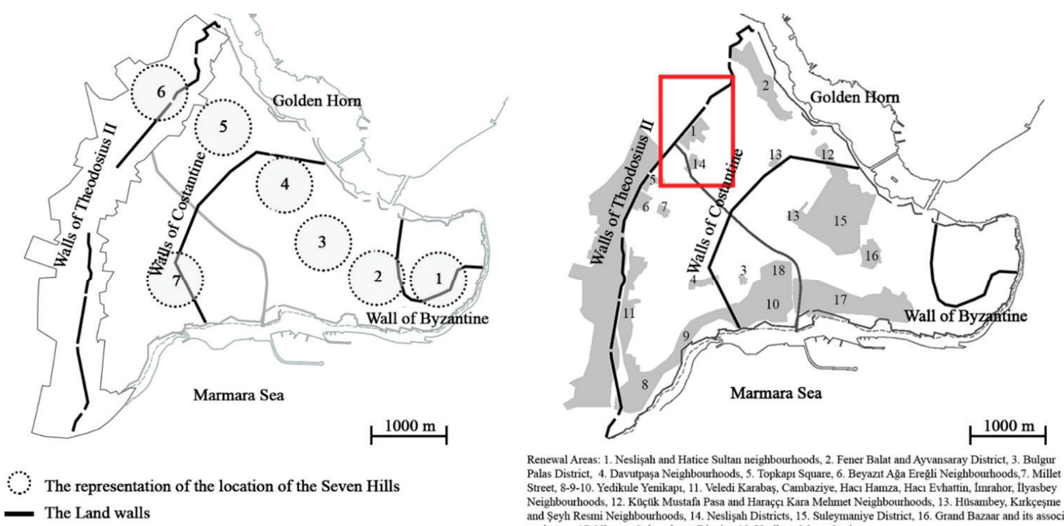

Figure 11. Renewal areas in the Historical Peninsula: (1) Sulukule neighbourhood based on [44]; re-illustration by the Author.

People living in Sulukule have undertaken responsibility for the entrance and exit control of the Istanbul land walls and still see these walls as part of their neighbourhood. The urban elements that define the Sulukule district are the narrow streets and the houses with adjoining two-story courtyards shared by the small households surrounding these streets. Nowadays, the change in the lifestyle of Roma people can be seen [55]. The former residential district, now a ruined and abandoned land, was declared for renovation in 2005. The Sulukule urban renewal project was initiated in 2006 and included 12 blocks, 378 parcels, 10 streets, and 645 architectural structures [56].

The Sulukule case study purposed to determine how the built environment transformed and demonstrates physical and visual integration differences within urban structures.

The changes in the historical landscape (building forms, blocks and patterns) and urban forms of Sulukule were analysed firstly with the urban renewal to identify the visual elements with mapping the area between 2006 and 2020 (Figure 12).

Figure 12. Sulukule renewal zone before and after, based on Google Earth; drawing by the Author.

The method applied to the area of 91,000 square meters [57] within the boundaries of the Istanbul Fatih Municipality. UNESCO has chosen this area as it has been evaluated in terms of cultural heritage values, illustrated in the heritage site as "red rectangular".

Located along the Byzantine city walls (marked with red lines), Sulukule is one of the most affected by urban development activities. As the first map shows, the urban form of the Sulukule neighbourhood represented a historical organic structure before the urban renewal process. After the renovation (second map), this structure was completely demolished and transformed into a completely different urban fabric with building blocks. GIS-based mapping analysis enables the characteristics of urban elements to be examined and defined, and how human behaviours in the past and today may have affected the field of visibility and all urban components. In this state, the neighbourhood has lost its identity (tangible and intangible character) and resembles a ghost town built with block buildings. Moreover, the fortification band determined by UNESCO is reduced to half, and the original parcels and street texture have not been retained. The elements belonging to the cultural heritage area have vanished.

One of the important statements of the renovation project is that the Roma Roman settlement that existed for centuries has been demolished, and their social–cultural identity has been separated from the urban context, and the continuity of the community network has been lost. For this purpose, the next stage of the research focuses on the historical values, to compare the visual link that the residents have with historical city walls (Figure 13).

Figure 13. Visibility analysis of historical land walls (red) by creating isovist geometries in the Sulukule neighbourhood, generated on the isovist platform [28] by the Author.

The previous analysis (Figure 13) gives information about the importance of the cultural characteristics of the Sulukule neighbourhood to be renewed by preserving the forms of buildings, cultural, and historical structures and landforms in the urban context. Therefore, the visibility analysis focused on the Byzantine walls of the neighbourhood consisting of 12 plots and 378 parcels. The analysis provides an opportunity to understand and discover the changes made in the historic district with its cultural values.

The analysis determines how the visibility of the historic walls has changed from the visual perspective of people who have cultural interactions with the Byzantine heritage in the neighbourhood as the UNESCO's land walls arrangement. Moreover, in most cases, the isovist model [17] is used to define the range of visibility in urban environments, while a viewshed of a topographic dataset in the region is visible from any location around a given observational point [58]. The analyses are applied in heritage regions to determine the visibility of the field of interest (land wall), which can be seen by an observer.

The effects of the isovist visibility modelling were analysed visually. Table 1 shows the number of areas visible before the regeneration process from the same point of view as an observer. The results of the analysis show quantitative evidence of the unpreserved historical identity; of the vanished value of the land walls; and the destroyed cultural heritage visibility. Furthermore, the results of visibility properties indicate spatial and social characteristic destruction of the historic neighbourhood; the identity, quality, and unique character of the heritage site has changed.

Table 1. Visible length (meters) of the land walls during the 2007–2020 time period (Source: the Author).

Period		2007	2020
	Non-visible	364.968	482.7486
	Visible	187.162	69.3814

7. Discussion

The results of the current study analysis show that the planned/unplanned developments, poor design neighbourhoods, and constantly densely-built environment constitute a distinctive visual/perceptual occupation on the historical, functional, and known values of cultural heritage sites. The urban renewal projects and gentrification efforts increased after 2006 and intensified the buildings in the immediate vicinity of historic icons. These decisions led to the loss of spatial difference and originality and ignored principles of preserving the integrity of monumental structures. The visibility analysis measurements and isovist models were used to describe visual and configurational properties, visual occupied fields and spaces, and observer behaviour in the heritage space. Visible or occupied visible conditions were validated through visibility graph analysis and comparative visual configurational properties of the spaces by observers' positions. It was observed that there is a high correlation between the visible field and the configurational properties of space. Therefore, to obtain object-level results (FOI)—the visual preservation of an element—it is recommended to take into account the spatial configuration of all elements within the designated area. However, there is a requirement to consider all possible positions of the observer in the given area. The question thus emerges whether the spatial configuration of other elements should be ignored while intending to reveal an element. Therefore, there was a requirement to incorporate the analytical potential of the space syntax and the topology of space into the methodology in order to focus on the geometric and topological properties of the built form in order to find and understand the interrelationships between the differences. On the other hand, it is difficult to track solutions by using GIS-based analysis to identify/predict the constructed and natural features of the environments. The method approach also uses the idea of exploring different possible forms and configurations to understand the interrelationships of factors that lead to visitors' choices. In this context, the research is seeking new contributions to the methodology (visualization/simulation tools/approaches). The idea includes deep learning/understanding the performance of spaces for predicting and improving the interdependence of possible geometric parameters that may arise in the geometry of the space during the renovation and development process. In future research, the simulation of urban space/urban design projects in the early design/planning may remove the limitations of the study in establishing the perceptual behaviour with the information of the built environment.

8. Conclusions

The visibility and comprehensibility of heritage sites play a significant and inclusive role in defining the character of the heritage patterns. However, seeing the built environment only in terms of its historical values leads to limited information in terms of seeing different dimensions (changes made in the built environment). Understanding the visible whole (information gathered about all aspects of the urban heritage pattern) and deciding which elements will fit or be included in heritage sites helps us to see the balance between what is planned and what is not. Detailed visibility graph analysis reveals the connection between the urban structure (plan) and the built environment (architecture); it is important to include the configurational analysis and obtain more comprehensive information.

The implemented methodological framework represents a contribution to how both tangible and intangible elements of heritage sites are designed to preserve historic character.

The current study showcases a monitoring/perception tool to evaluate multiple strata of heritage sites to be preserved and developed in urban systems. It is a methodological approach based on the analyses of all elements to reveal the spatial order of heritage sites with visibility analysis.

The main purpose of the study is to evaluate urban elements to be protected by modelling both the heritage environment and the heritage elements according to the visibility criteria. The ultimate purpose of the studies is to evaluate urban elements to protect by modelling both the heritage environment and the heritage elements according to the visibility criteria. In the case of Süleymaniye and Zeyrek, several questionable influences have emerged in the visibility of heritage elements. The concluded heritage elements are in the close vicinity of the listed building. Some of the surrounding buildings are not part of the visibility elements because they are far from or fall outside of the protective zone of the listed buildings. In the case of the renewal site, the built environment and planned urban development trigger the invisibility of heritage elements within the area and visually affect the heritage landscape and harm the protected heritage areas. Urban development around urban heritage sites may affect the heritage landscape visibility; (existing or future) planning guidelines should suggest the permissible building height of newly constructed buildings around the protection zone. The VGA results formed part of a visibility function that can prioritize information from the current observation position regarding features of interest. The findings present a step towards addressing the issues concerning the importance of protected areas and heritage sites by highlighting critical debates on urban environment evaluation and visibility.

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Article

Patterns of the Expanding City: An Algorithmic Interpretation of Otto Wagner's Work

Zoltán Bereczki

Department of Civil Engineering, City Science Research Lab, University of Debrecen, 4028 Debrecen, Hungary; bereczki.zoltan@eng.unideb.hu

Abstract: Central Europe witnessed an urban boom at the beginning of the 20th century. By that time, the leading state of the area was Austria-Hungary, with Vienna as its capital. Before the First World War, even larger expansion of the cities was predictable. Otto Wagner, a leading architect of the empire and an expert in urban planning and architectural theory, published his vision about the future of the evolution of cities in 1911. In this book, he formulates clear rules about how a city should sustainably expand in a controlled manner. In this article, these rules of the inherited patterns are systematised and turned into recursive algorithms to simulate the urban growth controlled by them and the resulting patterns. The algorithms are tested on 1911 Vienna and, as comparison, on 2021 Miskolc, a medium-sized city in Hungary with different geographic surroundings. In the article, the resulting patterns are presented in 2D and 3D.

Keywords: urban planning; pattern language; generative modelling; Vienna; Austria-Hungary

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1. Introduction: Otto Wagner's Urban Planning Perspectives

Viennese architect Otto Wagner (1841–1918) published his study about the perspectives in urban planning in 1911 (Die Groszstadt. Eine Studie über diese von Otto Wagner) [1]. As far as I know, a comprehensive English version of it has not been published yet, but a shortened version was published in 1912 in Architectural Record, with the commentary of A.D.F. Hamlin [2]. By that time, Wagner was one of the most influential architects of the Austro-Hungarian Empire, with experience not only in architecture but education, urban planning, and architectural theory as well. The most recent comprehensive monograph on his life and work was published in 2018 [3]. The majority of his works connects him to the imperial capitol Vienna. He can be referred to as an urban architect: the vast majority of his realised works were built in urban context, and he was interested in the urban architecture not only on the level of buildings. He created several solutions for urban squares (most importantly for the Karlsplatz in Vienna, even without mandate), he was the author of several award-winning regulation plans for Vienna, and with his work related to the Stadtbahn and the Donaukanal, he had invaluable contribution to the modern infrastructure and cityscape of Vienna as well.

As a theorist, he published his ground-breaking work on modern architecture entitled 'Moderne Architektur' for the first time in 1896, one year before the birth of Le Corbusier [4]. During his lifetime, this book was published in further three, expanded editions. He discusses principles for urban planning in these bands and in the regulation plans made by him. The aforementioned book 'Großstadt' can be seen as a conclusion of these [5] (p. 56). According to his own statement in the foreword, his invitation to a congress at Columbia University served as the first impulse for writing the book. Another aspect was that he was very unsatisfied with the contemporary regulation plans.

The era referred to as the Gründerzeit had witnessed an urban boom in Central Europe. In Austria-Hungary, the years between the Compromise (Ausgleich, 1867) and the First World War (1914) were especially flourishing. This is the era when the modern cities of the country evolved [6]. In many cities, the number of inhabitants had been multiplied during these years. Based on that, the main starting point of Wagner's book was the assumption that large cities double in size in thirty to fifty years. This means that "their governing bodies are forced to take care that houses, public buildings, main streets, sanitary arrangements, etc., shall be properly located in advance; otherwise, instead of the hoped-for ideal a chaos would result which could be restored to order only at enormous expense" [2] (p. 492). He separates the regulation of the existing neighbourhoods from the new ones and emphasises the need of foresight and advance planning to be able to deal with the problem of the rapid expansion of cities.

The Roots of Otto Wagner's Principles and Their Contemporary Context

Wagner's principles are deeply rooted in the urban development of Vienna. He already in 1892/93 used the existing, gradually evolving system of radial and circular streets as a starting point in his first, award-winning regulation plan for Vienna. In Vienna, the ring of the loosely connected individual outskirts (Vosstädte) outside of the Glacis existed already in the 18th century. (Figure 1) Their street grids were adapted with pragmatic irregularities to the respective local situation and the necessarily deviating angles of the radial streets [5] (p. 56).

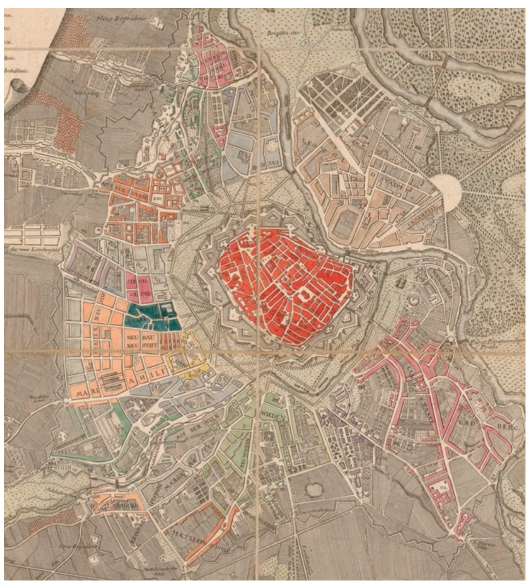

Figure 1. Vienna in 1798. The medieval city centre (red) is in the middle, the fortifications with the Glacis (grey) around it, and the external ring of outskirts (various colours). Source: [7].

Another Viennese feature to mention is the architecture of the Ringstraße. This representative boulevard was constructed on the empty area of the glacis, to connect the medieval city core with the aforementioned outskirts. According to Nikolaus Pevsner, this magnificent ensemble of monumental public buildings can be seen as a representative sign of the crisis of urban planning. It does not provide an answer to the sudden growth of the city, and the architects of that time "should have concentrated on the adequate housing of the vast new working-class populations of these cities and on the planning of adequate routes of traffic for the worker to get to his job and back every day" [8] (pp. 211–212).

Wagner was aware of these problems. He discusses already in 1898 the importance of traffic, economic, and sanitation demands [9] (p. 31). His expanding grid resembles Ildefons Cerdà's plan, which is an unvarying grid, realised in Barcelona [10] (p. 152). The main similarity is that the main element in both plans is the urban block and thus the enclosed streets. However, the similarities stop here. Cerdà's grid does not reflect the existing city core at all, and his randomly positioned diagonal streets are not present in Wagner's system. These diagonal streets are present in Daniel Hudson Burnham's plan for Chicago too (1909), another work, which is sometimes cited as a parallel to Wagner's work [5] (p. 58).

Wagner refused the use of the continuous green belt too because it would be an obstacle for the unlimited growth. Instead of that, he proposed large green centres for each district. The inspiration for this idea can be the Mall in Washington D.C. [5] (p. 56).

Discussing contemporary ideas, the most important theorist to mention is Camillo Sitte. He was also Viennese, and he was born only two years after Wagner. They are usually discussed in the literature as antipodes: Sitte would be the "romantic archaist" while Wagner the "rational functionalist" [11] (p. 27) [12] (pp. 95–101). It is true that Wagner argues in his writings with the ideas of Sitte (without naming him), but, as it will be discussed in this article, their principles are not so distant from each other.

2. Materials and Methods

2.1. Generative Simulation: The Algorithms

The aim of this article is to create a generative simulation using the rules discussed in the 1911 book. The artistic or architectural evaluation of the principles does not belong to the main goals, only their technical validation: whether an infinitely expanding city can evolve using these principles or not. I would like to emphasise that this is a theoretical question, a kind of thought experiment, but it can have its lessons in the aspects of the evolution of cities, parametric urban planning, and urban morphology "to understand the diversity of forms in terms of the underlying generative principles" [12] (p. 16). It is a procedural approach: through the establishment of generative processes, with the use of algorithmic 3D software, it is possible to generate the expanding city with the definition and variation of constants, parameters, and variables. The software of choice for this purpose is Rhinoceros 3D with Grasshopper. The geometry here is actually a data flow, using complex data trees. (Figure 2) Quoting Luca D'Acci, "quantification and mathematical modelling are means enabling us to discover partially predictable macro paths of our behaviours otherwise unreadable" [13] (p. 1).

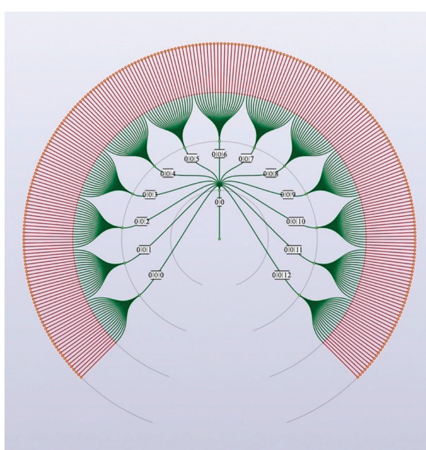

Figure 2. Data tree representation of the public buildings of the first ring of districts in the generative model discussed in this article. Source: Author's work.

Wagner's 110-years-old rules are especially suitable for generative modelling. His system is very similar to the hierarchical approach of urban morphology, where the base unit, the lowermost hierarchical level, is the single apartment as a cell [12] (p. 27) [11] (p. 28). In his book, he defined the district and the urban block as units of aggregation [6] (p. 190). Discussing cells, Hillier and Hanson describe two pathways of growth: subdivision and accumulation [14] (p. 19). In Wagner's book the growth of the districts is accumulation, while the evolution of the blocks inside of the districts can be seen as subdivision.

The accumulation of the districts as cells, based on the properties of their already existing neighbours is similar to the cellular automata. This model of self-reproducing automata was invented by John von Neumann (born in 1903 in Austria-Hungary) in the 1940s and today is used for modelling urban growth and transformation (among other fields) [15].

2.2. The Rules Provided by Wagner's Text and Related Drawings

As it was mentioned, Wagner discusses separately the existing parts of the city from the new districts to be established. In the case of the existing parts, the maintaining of the already existing beauty is the most important, and special consideration of each individual case is needed. "But it is the new and undeveloped quarters that can and must be systematized" [2] (p. 492).

The basis of this systematisation is the system of the districts (In German, *Bezirk*; in the 1912 translation, *ward*). "The situation and boundaries of the wards or boroughs form the foundation of the systematized regulation of the great city" [2] (p. 492). In his system, new radial roads connect to the existing roads on the edge of the existing city. These radial roads are connected to more or less circular zone roads (Zonenstrasse). The districts are determined by the radial roads and zone roads. The distance of the zone roads is 2–3 km, and the size of one district is 500–1000 ha. The districts are separate units, with own centre, facilities, public buildings, etc., and with 100,000–150,000 inhabitants. "The separate wards or boroughs will be developed at exact intervals fixed in advance according to a well laid plan, and thus form a group of small cities around a center" [2] (p. 493). The primary roads (radial roads, zone roads) have a width of 80–100 m.

There is no green belt present, but every district has plenty of green areas. The more or less concentric rings of districts surround the centre of the city. According to the conditions, these circles can be closed or open. The distance from the city centre is a key factor: some functions have to be closer (e.g., state and national parliaments, great art collections), some farther to it (e.g., cemeteries, depots, barracks, fields for sports of all sorts).

On the district level, each district has a large open centre (Luftzentrum, air centre) with a main square, greenery, and public buildings. Residential buildings reside on city blocks divided into four to six lots, and each block has to front a garden, square, or park. The streets inside of the districts are at least 23 m wide, and this is the maximum height of the residential houses as well.

Wagner provides three drawings to illustrate the general principles discussed above: a proposed zone map of Vienna at the scale of 1:100,000, displaying the primary (zone and radial) roads, to a radius of 14 km (Figure 3); a map of the proposed District XXII at the scale of 1:27,500 (Figure 4); and an artistic perspective visualisation of the centre of that district (Figure 5).

In the first drawing (Figure 3), it can be observed how the new districts connect to the existing streets of Vienna and how the terrain affects the order. The most important constraints are the Danube north-east from the centre and the Wienerwald mountains to the west. Two major roads flank the Danube on the two sides, and there is a bridge on each zone road. The concentric system of the districts on the flat area on the other side of the Danube can evolve almost without any disturbance. Since the rings are greater according to their distance from the centre, some radial roads branch to avoid the emergence of too large districts. However, due to the mountains, the grid becomes irregular on the west side, almost every zone road closes to itself, and thus the system is circular. The mountainous districts are larger, and therefore with the same number of inhabitants (which is a key factor), the population density, and thus the building density, in them must be lower.

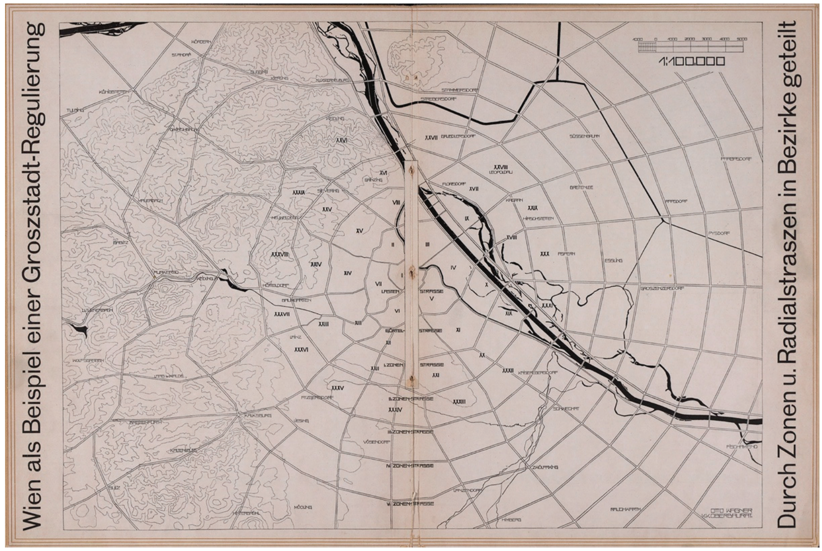

Figure 3. “Vienna divided to districts by radial and zone roads, as an example for the regulation of a large city.” Drawing: Otto Wagner. Source: [1] (pp. 12–13).

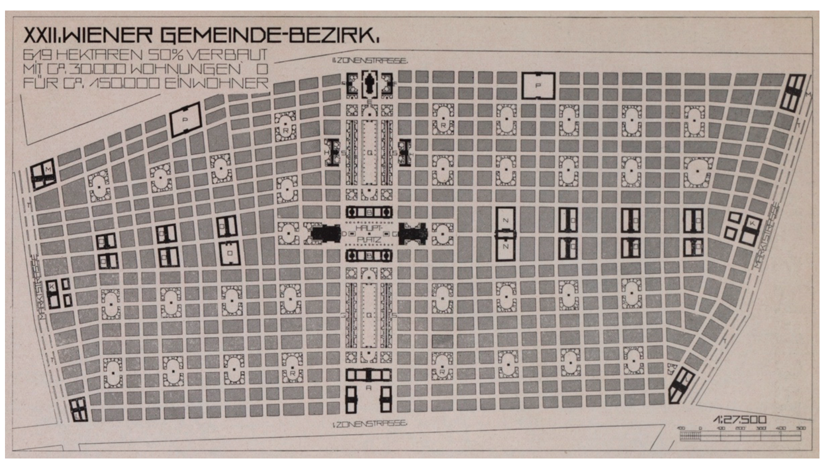

Figure 4. “Layout plan of the proposed District XXII of Vienna.” Drawing: Otto Wagner. Source: [1] (p. 11).

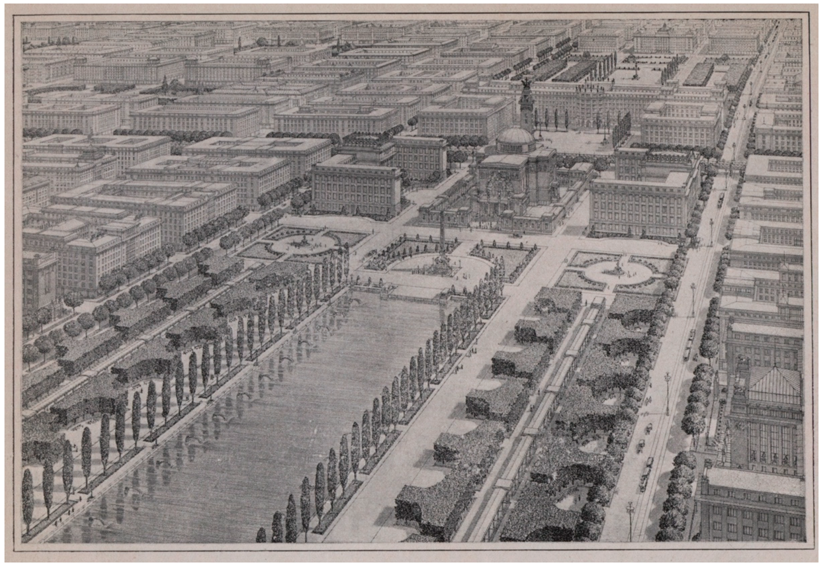

Figure 5. "View to the air centre (Luftzentrum) of the future District XXII of Vienna." Drawing: Otto Wagner. Source: [1] (p. 14).

In the drawing of the proposed District XXII (Figure 4), the layout of the blocks, public buildings, and parks can be observed. The drawing is oriented approximately to the south. The district's position is approximately on the Wienerberg, with the Triester Straße as its axis. Unlike the current Triester Straße, which is an expressway, the main axis here is an open area with the width of 280 m. It serves as the centre of the district with the main public buildings and as its Luftzentrum with the large parks. The four- or six-plot blocks are clearly distinguishable. The smaller parks form a secondary grid, and they have the area of two six-plot blocks. There is a secondary axis, perpendicular to the main one. Around this axis, the blocks are larger (approximately eight plots), and several other public buildings are located here too. In contrast to the text discussing the general rules, not every residential block is facing a park, although at least the corner of each is adjacent to one. The only exceptions are on the edge of the district, where the non-parallel radial roads distort the system.

The artistic representation (Figure 5) displays the connection of the proposed District XXII to the proposed District XXXV from a bird's eye view. The view direction is to the south. It displays the Luftzentrum with an architectonic garden including a major pool, a church, public buildings, and the zone road II behind the church. Behind it, the main axis of District XXXV can be seen with its public buildings and all around the blocks of the residential buildings. These buildings shape perimeter blocks, surrounding a common courtyard (this arrangement is not displayed on the less detailed district plan (Figure 4), where the blocks are represented only by solid rectangles).

2.3. Wagner's Rules as a Base of Algorithmic Modelling

Wagner's text and drawings provide clear rules for algorithmic modelling. The input data for the algorithm are the following:

- The exit points of the main streets on the perimeter of the existing city.
- The elements of the terrain that distort the system of the districts: rivers, mountains, etc.

The generative algorithm consists of two main parts (Figures 6 and 7). The first one generates the boundaries of the new districts (and thus the radial and zonal roads, similarly as it can be seen in Figure 3), and the second one populates the districts, based on Wagner's two drawings about District XXII, seen in Figures 4 and 5.

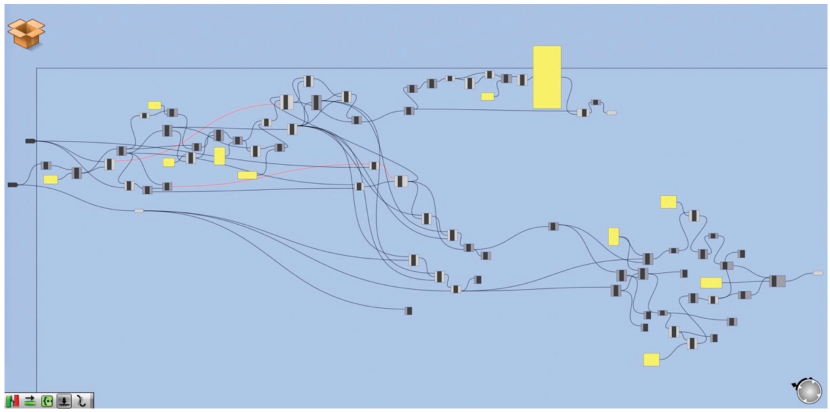

Figure 6. The Grasshopper definition (algorithm) coding the system of the districts. The data flow from the left to the right. The aggregation is a recursive process: the subsequent rings inherit their input from the output of the previous ring. Source: Author's work.

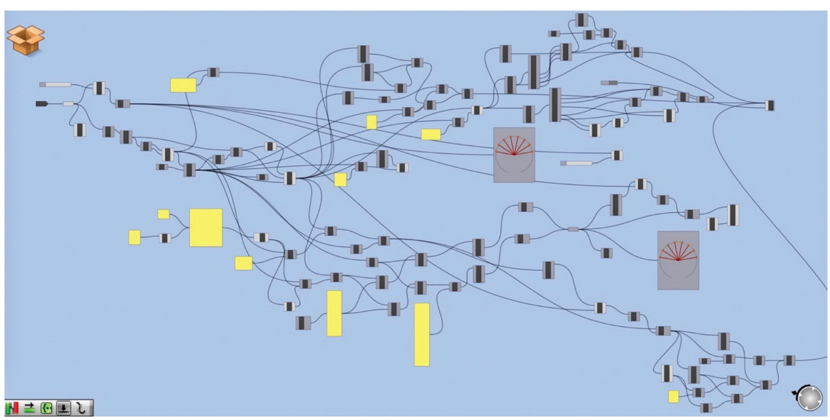

Figure 7. The Grasshopper definition (algorithm) that populates the districts with buildings. The data flow from the left to the right. Each district is populated with the same algorithm, only the input—the boundary of the given district—differs. Source: Author's work.

The main steps for generating an (either open or closed, based on the circumstances) ring of districts are the following:

1. An (either open or closed) curve is generated using the aforementioned exit points;
2. The curve is offset to the outside by 2 km (this amount can be measured on Wagner's drawing);
3. Trapezoids are created using the relevant corner points of the two curves;
4. The trapezoids are offset to the inside by 50 m to create the segments of the radial and zone roads.

For the generation of the next ring, input points are needed again. It is not possible to simply use the corners of the curve generated in the first step above because as the city expands, the edges of these polylines grow gradually, and, according to Wagner's rules, the area of each district has to be limited to 500–1000 ha. To avoid the too large district area, if the external edge of a district-trapezoid grows above 4700 m, an extra point is added as a starting point of a new radial road on the next ring. To incorporate some controlled irregularity to the system, the position of this point is randomly generated: it is either in the middle point of the relevant segment or in either trisect point. This point is then slightly moved in the direction away from the centre to avoid the too long straight segments of the zone roads.

The other extreme value has to be treated as well: the districts cannot be too small. Based on the initial situation, it is possible that some of the corners of the offset polyline generated in the first step get closer than the corners of the original one. In the concluding steps, this distance would be gradually smaller, converging to zero and even turning into negative. To avoid this, a subroutine is created. If the summary of any adjacent segment lengths is under 2100 m, the common endpoint of the two segments is deleted from the output, and therefore the relevant radial road ends there. Thus, not every radial street is a straight line with infinite length. As it was discussed above, not only the points serve as input data but elements of the terrain too. These are implemented as closed curves, which distort the system. If the position of a generated point is inside of such a curve, that point is either repositioned to the closest location on the boundary curve or is removed from the inputs to the next level.

Eventually, the 'unbegrenzte Großstadt', the expanding city, is a recursive process, where each ring of districts is created by the same algorithm. Only the inputs vary: each level inherits the output of the previous one as input, and this can theoretically be repeated infinite times.

The second main part of the algorithm generates the blocks and buildings inside of the districts. The input here is the trapezoid, which is the boundary of the relevant district. For the creation of the layout, Wagner's rules and his drawings of the proposed District XXII were used (Figures 4 and 5), with simplifications. The base point is the middle point of the smaller parallel edge (the 'inside' segment) of the trapezoid. This point serves as a local origin, the local X axis is parallel to the aforementioned inside segment, and the local Y is perpendicular to it. The base point is then moved by 35 m on the local Y towards the middle of the trapezoid and serves as the base point of the grid defining the base points of the public buildings and residential blocks. Because of this grid system, the position of the blocks and buildings can be flexibly defined. (Figure 8) In the solution shown in Figure 8, the width of the main axis (the Luftcentrum with the main square) is 300 m; then, after the first row of the blocks, the rhythm of the grid along the local X axis is the following, repeating to both directions: 100-118.75-118.75. Using 75 × 75 m dimensions for the four-plot blocks and 75 × 112.5 m for the six-plot blocks, this results in 25 m wide streets (according to Wagner, the minimum width of the streets has to be 23 m). The height of the residential blocks is randomised between 18 and 23 m, the maximum defined by Wagner.

Along the local Y axis, each grid point (block centre) is 100 m away from the other. In the case of the rows with four-plot blocks, every grid point is occupied; in the case of the six-plot blocks, the rhythm is the following: ABBBAABBABBBABBAABBA, where A means block and B means void. With this solution, the situation is almost the same as in Wagner's drawing (Figure 4). Some public buildings are also defined: two of them are flanking the main square; on one side of the main axis, a church is defined, on the other side, another public building; and on the secondary axis, 1–1 building in the third park to both directions.

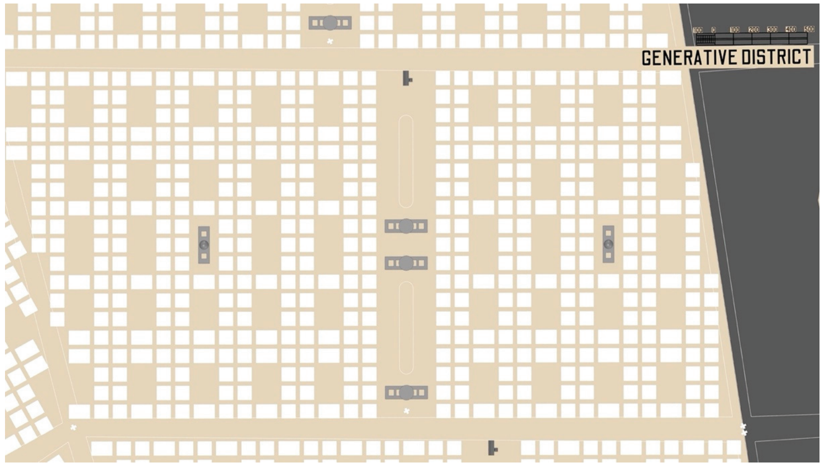

Figure 8. A generated district with the boundary trapezoid and the base point of the grid (white X). Source: Author's work.

To summarise, the two-step algorithm at first aggregates the districts as cells then populates them with urban blocks. In the first step, one district can be considered as a cell, in the second, one block. In the first step, the aggregation is infinite, in the second one, its limit is the boundary of the given district.

There are still some limitations and simplifications in the algorithm. Most importantly, the line-like elements, such as smaller rivers, railways, highways are not implemented as constraints. Secondly, the districts differ only by their shape. The given layout of the buildings is only one solution of the possible many, but for this experiment, I wanted to keep the system as simple as possible. (Figure 7 is a hint of its complexity.) In the next step, it would be possible to incorporate variables, define more building types, and use a more differentiated street layout. For example, the streets next to the radial roads could step out of the strict grid and could be parallel to the radial road, as they are in the drawing of Wagner. (Figure 4) An important key parameter to implement—mentioned by Wagner too—is the distance from the centre. Using this parameter, more differentiation in layout and functions could be defined.

3. Results: Proof of the Generative Concept

The algorithm was tested on two cities. At first, as an obvious choice, Wagner's map of Vienna served as a starting point (Figure 3). The aforementioned two inputs—the exit points of the roads and the closed boundary where no points and built-in area can exist, namely the Danube—were defined on that map. (Figure 9) A major simplification is that the terrain of the Wienerwald was not taken into account. The circles of the districts are closed, as they are in Wagner's drawing. The fully automatised system follows fairly the system proposed by Wagner (except, of course, on the aforementioned area of the Wienerwald). (Figure 10) The grid is distorted by the Danube. New points emerge in the intersections where the axis of a zone road meets the boundary of the Danube, and they obey the same rules discussed before. When a district trapezoid is inside the Danube, the algorithm coding the buildings of that district is blocked. This has an interesting result: in some cases, larger inhabited areas emerge next to the Danube. Of course, with manual post-working this could be omitted, but the goal was to entirely automatise the generative process. In Figures 10–13, five rings are present with a total diameter of 32 km, and the process can be continued infinitely.

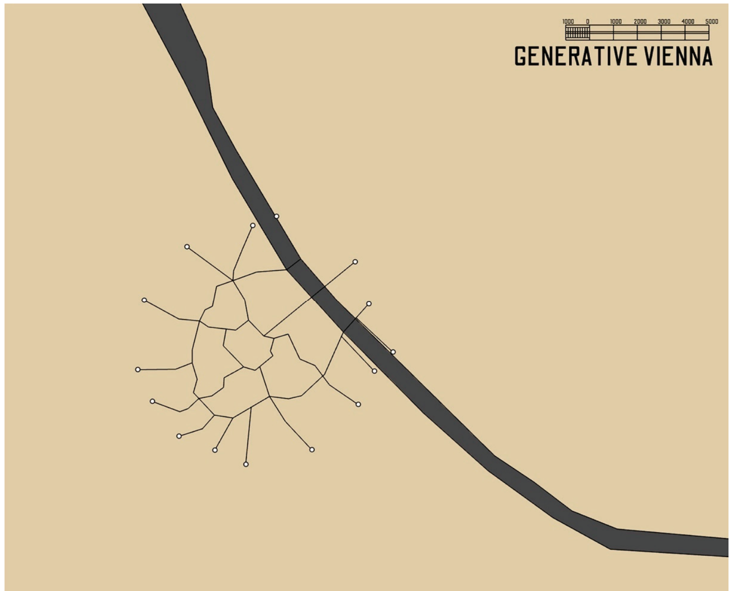

Figure 9. The inputs for generating the system of districts for Vienna. The white dots are the starting points of the radial roads; the dark grey surface is the area where no points or buildings can exist. Source: Author's work.

Figure 10. The generated district system using the input seen in Figure 8. Each ring of districts is generated by the same algorithm. Source: Author's work.

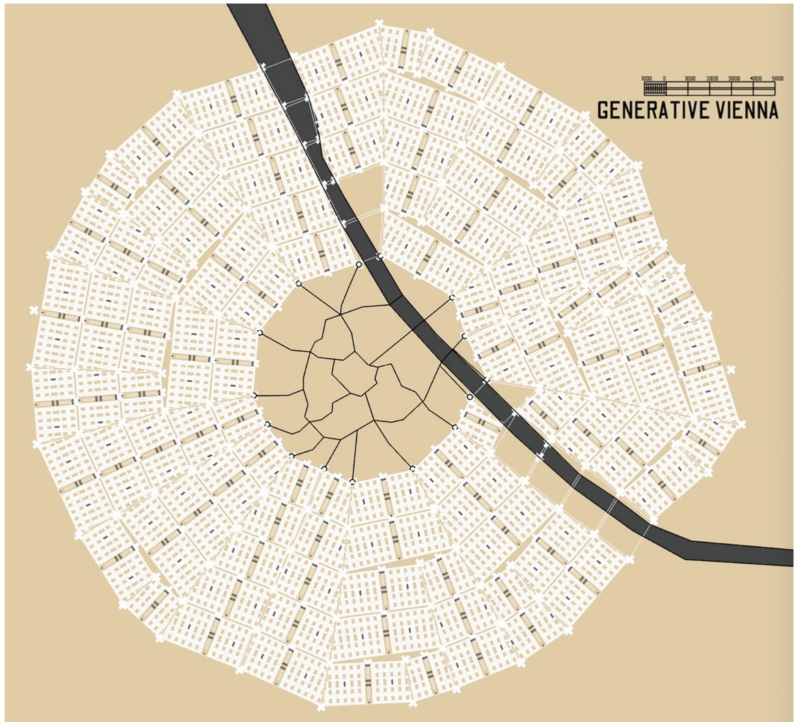

Figure 11. The district system populated by buildings. The buildings in each district are generated by the same algorithm. Source: Author's work.

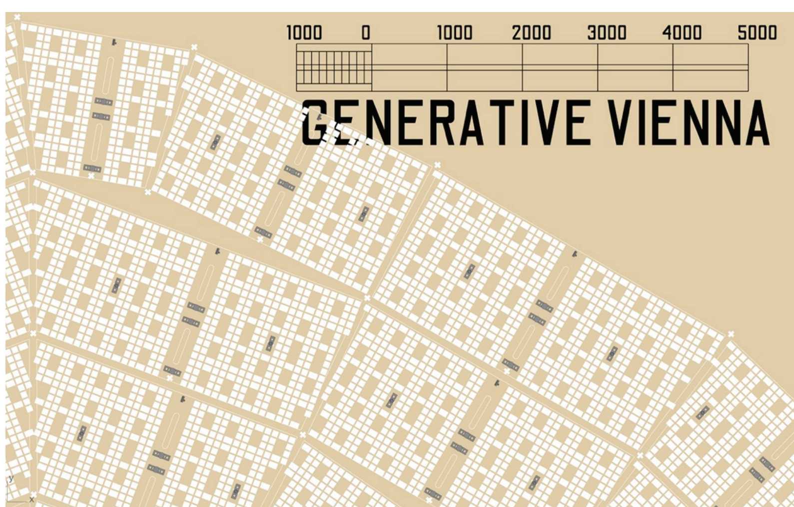

Figure 12. Scaled-up detail of Figure 11: the external districts. Source: Author's work.

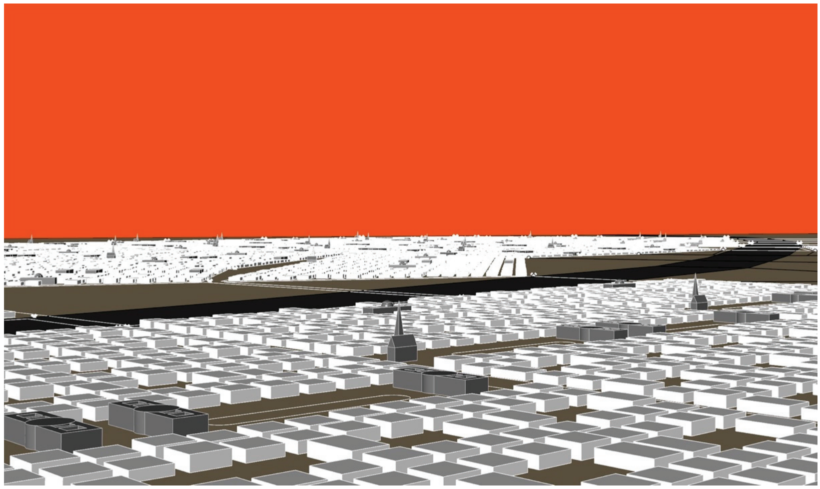

Figure 13. Three-dimensional view of the model seen in Figure 10. Source: Author's work.

The second testing ground was the current state of Miskolc, a medium-sized city in Northern Hungary. (Figure 14) Its geographic location is irrelevant: since the rules in Wagner's work, and thus the generative algorithm based on them, are intended to be universally usable, it could be tested on any other city. The goal was to test the feasibility of the algorithm on a city that differs from 1911 Vienna. Here is no major river, but the mountainous area to the west was defined as a restricted zone, and thus the rings of the districts are open. (Figure 15) The irregular boundary of the mountain zone served as a good testing ground for the algorithm. In contrast to the case of Vienna, a manual preselection of the points was needed between the algorithmic levels. In some cases, some of the output points of the lower level had to be manually disabled before the set of points could be provided to the next level as input due to the irregular boundary and the open ring. (Figure 16) Besides that, the algorithm created by the rules for Vienna worked very well for the very different situation, as it can be seen in Figure 17.

The generative cities could be tested with different quantitative methods to compare them to real cities, but this is out of the scope of this article. Just to mention one aspect, according to Bellomo and Terna, the following features can be referred to all living systems:

1. Ability to chase a purpose or a strategy
2. Heterogeneous expression of the said purpose/strategy
3. Nonlinearly additive interactions evolving due to learning
4. Darwinist selection and time as a key variable
5. Complexity in the interpretation of reality and rare events [16] (pp. 317–318).

For these generative cities, these points are more or less valid. With the implementation of all of the details in Wagner's work, the resulting cities could be considered as living systems.

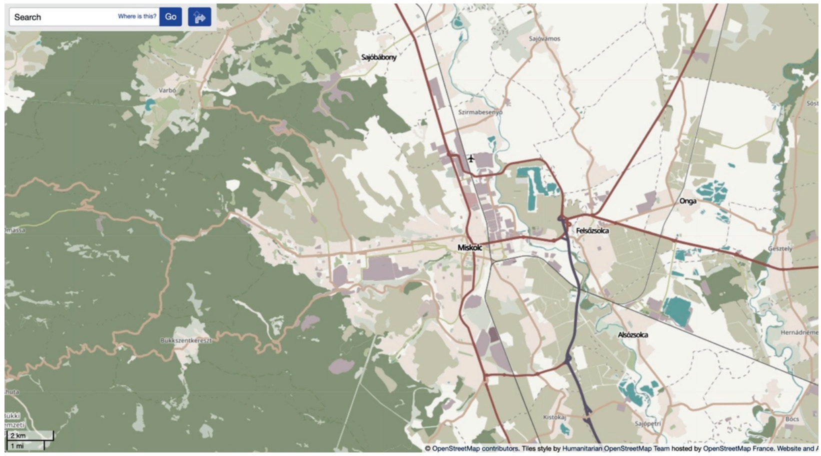

Figure 14. Map of Miskolc, Hungary. Source: OpenStreetMap.

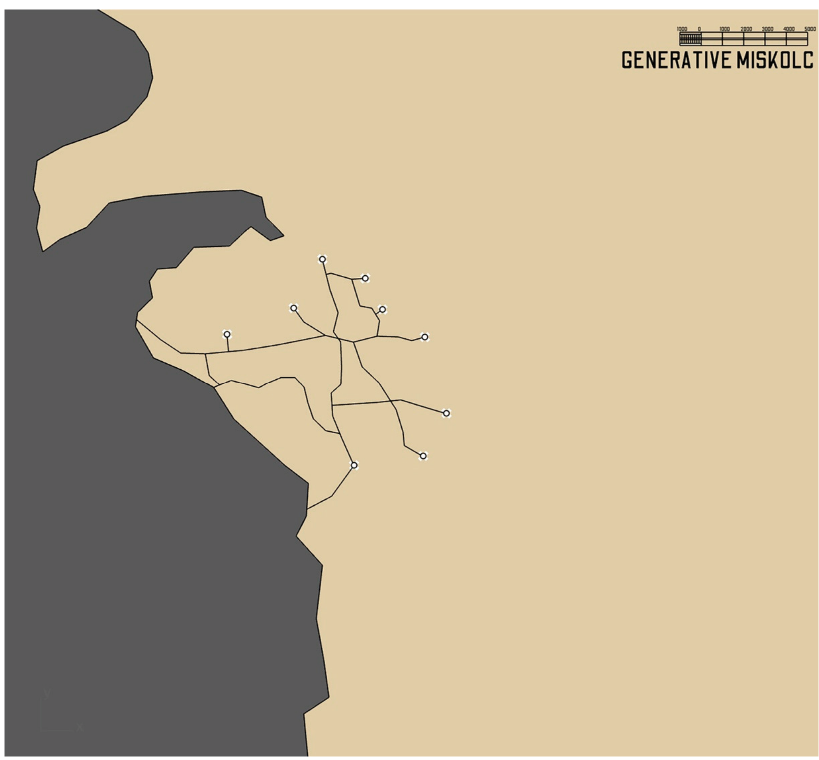

Figure 15. The inputs for generating the system of districts for Miskolc. The white dots are the starting points of the radial roads, the dark grey surface is the area where no points or buildings can exist. Source: Author's work.

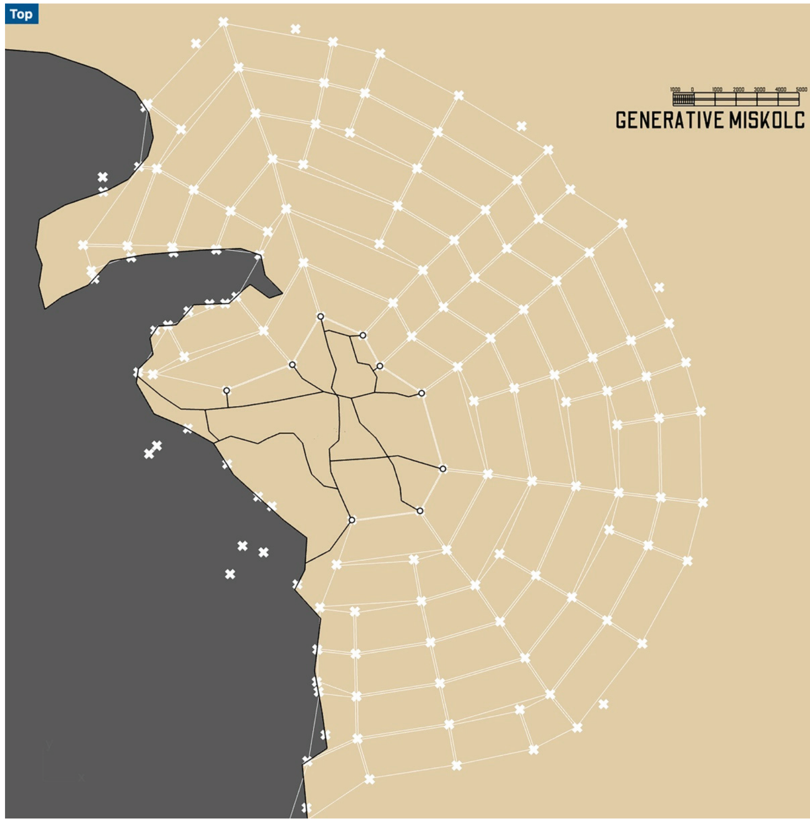

Figure 16. The generated district system using the input seen in Figure 13. Each ring of districts is generated by the same algorithm. Source: Author's work.

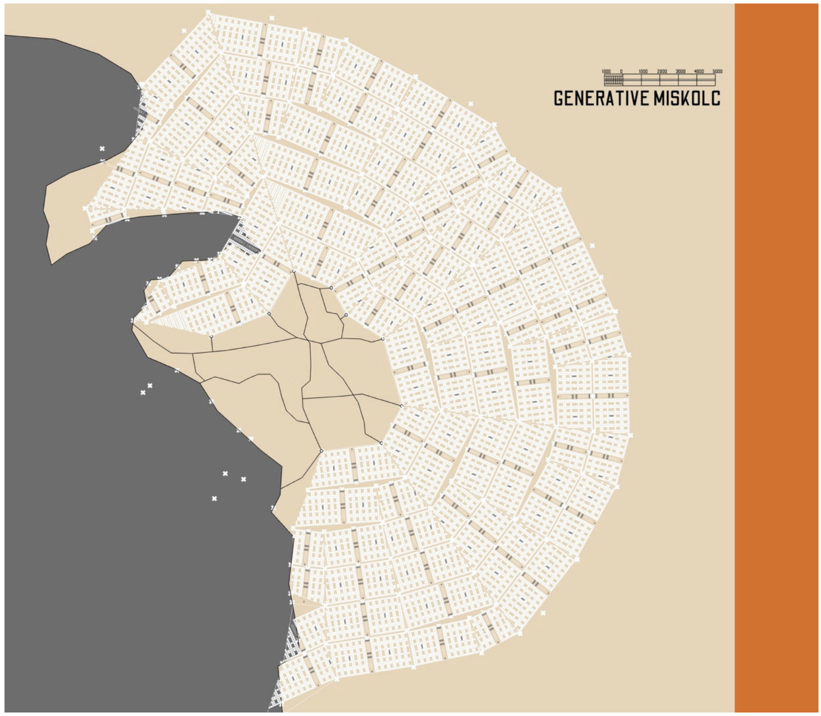

Figure 17. The district system populated by buildings. The buildings in each district are generated by the same algorithm. Scheme 16 (pp. 317–318).

4. Discussion: Wagner's Rules and the Current Trends of Urban Planning

To put Wagner's rules in context, it is important to emphasise that they are the result of a very different era than ours. In 1911, the Ford Model T was only 3 years old. The industrial, technical, and economical progression seemed to be infinite and therefore the evolution of the cities. Looking back from 2021, Wagner's foresight to avoid what is now referred to as urban sprawl is striking: he propagated the mixed-use neighbourhoods, the importance of the enclosed spaces, the sustainability, the importance of the public transport and the local centres, the appropriate density opposite to the idea of the garden city, and the careful, long-term strategic planning. His principles are echoing in the contemporary tendencies of urban planning. Karsten Pålsson lists in his book entitled 'How to Design Humane Cities' the following general guidelines:

- High land-use intensity to create sufficient, critical mass as the basis for urban life;
- High building configuration coverage, attractive common urban space;
- Limited building height;
- Spaciousness near housing and access to large parks. Contrast between dense buildings and parks provides an alternative to suburban landscapes;
- Mixed use.

According to him, the final goal is to create low-rise high-density cities of five-to-six stories [17] (p. 41).

All of these principles are present in Wagner's book. Discussing the redesign of cities, Pålsson emphasises the importance of the local centres, the developing new dense urban areas, and the densification of modernism's urban areas. His proposals and advice converge to Wagner's principles.

On a more local level, it must be emphasised again that Wagner's principles are rooted deeply in the urban pattern of the contemporary Vienna. He and Camillo Sitte were the two most influential urban planners of the empire, and both of them used Vienna as a kind of lab: they proposed several theoretical plans for parts of the city. At first sight, their principles differ a lot: Sitte is considered 'artistic', with the ideal of the picturesque small town, while Wagner 'rationalist', with the ideal of the unlimited, geometrically designed metropolis. However, under the surface, their principles are strikingly similar: they both emphasise the importance of the preservation of the existing beauty of the cities, the importance of the carefully planned enclosed spaces, the limited heights, the urban blocks, and the carefully positioned public buildings [5] (p. 59). This similarity between the two Viennese is even more striking when we compare them to the seminal principles of Le Corbusier. He denied the raison d'etre of the urban tissue itself: in his ideal city, there are no streets and urban blocks at all, the old neighbourhoods are to be demolished, and the districts are single-use. "All reference to an urban life, to a traditional neighbourhood life, is abolished: no more ‚corners', or ‚opposites', or ‚next doors'" [18] (pp. 114–123).

Although Wagner's system of the districts was not realised, Vienna is even today a relatively dense city, where the urban sprawl barely exists: there are districts where the urban blocks reach the edge of the city. This pattern is the result of an almost organic growth, echoed in Wagner's principles and survived until today [19]. The famous social housing programme of Vienna started in the era of the 'Red Vienna' (1918–1934) has been using similar urban blocks as Wagner [20]. According to Wolfgang Sonne, an unbroken line is reaching from the Ringstraße-Vienna to the Red Vienna, from the Heinrichhof to the Reumannhof, and the link between them is the Großstadt of Wagner [5] (p. 59). The line is even longer: similar patterns can be recognised in a relatively fresh urban development plan for the neighbourhood Aspern [21].

Vienna is chosen year by year for the title of the most liveable city of the world by Mercer's international comparative study. Mercer examines the following factors [22]:

- Political and social environment (political stability, crime, law enforcement, etc.).
- Economic environment (currency exchange regulations, banking services).
- Socio-cultural environment (media availability and censorship, limitations on personal freedom).
- Medical and health considerations (medical supplies and services, infectious diseases, sewage, waste disposal, air pollution).
- Schools and education (standards and availability of international schools).
- Public services and transportation (electricity, water, public transportation, traffic congestion, etc.).
- Recreation (restaurants, theatres, cinemas, sports, and leisure).
- Consumer goods (availability of food/daily consumption items, cars).
- Housing (rental housing, household appliances, furniture, maintenance services).
- Natural environment (climate, record of natural disasters).

Without further exposition, this is how Wagner characterises the urban life: "Profit, social position, comfort, luxury, low death rate, the presence of all the spiritual and physical necessities of life, possibilities both good and evil of recreation, and lastly Art, are all factors" [2] (p. 492). He was aware of the growing importance of public services and transport too: "an efficient system of transportation, a faultless street-cleaning department, living accommodations provided with every comfort and suited to every social grade" [2] (p. 490).

A.D.F. Hamlin's words from the 1912 Architectural Record are perfect as a closing remark:

"It [Wagner's 'Großstadt'] emphasizes the fundamental importance of carefully planned thoroughfares and transit facilities, laid out ahead of the need, not long after the need has become acute; for public service rather than for speculative profit; facilities which shall guide urban development into favorable conditions and not follow the haphazard growth of ragged and unrelated fringes of speculative suburbs.

Perhaps fifty years hence Professor Wagner's propositions will appear less fantastic and chimerical to Americans than they will to some who read them for the first time today" [2] (p. 486).

5. Appendix

It is part of the beauty of generative modelling that during the work sometimes shocking results can emerge, usually due to unintended data tree matching. These are sometimes instructive, sometimes strange, and sometimes simply beautiful. Some of these can be seen in Figure 18.

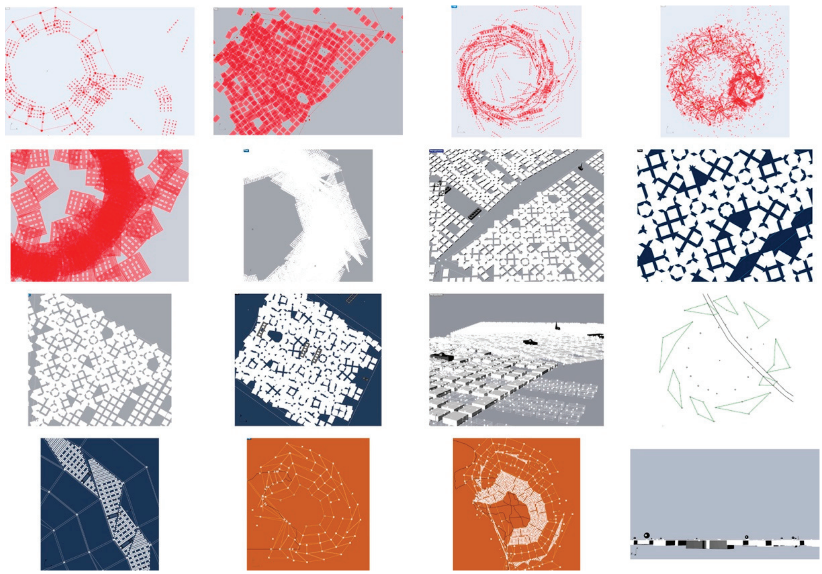

Figure 18. Unintended geometries during the modelling process. Source: Author's work.

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heritage

Article

The Spatial Morphology of Community in Chipping Barnet c.1800–2015: An Historical Dialogue of Tangible and Intangible Heritages

Laura Vaughan and Sam Griffiths *

Space Syntax Laboratory, The Bartlett School of Architecture, UCL, 22 Gordon Street, London WC1H 0QB, UK; l.vaughan@ucl.ac.uk
* Correspondence: sam.griffiths@ucl.ac.uk

Abstract: This article presents a case study of the London suburb of Chipping Barnet to show how a spatial-morphological approach to tangible heritage challenges its archetypal image as an affluent commuter suburb by highlighting its resilience as a generative patterning of social space that has weathered successive phases of social change. We argue that the enduring spatial-morphological definition of Barnet as a local centre explains how it has been possible to preserve something less tangible—namely its identity as a suburban community. We show how Barnet's street network constitutes community heritage through a combination of local- and wider-scale affiliations that have sustained diverse localised socio-economic activity over an extended period of time. Noting how local histories often go further than sociological studies in emphasising the importance of the built environment for indexing the effects of social change on everyday life, we draw on a range of archive sources including the analysis of historical maps using space syntax techniques, to reveal Barnet's street network as a dialogue of both tangible and intangible heritages that are formative of a suburban community.

Keywords: Barnet; suburban centres; spatial morphology; heritage syntax urbanism; community heritage; tangible heritage; intangible heritage; space syntax

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1. Introduction

The complex history of Greater London's suburban development is sometimes represented in culture as an essentially destructive process in which peripheral local communities were transformed into generic commuter suburbs by successive phases of rail- and car-based development. [1,2]. The conventional representation of suburbs in planning textbooks portrays them as functional expressions of the physical expansion of urban centres, with the corresponding increase in social and corporeal mobilities this signifies. The contrast between a lost—notionally local—past and the atomised suburban present that this image perpetuates may well be as ancient and resilient as that between town and country itself, a pervasive cultural distinction which the existence of suburbs only complicates (often to their detriment) [2]. British popular culture has tended to focus on the domesticity of the suburban home rather than the urbanity of the suburban centre, with the effect that suburbs as places with specific historical identities can seem barely to exist [3]. For all their ubiquity, or perhaps because of it, one might conclude that the suburbs are too much characterised by *instability* to have a distinctive built environment heritage, with the exception of cases where there has been the chance survival of historical sites, or the occasional example of architectural virtuosity amidst the swathes of unremarkable residential development. Yet, such an assumption stands contrary to the status of many suburbs as historically enduring communities with a recognisable spatial character [4].

This article presents research on the Greater London suburb of Chipping Barnet, located on the edge of Greater London, in the southern English county of Hertfordshire, sometimes known as High Barnet (and from now on referred to as Barnet) to offer an empirical account of what we call its spatial-morphological heritage. The purpose of the case study is to show how a consideration of the historical role of a street network in sustaining the socio-economic life of a suburban centre can help in defining what is at issue when considering 'ordinary' or 'everyday' heritage as an aspect of urban design [5]. The research seeks to arrive at recognisable empirical descriptions of an historical suburban landscape that is integral to the life of a contemporary community, rather than to draw attention to particular heritage sites that happen to be situated in Barnet. In a spatial-morphological sense, we are most interested in how the different aspects of the built environment are configured to sustain the characteristics of place.

Increasingly, built environment heritage policy is being developed using the broad contextual framing of historical urban landscapes (HUL) rather than the traditional emphasis on prestige historical sites of the kind that attract tourists [6]. Yet, there remains a problem of empirical description and delineation when it comes to conceiving of urban heritage in this wider sense [7]. This problem is even more acute with regard to the suburbs than with urban areas, despite the fact that many suburbs in the UK (including Barnet) developed from pre-industrial settlements with long histories as market towns. When suburban built environments are represented in culture as uniformly banal, it renders the everyday experience of the suburbs as generic and essentially alienating [8]. While social historians will always resist such simplifications of suburban history, their concerns are likely to remain marginal in policy arenas where there is a necessity for developing generic categories of description and delineation that can be applied to different kinds of historical urban landscapes. A spatial-morphological approach, which can be applied to any built environment, can make an important contribution to raising awareness of suburban heritage because it prioritises the formal description of everyday networks of public space ahead of the mapping of particular sites of local interest that are embedded within such networks. In this sense, it promises to assist with the task of offering generalisable definitions of historic suburban landscapes, while insisting that such characterisations have an empirical basis in the study of actual suburban places.

Space syntax theory and methods provide a way of conceptualising and representing the spatial morphology of settlements as dynamic encounter fields of socialising action [3]. Importantly, it regards the *intangible*, because largely ephemeral, practices of everyday life (such as movement and encounter) as emergent patterns shaped by the configuration and interfaces of the *tangible* elements of built environment heritage (such as streets and buildings). Karimi, for example, justifies his prioritisation of street networks in characterising the urban heritages of English and Iranian cities on the basis of their role in preserving the essential 'spatial spirit' of a city's street life [9]. This essential socio-spatial dynamic arises from the role of streets in generating the life of cities, for example by distributing pedestrian activity and urban land uses in an intelligible way [10]. Karimi's 'spatial spirit', one might say, describes the historical interplay of tangible and intangible heritages that constructs a sense of time in place. The way in which the material and immaterial aspects of built environment heritage implicate one another points to the fact that is the process of *patterning urban life over time*, rather than a particular quality of urban life at any given time, that is at issue in delineating historical urban and suburban landscapes alike.

A spatial-morphological focus on the role of street networks in sustaining predictable patterns of movement and land use recommends itself to considering how suburban centres might construct the spatial spirit of suburban places as a kind of community heritage. Everyday patterns of movement, spatial co-presence and encounter are implicated in giving rise to a shared experience of place and *emplaced* collective memory [11]. In the context of Greater London's suburbs, this has much to do with familiar spaces of sociability such as high streets that sustain a sense of temporal as well as spatial co-presence—that is a sense of the continuity of the life of the community in time, even while the membership of that community changes [12]. This quotidian dialogue of material and immaterial (or virtual) communities calls the simplistic opposition of past stabilities and present flux into question by acknowledging the ongoing role of streets in negotiating processes of change and continuity in London's suburban centres, and delineating an encounter field familiar to the many different kinds of people who live in them. It follows that the everyday routines of suburban places are not assumed to be fixed at any particular scale or orientation (though some may be more typical than others) but are equally likely to be formed in relation to other places at greater or lesser proximity to the centre itself. For example, in Greater London, many people either live and work close to home, or commute *into*, rather than away from, the suburbs every morning.

The notion of heritage syntax urbanism was proposed by Palaiologou and Griffiths to address the problem of identifying robust empirical descriptions of urban social space in the context of developing heritage policy [13]. It proposed: (a) prioritising a description that accounts for how the street network is configured as a globally connected system, rather than assessing the urban landscape's structure as if it were comprised of uniform and localised polygon shaped areas; (b) focusing on how streets contain varying patterns of social practices at different places within the local, urban, and regional network; and (c) characterising urban 'spatial culture' through a focus on how the characteristic patterning of community life is sustained through the intricate spatial variations within its built environment [14]. By bringing the perspective of heritage syntax urbanism to bear on Chipping Barnet as a particular suburban context, we hope to contribute to a human-centred and democratic definition of historic suburban landscapes that does not regard heritage as restricted to prestige urban centres or sites of special interest alone but as pervasive across all kinds of built environment that people value.

If contemporary Barnet is described by estate agents as a 'desirable' place to live, its origins were not so auspicious. It has been characterised by one historian as 'a messy and informal development of inn-keepers and traders locating on the heath, common-land, woods and pastures beside the highway . . . ', rather than a 'planned street town' (see Figure 1) [15].

Figure 1. Ordnance Survey map of Barnet environs 1805–1873, courtesy http://nla.gov.au/nla.obj-231917809/view (accessed on 14 May 2021).

Nowadays, Barnet is probably most likely to be regarded as a suburb of the capital at the end of the underground's Northern Line. Historically though, Barnet was defined by its situation on the Great North Road leading northward out of London that sustained its well-known market and hostelry. Unlike a railway network, a spatial configuration is not defined in terms of fixed origins and destinations because it also defines many in-between scales of movement. A major thoroughfare linking London to the north such as the Great North Road, for example, can equally be described and analysed as part of a local neighbourhood (Barnet), and as part of a regional network of suburban and small town centres. The history of busy roads is generally one of privileging their global (i.e., long-distance) connectivity by a systematic process of widening and straightening. Local centres necessarily resist this process of scale erosion, so far as they can. Indeed, their identity as local centres largely depends upon the quality of the localised street network to generate activity at socially meaningful scales that are differentiated from traffic passing through. While this effect can, to an extent, be stimulated through traffic calming, it is more robustly sustained by the spatial morphology of the suburban centre itself in constructing an interface between relatively localised and globalised patterns of movement. This implies pedestrians and vehicles of different kinds moving at different speeds, even while they may be sharing the same spaces [16]. We propose then, that the spatial spirit of Barnet is characterised by a hybrid spatial morphology that involves social affiliations constituted within and across spatial-morphological scales in an historical dialogue of tangible (built environment) heritage and the intangible (social-relational) quality of place.

Barnet as an Historic Centre of Socio-Economic Activity

Barnet was established as a market town by royal charter in the twelfth century. A combination of factors led to its successful functioning as a market town over many centuries. Its poor soil led its hinterland being used for woods, rather than agriculture [17], while its lack of rivers (pushing goods onto the roads), as well as its location a convenient day's travel from London, meant that it became one of a ring of markets used by 'dealers and drovers from farther afield' to sell onto City traders [18]. The result was a market town located in a strategic position on the Great North Road. Its subsequent plot development followed the demands of trade, with subdivisions derived from previous pasture patterns and roadside adjacencies.

While none of the Hertfordshire's towns gained primacy over the centuries, historians agree that a number of geographical and political factors contributed to Barnet's success. Its situation at the intersection of parish boundaries meant that it not only benefited from increased trade for its market, but also that it did not suffer from the control of a single manorial overlord. This jurisdictional complexity meant that its 'merchants, craftsmen and traders' escaped regulation by a dominant landowner [*op cit*]. Barnet's accessible location on the Great North Road meant that its market benefitted from regular traffic through the town, while its proximity to London resulted in it serving as a trading post, a way-station at a convenient distance away from the city, and a processing centre for supplying the capital's needs for products such as meat, leather and cheese [*op cit*]. Together, these characteristics meant that Barnet's occupational diversity evolved over an extended period of time and contributed to its economic resilience.

The socio-economic life of Barnet has been historically constructed over distance, though the nature of these connections has changed. Long before it became a suburban centre, for example, it was home to a Militia Barracks for Middlesex regiments and a weekly cattle market that supplied London with much of its meat c.1600–1950. On the other hand, Barnet's public architecture from the 1700s into the early twentieth century points to the existence of a strong sense of locality and status as the administrative centre of various civic jurisdictions. Barnet's history has therefore been forged historically both spatially, in relation to people living or working in its vicinity, and across space, in relation to the surrounding counties and London. At one time, over a hundred and fifty mail and stagecoaches, besides post-chaises, private carriages, wagons, &c., passed daily through the town [19,20]. Samuel Pepys mentions travelling by coach from the City via Barnet, taking the waters at 'the Well' [21], and travelling on to visit Lord Salisbury at Hatfield, returning back to a friend's lodging for a meal. The anecdote illustrates perfectly how

Barnet served both as link and place in the street network [22]. Similarly, Cary's 1790 Survey of the High Roads from London illustrates the importance of the Great North Road in connecting Chipping Barnet to Welwyn via Hatfield [23]. (Figure 2). Subsequently, Barnet was connected to St Albans to the north-west and via the Great Northern Railway and then the London Underground into central London. One might say that this remarkable connectivity is no less a part of Barnet's heritage than its market and civic buildings—and indeed the two things are related.

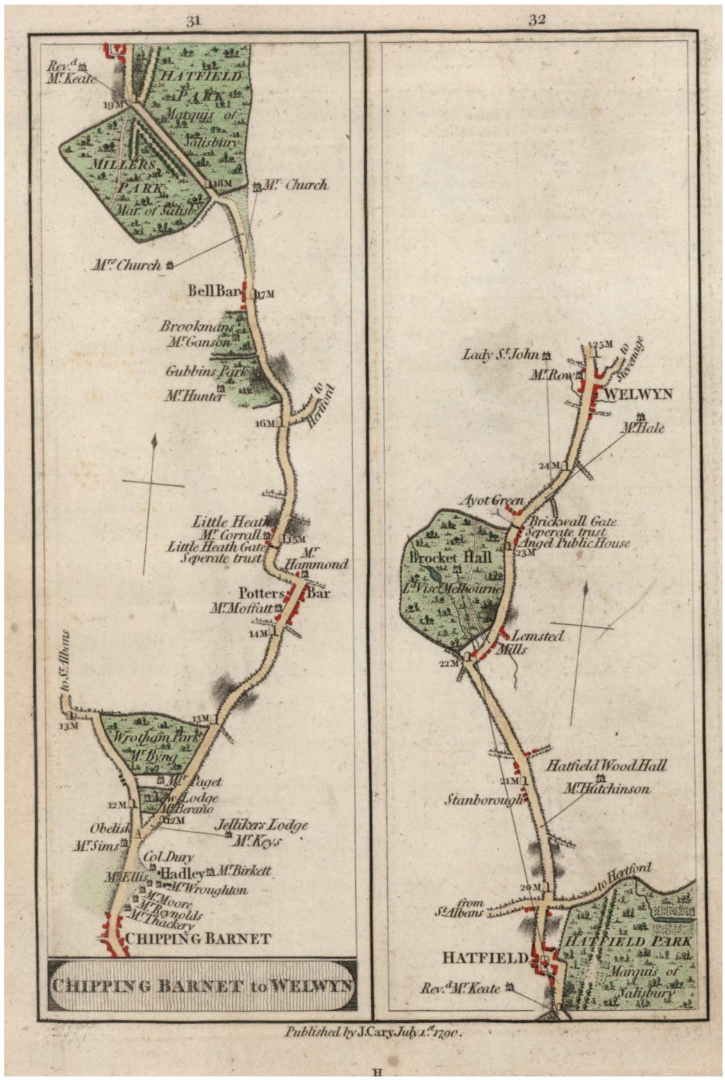


Figure 2. Chipping Barnet to Welwyn, London to Hertford. 1790, from Cary's 1790 Survey of the High Roads from London (see [23] for full citation).

Transformations in transportation technology: roads, tolls, mail services, and trains have intensified connections between and across the social spaces of Barnet. These sorts of generative connections have tangible manifestations on the ground: for example, in the spatial alignments of the road network that directs traffic through Barnet, and in the eighteenth- and nineteenth-century buildings that indicate affinities extending beyond the historic town, such as the alms-houses for the City of London's Leathersellers' Company. Other historic structures mark boundaries, such as tollgates, inns and road junctions, while temporary structures, such as the weekly market, which though now a sad remnant of its recent past, still represents a continuity with centuries of market activity.

It is interesting how local histories often do better than more sociological studies in reflecting on the curious admixture of change and continuity that characterises suburban life. These tend to be less concerned with the chance survival of heritage buildings than with the relatively unphotogenic high street shops that are offered as indices of change and continuity in the collective memory of the community. Although rarely the focus of explicit reflection, these characteristic photographs and postcards pose interesting questions regarding this continuity from the past into the present. The simple fact that such images remain on sale in local shops suggests a degree of value is placed on acknowledging the balance of historical change and continuity in Barnet as a community [12].

The postcards of Barnet High Street (see Figure 3) indicate the presence of a persistent spatial culture of social and economic life focused on a linear high street that has been in continual use for at least several centuries [24]. This poses an historical question. It would be no more correct to state, for example, that Barnet is an idyllic chocolate-box suburb (perhaps featuring a rose-garden Edwardian cottage or even the apparently carefree affluence of the popular 1970s sitcom *The Good Life*), as it would be to say that its individual identity has been dissolved into Greater London. Labels such as 'suburb' are not necessarily helpful in heritage contexts since they carry a cultural freight that leads us ultimately to questions of what the suburbs *mean* in a rather intellectual sense, rather than what it is that people most value in suburban built environments.

Figure 3. Postcards of High Barnet.

In contrast with Barnet's regionally connected road network, its civic infrastructure has largely maintained the historical spatial boundaries of its situation on the edge of the

London which distinguishes it as a place with its own identity. Institutional buildings relating to jurisprudence (a local magistrates court, now closed), ecclesiastical functions (a parish church), and law and order (a militia barracks that housed the seventh battalion King's Royal Rifle Corps, today the headquarters of the 151 Regiment and Territorial Army recruitment centre) all speak to a tradition of significant civic autonomy that reached its high point in the late nineteenth century. Although such institutional autonomy is largely historical it also suggests why, in heritage terms, the suburbs *do exist*! While Barnet's suburban civic architecture might not be remarkable, it stands testimony to the spatial-morphological resistance of the centre to being identified entirely with its location on the Great North Road. If local institutional autonomy may be degraded in the contemporary political context, the local street network, established centuries before, sustains the sense of Barnet as a distinct centre.

Of course, there have also been changes in urban planning regulation that affected the historic street network of Barnet in the modern era. In Barnet's case, there have certainly been positives. The twentieth-century Green Belt, by interrupting development within its vicinity, has played an important part in preserving something of the 'spatial spirit' of the historical settlement. All in all, it seems justifiable to propose the spatial morphological 'signature' of Barnet's suburban centre as the defining feature of its tangible heritage [25]. In the following analysis, we will describe the process of Barnet's spatial development over time in order to relate this spatial-morphological definition of suburb to its enduring life as a community.

2. Materials and Methods

Slater has pointed out that closer scrutiny of the supposedly 'simple' plans of Hertfordshire reveals how the urban landscape has been shaped by a combination of factors over time, a temporal dimension that also belies the almost meaningless designation of non-grid street networks as 'organic' [26,27]. Whitehand has emphasised the importance of plan analysis for its providing a framework for studying 'the relationship between plots and the block plans of building' [28]. Whitehand's account of M. R. G. Conzen's classic analysis of plot development in the English town of Alnwick was an important influence on our own work in its emphasis on how the boundaries and dimensions of plots, and particularly the shifts in frontage length and footprint size over time, drive spatial change in a given location. Conzen describes the temporal cycle of progressive in-filling of buildings on plots until they reach capacity and fall fallow as a process of morphogenesis. Conzenian analysis informed our focus on the interrelationship between buildings, their uses, and the characteristics of the streets on which they sit. Yet, there is a danger that an emphasis on defining boundaries according to their local plot-building characteristics, can lead morphogenetic descriptions to understate the influence of the global street network in sustaining centrality 'as a process' that re-produces the essential messiness of lively places [10]. Thus, without a configurational account of the historical street network, planners or heritage experts may struggle to challenge the largely functional planning designation of suburban space, as it does not give due regard to the importance of the encounter field as generative source of community life and spatial culture [13].

The mapping of Barnet's built environment in time-series using historical cartographic sources from Ordnance Survey (c. 1880, 1910, 1960, 2013) and linked to land-use data from business directories linked in GIS (Geographic Information Systems) made it possible to think in detail about the balance of change and continuity that, we argue, is relevant to a characterisation of the 'spatial spirit' of Barnet as a local place—a quality which is difficult to explain on the basis of more qualitative indices alone. By mapping the development of the road network from the nineteenth century, we can offer a different perspective on simplistic narratives of peripheral suburban growth to consider how a locale such as Barnet functioned both as place and a link between places at different scales of movement. The emergence of these kinds of multi-scaled high-street spaces may well be the defining characteristic of historic suburban landscapes.

Quantitative descriptions of urban street networks using space syntax have been deployed by scholars of history and architecture alike to formulate hypotheses regarding the use of urban and suburban places in the past [29]. When applied to the history of Barnet, space syntax methods find the tension between the centre's socio-economic accessibility to the surrounding region and the aggregation of place-bound (or localised) activities to be reflected in the way in which Barnet's street network has evolved over time. The configurational analysis of street networks produces detailed quantitative descriptions (and visual representations—see *Results* section) that can help explain how a given street may simultaneously sustain multiple activities by facilitating movement at a variety of scales and bringing them into spatial co-presence: from the micro-morphology of local socio-economic activity to the regional scale of inter-urban transport mobilities.

A detailed account of the space syntax method deployed in a suburban built environment is available elsewhere [16]. For our present purpose, it is sufficient simply to state that the method takes the town plan or map and translates it into a computer-based representation of the street network as a pattern of accessibility. This is used as the starting point for empirical research into the historical relationship between urban space and urban life by analysing each street's connections to all other streets and how these change over time. Space syntax research views streets in configurational terms as a differentiated system of connected, habitable, spaces. The analysis allows us to compute with great precision the relative centrality of all the streets in the system, and from this to estimate with some certainty the patterns of pedestrian use they might have sustained. These estimates can be cross-referenced with other forms of historical data such as land-use patterns, since certain land uses (most notably retail) are likely to favour locations with high footfall.

Our purpose here is to examine the validity of the proposition that while successive phases of growth in and around Barnet may have eroded and displaced the typical scale of everyday life in the historical settlement, a proper understanding of this process should not simply be in terms of periodic erasure, implying a deterministic narrative of sequential change from outlying market town to commuter suburb. Rather, the spatial-morphological analysis develops the proposition that social change is not necessarily a question of an accumulation of layers, but involves the complex material entanglement of old and new social practices. Our analysis intends to assess how far these practices can be identified in the description of the varied affordances of Barnet's quotidian spaces in the spirit of Michael de Certeau's proposition that 'space is a practised place' [30]. Heritage, in this sense, is regarded as a dynamic legacy of historical settlement forms, rather than a passive remnant of another way of life.

This perspective on spatial morphology as a dialogue of tangible and intangible heritages can help explain how residual local social activities such as bumping into neighbours that were likely to have been familiar to our eighteenth-century ancestors may persist and even feed into building global communities of interest on contemporary social media platforms [31]. At the same time, other activities (e.g., chairing a work meeting for clients of a central London firm, while working from home on a broadband connection) assume work practices and a telecommunications capability barely conceivable even in the late twentieth century, yet find ways of re-using much of the same built environment infrastructure. In Barnet—one can speculate—this might involve adapting the interior of a Victorian terrace house to accommodate a home office (a necessity forced on many people in the current pandemic), with its situation off the pre-urban main road giving easy access to footpaths onto the high street, allowing inhabitants to pop out for a coffee during their working day. Thus, the adaptability of the historical infrastructure makes it possible to sustain contemporary social practices. The effectiveness of new infrastructural interventions is, to an extent, dependent on how well they accommodate to this historical legacy. The local-to-regional accessibility of Barnet allows us to characterise the town's varied relationships over closer and greater distances through time. It follows that defining suburban heritage requires both recognising and describing the spatial-morphological signatures of communities that have adapted to successive phases of social change; enquiring what made such resilience possible, to the extent that this is the case. In this sense, the heritage of Barnet as a suburban place is not simply something that *is*, it is something made and remade.

While maps are useful sources for the spatial-morphological analysis of the urban past, the analysis of business directories allows for a snapshot on non-domestic activities in a town centre. It is important to emphasise the gaps in this dataset: small businesses, especially those that could not afford to pay for an entry, and frequently those run by women, were more likely to be omitted and in general, these are less comprehensive on economic value than rate records. However, for the purpose of complementing information on building form and plot layout, and particularly when studying a large area historically, data on land use patterns from business directories can be highly revealing of the economic character of a place through time (see Figure 4). Our study obtained data from Post Office Trade directories and Kelly's London Suburban Directories for the periods 1874, 1914, 1969 and, for the contemporary period, from the Ordnance Survey c. 2014. These data were transcribed and classified to fix the entries to the nearest street segment (the section between two junctions) and, where possible, were geocoded to a specific location using an Ordnance Survey map from the most closely corresponding period. Land uses were classified according to contemporary standard types that amount to 25 uses in 5 broad groups (see legend for Figure 8, below).


DIRECTORY.] HERTFORDSHIRE. BARNET. 39

Burgess John, farmer, May's lane
Burrows James, dairyman, 42 Union street
Butcher M. & Son, florists, 109 High street
Byfield & Son, solicitors, 12 High street. T N 42
Byfield George Dickinson (firm, Byfield & Son), solicitor, & clerk to the Barnet & South Mimms Rural District Councils & to Barnet Sub-Committee of Herts Local Pension Committee, 12 High street. T N 42
Carrick, Davies & Partners Ltd. coal mers. 88b, High st
Carter Henry James, butcher, 145 High street
Challen George Allen, Old Red Lion P.H. Underhill
Chancellor William Bartlett, surveyor to the Urban District Council, 40 High street
Chapman John T. The Mitre P.H. 58 High street
Chappel John William, shopkeeper
Charles Thomas, solicitor &
High street
Charrington, Sells, D
Cheek John & Son
Cheek Wm. Geo.
Child James &
Child Lucy
Clark J. A.
Clarke He
Coleman
Collis Ge
Congreve
Cordwell
Convent
school
Cook Al
Cook Lo
Wood
Coombe
Coomber
Cooper Reg
oaths, Hig
Cooper Squad.
D Squadron
Salisbury road
Coote & Warren Li
& Railway station
Coppin Samuel, boot & sho
County Court (His Honor James
William Osborn Boyes LL.D. registrar
Union street
Cousins Rebecca (Mrs.), dairy, 2 Puller road
Cowing E. & Son, printers & proprietors of "Barnet

Farrow William Charles, tobacconist, 46 High street
Fielder Mabel (Miss), costumier, 9 Strafford road
Finch Charles E. & Son, painters, 4 Salisbury road
Fire Brigade (Urban District Council) (W. J. Ridgway, captain), High street
Fitzgerald Henry, mechanical engineer, New road
Flashman & Son, builders & decorators, 13 New road
Flecknoe William, tailor, 20 Union street
Fort W. R. laundry, 3 New road
Foster Walter Thomas, carpenter, Bells hill
Fowler Mabel (Miss), Green Man P.H. 143 High street
Francis Brothers Limited, cycle agents, 202 & 204 High street & motor engineers, Marriott road
Freeman, Hardy & Willis Ltd. boot makers, 112 High st
Walter & Stanley, butchers, 90 High street
les, insurance agent, 25 Falkland road
insurance agent, 15 Thornton road
ohn, baker & confectnr. 140 High st
), draper, 204b, High street
r, 15 Union street
or of King's taxes for Barnet,
que dealer, 175 High street
6 Wood street
er, see Steele & George
ker, 61 High street
wool dealer, 61 High st
High street
Thornton road
25 Union st. & Wood st
11 Union street
onfectioners, 67 High st
er, 71 High street
rt's Horns P.H. 79 High st
schi. Ripley ho. The Avenue
tioner, 39 High street
er, Rowley Grn. frm. Arkley
chine agent, 232 High street
(Misses), hosiers, 120 High st
an, Elm farm, Arkley
ware dealers, 117 & 119 High street
mon. masons, 1 South view, West End la
de (Mrs.), Willington P.H. 141 High st
Charles Frederick M.A., M.B., B.C.Camb., M.R.C.S.Eng., L.R.C.P.Lond. physician (firm, Stewart, Hardie & Hughes), medical officer of health to Barnet Urban District Council & medical officer & public vaccinator for Barnet district & surgeon to Victoria

boot & shoe maker, 114 High
rt (His Honor James Aloysius Scully
m Osborn Boyes LL.D. registrar & high ba
on street
sins Rebecca (Mrs.), dairy, 2 Puller road
owing E. & Son, printers & proprietors of "Barnet
Press" & "Weekly Telegraph," 118 High street
Cowing Jane (Miss), bookseller & stationer, 116 High st
Cox James, dairyman, Manor road
Crawshaw John Nolan, Rising Sun P.H. 73 High street
Creigg William, boot repairer, 80 Strafford road
Crowsley Sarah (Mrs.), shopkeeper, 234 High street
Cude Thomas, builder, 11 Normandy avenue
Cuffe Annie M. (Miss), dress maker, 19 Stapylton road
uffe Hilda (Miss), Swedish massage, 21 Stapylton road
tbush William & Son, nurserymen, 14 & 16 New r
N 2 Barnet) & Wood street
t Ernest, outfitter, 204c, High street
lizabeth (Miss), dress maker, 33 Carna
Edwin, assistant insur. supt. 6
erer, 102 High street

Figure 4. Sample page from listings for Barnet, in Kelly's Post Office Hertfordshire business directory, 1914. London: Kelly's Directories, pp. 32–41 (with inset of a magnified section).

3. Results

It is evident from the historical account provided above how the pre-industrial era genesis of the street and road network surrounding Barnet—together with local patterns of land ownership—established subsequent trajectories of development that give spatial-morphological definition to the suburb's heritage. Slater notes how 'the properties which line both sides of High Street and the south side of Wood Street clearly derive from the roadside ends of earlier pasture closes... Barnet's plan therefore quickly achieved an urbanity to match that of other market towns' [29]. This *suburban* urbanity is evident also from a simple figure-ground analysis of the town, as seen in Figure 5 (refer also to Figure 1 for the earlier map of the area), which highlights the spatial dominance of Barnet within its vicinity c. 1880, even when compared to East Barnet, apparent in the south-east edge of the map.

Figure 5. Figure-ground map of Barnet and environs c. 1890, with inset showing high street at scale 1:1000. Created using "Old Map of Hertfordshire", [BMP map], Scale 1:10,560, Ordnance Survey County Series 1st Edition published 1865–1894, © Crown Copyright and Landmark Information Group Limited: Edinburgh (2010), UK. Using: EDINA Historic Digimap Service.

A systematic study of movement flows using structured video observations of a large range of streets in the area during the working day was conducted by the authors' research team approximately one decade ago. It found two distinct groups dominating the high street area during the working week. The first was those out with a purpose; these were often young mothers and—significantly—those working in the town centre, out running errands or for meetings in local cafes. The other group were in the town centre as browsers, and were typically the elderly and the young alike, who used the town centre as a way to spend leisure time. By the evening rush-hour, many casually dressed pedestrians were observed entering the underground station from the centre, suggesting once more that commuters do not dominate this town. The restaurants and bars were also starting to fill up, indicating a night-time activity.

The space syntax analysis presented in Figures 6 and 7 was originally undertaken for an extensive study into London's evolution from 1890 to the early twenty-first century [32,33]. It shows how Barnet continued to expand throughout the nineteenth century, with significant intensification having taken place by 1890 as a consequence of residential expansion around the railway station. It is evident from a space syntax analysis of the development of Barnet's built environment from 1880 to the present time how Barnet High Street retained its centrality despite the extensive expansion in the built-up area and intensification of the road network during the period. Figure 6 shows the time-series sequence of maps of the area during four periods. The configurational analysis considers each street segment's connections to all other segments within a six-kilometre radius, resulting in a table of numeric values displayed here as a spectrum from red to blue. While the principal route running through the town centre is the Great North Road (named High Street for the sections within the town's built-up area), it is also important to note that in the most recent period the impact of the peripheral M25 motorway is visible (on the north-west edge of Figure 6). This results in a shifting of peak centrality from the high street to the road sections linking it southwards towards London.

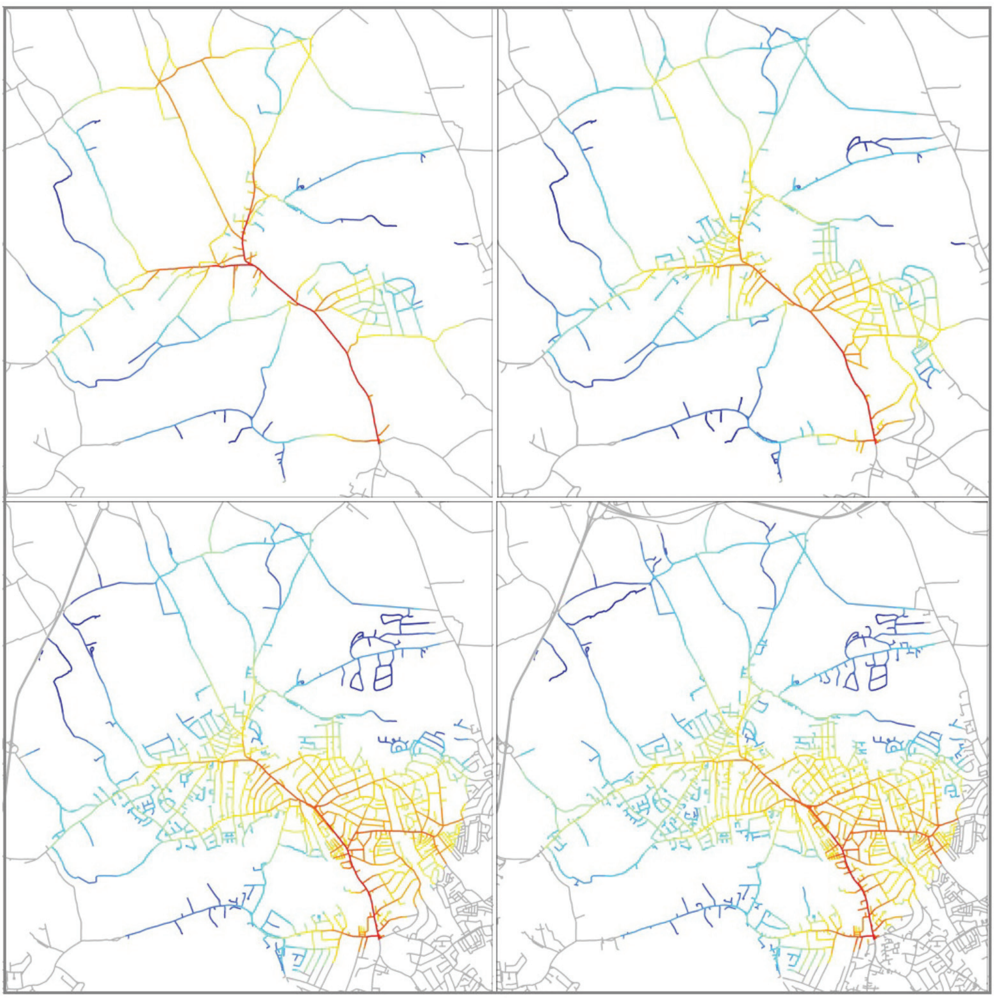


Figure 6. Barnet and environs c. 1880, 1910, 1960, 2013, (**top-left**) to (**bottom-right**), respectively, analysed according to their potential for movement through the area, measuring relative centrality for routes at a distance of 3 km. The warmer the colour in a spectrum from red to blue, the higher the predicted centrality.

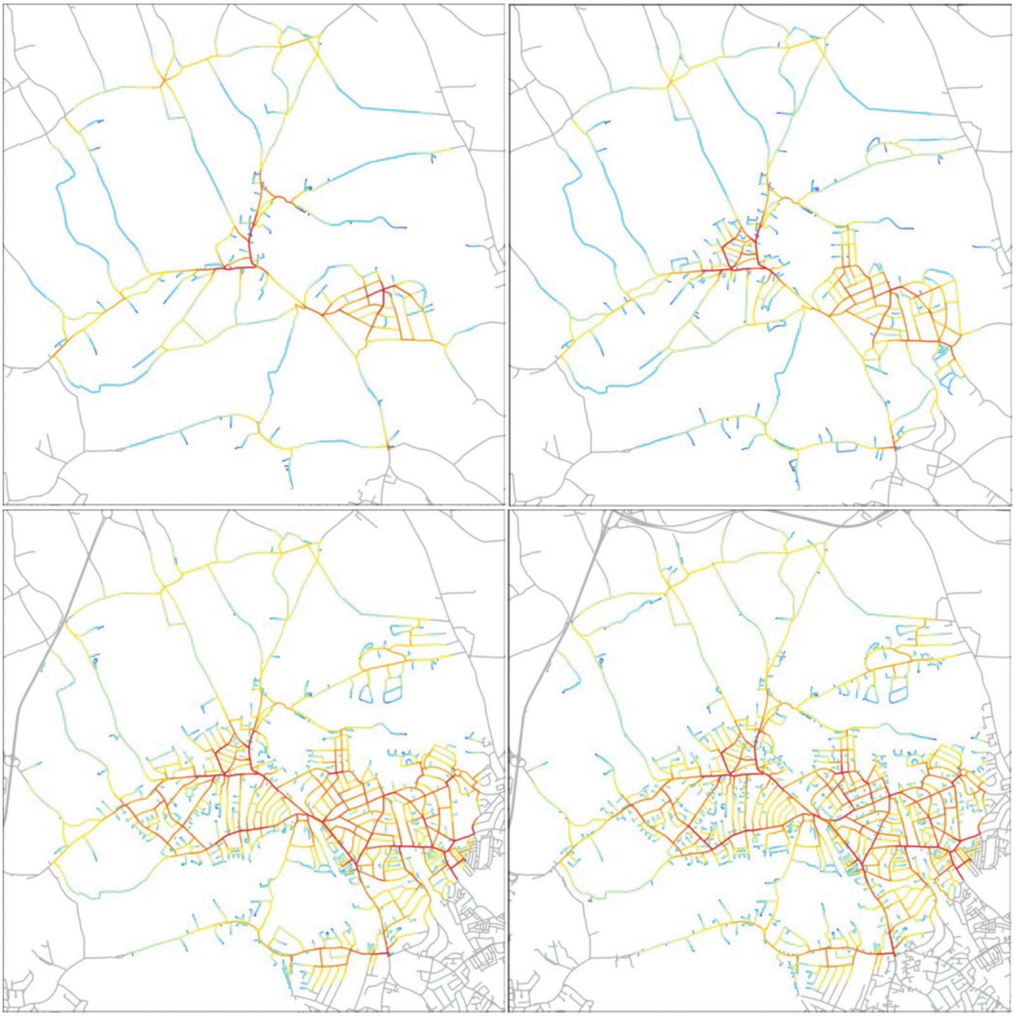


Figure 7. Barnet and environs c. 1880, 1910, 1960, 2013, (**top-left**) to (**bottom-right)**, respectively, analysed according to their potential for movement to each street the area, measuring relative accessibility for routes at a distance of 800 m, approximating a 10 min walk. The warmer the colour in a spectrum from red to blue, the higher the predicted accessibility.

A different sequence of maps considers the same area for its local accessibility. Figure 7 shows the streets coloured in a range from red to blue, indicating how accessible each street segment is for local connections to/from approximately 800 metres away. It is evident that whether considering only its local connections, or its local-to-global connections through its high street to other places, Barnet possesses what Hillier termed 'pervasive centrality'. This refers to the network connectivity of centres at all scales, some smaller and some larger, with Barnet's high street and to a lesser extent Wood Street (the red-coloured alignment running east–west on the in the model) maintaining a constant prominence in the upper bands of connectivity [34,35]. Hillier argued that the way in which local centres fit into a pattern of connections at different scales reflects the potential for those connections to support flows of movement across different distances. This is not purely a matter of absolute distance measured in meters or kilometres, but what he referred to as 'intelligible distance', namely the intricate linkages from footpaths to streets to roads and thoroughfares that together form an emergent, and highly intuitive, pattern of connectivity over time. This does not, of course, mean that such a network structure *transcends* historical events. On the contrary, the argument is that the deep structure of historical road network is able to accommodate a large number of localised changes, while changes at the scale of the network itself are relatively gradual and infrequent. In this respect dramatic large-scale interventions in the road-network such as ring-roads and bypasses are the exceptions that prove the rule—even here the resilience of the historical street network is often remarkable. This emergent spatial configuration sustains patterns of accessibility over time. It adapts to periodic shifts in road connectivity as well as local changes to building shapes and layouts, and it mediates social changes that mould the 'spatial spirit' of place [35].

The analysis shown in Figures 6 and 7 indicates how the network of footpaths, streets and roads connects from the residential areas of Barnet through to the high street, with the most prominent street segments being continuously accessible from the past to the present. This means that even today, when the district has many of its inhabitants commuting out of the area, the street network continues to support local circulatory trips around the centre, whether it is to pass the time of day, to be sociable, or to go to work locally. Indeed, the evidence from observations made in the field, and census data on commuting patterns, both sustain this pattern of behaviour [36]. The result in Barnet is a suburban centre that can maintain its vitality both economically and socially, despite the town's social and economic character having been transformed over the past century and more. Even today we can see small business premises and workshops situated to the rear of the high street, meaning that the people using the area are not just local inhabitants—but also include people working and visiting the area.

If one were to focus purely on the land uses along the section of the high street north and south of today's semi-enclosed shopping centre, The Spires, it would be possible fall into the trap of describing Barnet as an example of 'Clone Town Britain'—to adopt the pejorative terminology of the New Economics Foundation (NEF) [37]. Yet, the Ordnance Survey database finds businesses ranging from two national supermarkets, two national opticians, one each of a national chain of hairdresser's and opticians alongside a relatively small number of independent or local chains of bakery, clothing and cash converters. If we analyse a more representative sample along the high street the picture shifts dramatically. Figure 8 shows the contemporary land uses along the full length of the section of the Great North Road that is named High Street. The buildings are coloured according to their land uses, shaded according to 25 possible categories, with additional shading for mixed uses. The land uses classification is placed alongside a space syntax analysis of integration at a local (800 m) and larger scale (3000 m). A comparison of these figures reveals how Barnet's street network comprises a spectrum of street segment characteristics associated with both high levels of pedestrian and vehicular movement at different scales (including both highly localised patterns of pedestrian intensive circulation which serves as an attractive destination for trips over longer distances). These complementary configurational qualities sustain different categories of land use in Barnet's town centre. Even such a relatively detailed land use classification though, is incapable of emphasising the diversity of specific uses, which comprises independent estate agents, a local chain of hairdressers, dry cleaners, a number of independent as well as chain restaurants and coffee shops, banks, independent jewellers, and both independent and chain chemists and bookshops. Even at the time of writing, a year into the global pandemic, new land uses are emerging, such as a florist's offering local deliveries during lockdown. The continual churn of commercial land uses preserves as much as it displaces. The discovery in 2020 of a fourteenth-century building concealed behind the façade of an apparently unremarkable shop unit (a hair salon being refurbished as a florist) is an interesting example of an intersection between the everyday heritage of the suburban high street and the high status heritage represented by important historical buildings. In this case, it is unlikely that the latter could have survived in the absence of the former.

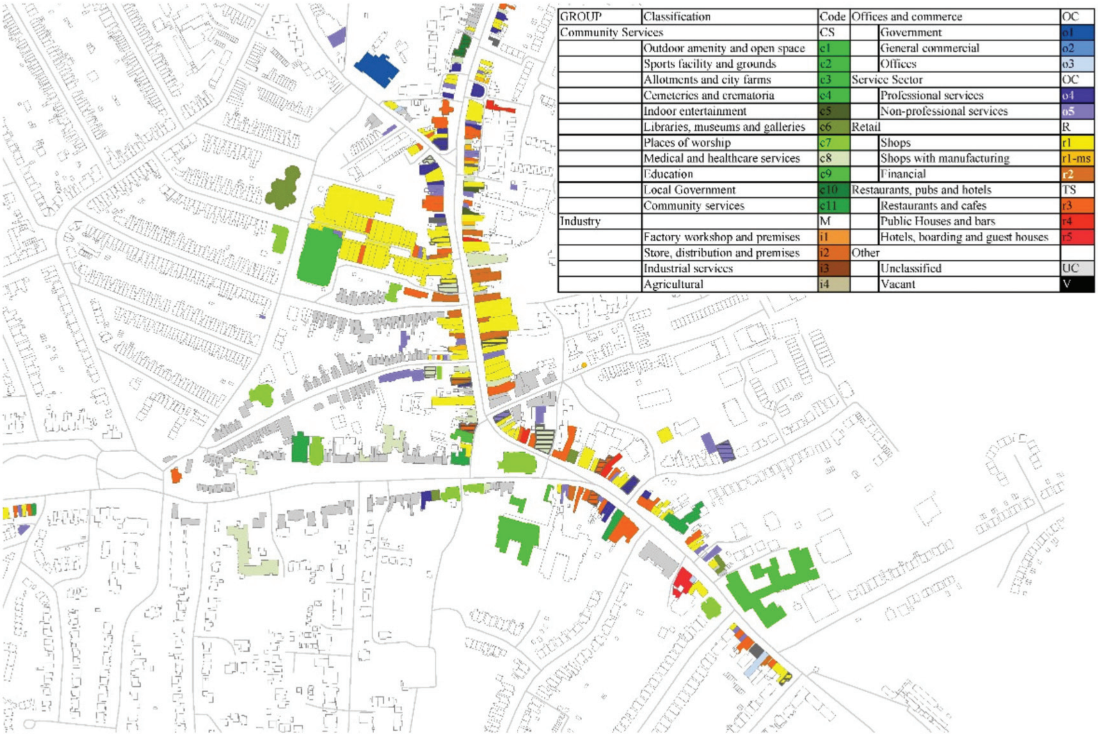
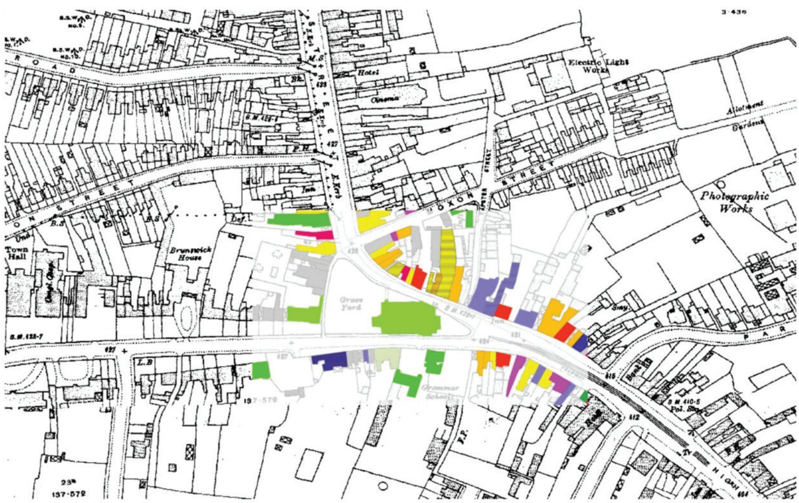


Figure 8. Land use classification for High Street Barnet, c. 2013. Refer to Figures 6 and 7, (**bottom-right**), for spatial analysis of the contemporary map.

Many civic and communal institutions are arrayed along the streets turning off from Barnet High Street. Another striking aspect is that the section of the high street south of the junction with Wood Street (the section running south-west), the site of St John the Baptist church today—and in the past myriad additional other town functions—marks a shift in both building scale and land use type, with a significantly larger number of small, independent shops and businesses. In addition, over the shops and in the rear of many plots are subsidiary businesses, such as printers. The character changes again at the point at which the street becomes the Great North Road. Each of these changes in land use and built form character are reflected in the distinctive spatial accessibility of the street segments in question, with the northernmost section of the high street being most dominant for trips at the local scale, and the southern sections being more central at the higher, 3000 m scale.

Further analyses of the relationship between the street network, built form and land use diversity can be seen in the series of images in Figure 9a–d, which trace the evolution of the section of the high street where it intersects with Wood Street, meeting at the site of St John's Church. All the buildings coloured up are listed in Figure 10, which shows all land uses listed in the relevant directories for the four epochs studied. Even without the statistical analysis of diversity (which we have reported elsewhere), it is evident that the mixing of commercial, retail, production, and service activities has remained apparent throughout the periods covered by the study [27].

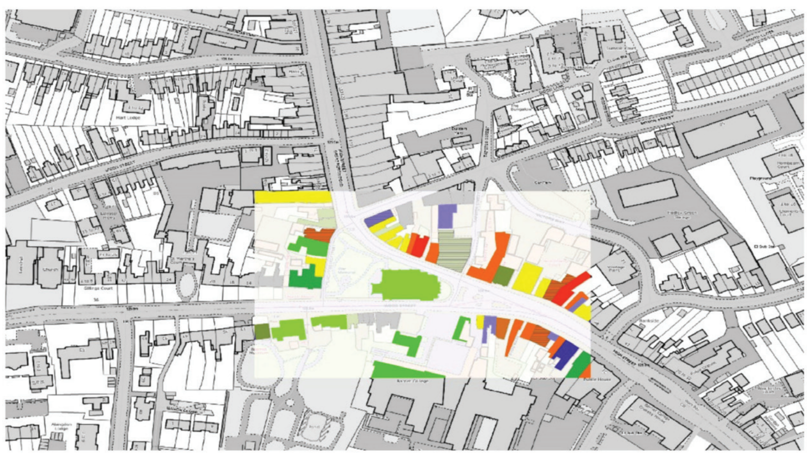
(**a**)



(**b**)

Figure 9. *Cont*.

(**c**)



(**d**)

Figure 9. Land use diversity overlaid on contemporaneous map for (**a**) c. 1880, (**b**) c. 1910, (**c**) c. 1960, (**d**) 2013 © Crown Copyright/database right 2013. An Ordnance Survey/EDINA supplied service. See Figure 8 for legend.

1880 directory	1910 directory	1960 directory	2013 directory
West side of High Street (southwards)	**West side of High Street (southwards)**	**West side of High Street (southwards)**	**West side of High Street (southwards)**
butcher	fancy repository	chemist	pharmacy
coach-builder	chemist	employment agency	dentist
		office	restaurant
		bank	cafe
		newspaper press	charity shop
		ladies' outfitters	Barnet College Hyde Institute (rear)
		betting office	skincare shop
East side of High Street (southwards)	**East side of High Street (southwards)**	**East side of High Street (southwards)**	**East side of High Street (southwards)**
baker	baker	fruiterer	travel agent (and above, recruitment agency)
watch-maker	tailor	tents and camping shops	charity shop
coal merchant	cycle maker	bakers	optician
grocer	butcher	men's outfitters	second-hand clothing shop
draper	butcher	pram shop	optician
butcher	coal merchant's	confectioners	sweet shop
The Old Kings Head public house	piano forte warehouse	cafe	restaurant
baker	dairy	*The King's Head public house*	*The King's Head public house*
boot-maker	*The King's Head public house*	cafe (Wimpey)	restaurant
ironmonger	stationer	shoe shop	restaurant
chemist	tobacconist	lingerie	alternative health centre
stationer	baker	men's tailors	grocery store
The Bull Inn	ironmonger	grocer (Tesco)	restaurant
draper	lady's outfitter	Magistrate's Clerk's Office	bar
watchmaker	draper	drapers	theatre
The Mitre Inn	hairdresser	wine & spirits merchant (Unwin's)	supermarket (Tesco)
surgeon-dentist	stationer	boutique	bookmakers (Paddy Power)
grocer	*The Bull Inn*	*Ye Olde Mitre Inn*	restaurant (and above, secretarial college)
boot-maker	draper	snack bar	*Ye Olde Mitre Inn*
	dental surgeon	estate agent's	cafe
	watch-maker	opticians	hairdresser
	public house		cloth shop
	tobacconist		phone shop
	photographer		
North side of Wood Street (eastwards)	**North side of Wood Street (eastwards)**	**North side of Wood Street (eastwards)**	**North side of Wood Street (eastwards)**
St John's Church	Church Lad's brigade, Barnet Co.	solicitor's	Church House (hall)
coffee rooms	*St John's Church*	Council Housing Department	*St John the Baptist church*
baker		*St John the Baptist Church*	
South side of Wood Street (eastwards)	**South side of Wood Street (eastwards)**	**South side of Wood Street (eastwards)**	**South side of Wood Street (eastwards)**
brewery	school	Barnet Museum	Barnet Museum
Barnet County Court Office	solicitor & commissioner for oaths	*Barnet Council Offices*	*Barnet Council Offices*
carpenter	building society	accountant	Court House
boot-maker	*Barnet County Court Office*	solicitor	orthopaedic clinic
Queen Elizabeth Grammar School	carpenter	dentist	*Barnet College*
tailor	doctor	*South Herts./Barnet College of Further Education*	
photographer (same address as tailor)	*Queen Elizabeth Grammar School*		
Wood Street Public House			
builder			
builder			
general dealer			
... continuing down High Street	**... continuing down High Street**	**... continuing down High Street**	**... continuing down High Street**
wine merchant	tailor	tobacconists/confectioners (Mackenzie's)	newsagent
baker	tobacconist	estate agents	hairdresser
house furnisher	ham & beef shop	land surveyors	restaurant
surgeon-dentist (same address as house furnisher)	Crown & Anchor inn	Crown & Anchor bar	employment agency
	harness manufacturer	cafe	cafe
	baker	bakery	funeral directors
	auctioneers	building society (Halifax)	restaurant
	confectioner	funeral director's	insurance agency
	mineral water manufacturer	hairdresser (rear or above)	estate agency
	dentist	launderette	*Barnet Conservative Club*
	Barnet & District Constitutional Club	pianos	
		furniture sales	

Figure 10. Land uses at junction of High Street and Wood Street 1880–2013, with each street section compared across the four epochs.

The significant amount of persistence in types of land use is also apparent in Figure 10. Aside from the obvious example of the church, several pubs and institutions (marked in italics) have managed to maintain a presence over the 125 year period. Yet, it is equally clear that the buildings themselves have usefully adapted over time. Church House on Wood Street, for example, which in the 1920s and 30 s was regularly used by Church organisations. Subsequently, the building has been the home to Barnet Library; used by the military during World War II; and then as a venue for school meals. Today, it continues to serve a variety of community functions: from wedding receptions, to yoga, badminton, and theatre groups [38]. If we have learnt anything from our enquiry into the centuries-long history of London's suburbs, it is that suburban town centres are continually adapting to changing socio-economic and cultural norms. This suggests a dynamic, rather than static, definition of suburban heritage. Key to Barnet's legacy in this, spatial-morphological, sense is the configuration of its street network that serves to differentiate the stretch of Barnet High Street from the national highway of the Great North Road—of which it is a part. This has enabled relatively localised patterns of socio-economic activity in Barnet to benefit from more regionally extensive accessibility.

Smaller buildings adapt generically, so a pub becomes a café, or a pharmacy becomes a health food shop. Small-scale production persists, such as the printer to the rear of Wood Street. Other buildings have been replaced with the same generic use. A good example of this is Barnet college, located on the junction of Wood Street and High Street Barnet, a short distance from High Barnet underground station, on the site that originally belonged to Queen Elizabeth's School founded in the sixteenth century (Figure 11). The *Saturday Review* of 1879 helpfully explains how the school had been recently revived from its 'neglected, half-ruinous' state, with the construction of a range of 'excellent school buildings, large playgrounds, and a headmaster's dwelling-house' to form a new grammar school. It benefited from 'easy access from London', so that . . . 'instead of an unbroken silence, there is now, at due seasons, the bustle and stir of a very considerable school' [19].

Figure 11. Original site of Queen Elizabeth's Grammar School, Barnet (now part of Barnet College), sited opposite St John's Church. The blue plaque states that 'This Tudor Hall housed the free grammar school of Queen Elizabeth I who granted its charter in 1573′. Photo by Philafrenzy, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=51126572 (accessed on 4 October 2020).

4. Discussion

Our analysis has shown that Barnet's history as a suburban place constitutes a distinctive spatial-morphological heritage in relation to its immediate community, the surrounding counties and London. Its steady local growth over the centuries took a significant leap after the coming of the railway in the nineteenth century, which intensified building around the streets in its vicinity. Yet, the growth that resulted from this increase in global connectivity did not lead, as other of London's suburbs have suffered, to local severance by railway tracks, as the local train station was situated sufficiently outside of the main built-up area (and at a different topographical grade) to allow street connections to be maintained. This enduring spatial-morphological coherence has certainly helped to keep Barnet relatively intact as a centre of community. Another unexpected result of its pre-industrial era landscape has meant that the town's principal streets lie parallel to or away from the railway tracks, which means they are not quite as dominated by through traffic generated by the railway. As the business of retail has changed, the groups of shops with houses upstairs have been demolished, in some cases to make way for new enclosed shopping centres with parking attached. Interestingly, in the case of High Barnet, the creation of the roofed 'Spires' shopping mall improved the internal accessibility of the town centre, creating a new connection from the older part of settlement to its late nineteenth-century high street. In this context, one might reflect that such an intervention is consistent with Barnet's heritage as a localised 'deformation' of the Great North Road.

The changing nature of retail in Barnet also reflects demographic changes in the suburb. In Barnet, the effects of the incoming population post-World War II can be seen in the range of moderate to quite prosperous residences in the northern, more rural end of the town. Its demographic profile is, of course, influenced by proximity to London but this does not always result in traditional orientation of commuter journeys. For example, a young and socially diverse population travelling into the area to attend Barnet College, which was rebuilt and expanded in 2011, forming part of a regional consortium of schools. French makes a similar point in discussing community life in similarly peripheral nineteenth-century Surbiton in south-west London. He argues that Surbiton was not place based in the sense of being geographically determined, as its residents did not belong to a single community [39].

In the case of Barnet, it is important to emphasise that we do not seek to identify a dominant representation of 'community heritage' in a suburban context. Rather, the spatial-morphological approach to heritage seeks to identify how a diverse and dynamic community life may be sustained by the patterns of everyday life, where it is possible that there is neither an explicitly shared nor a widely articulated sense of what that community actually means. We propose this has something to do with the way in which resilient suburban centres can bring people together in familiar relatively stable routines of spatial co-presence and encounter precisely *without* imposing a particular cultural idea. Indeed, the frequent accusations of the suburbs being banal is largely premised on the idea that conformity to the routine norms of everyday life allows significant scope for the fulfilment of personal aspiration.

We intend the spatial morphological approach developed here, therefore, to resonate with current thinking in heritage management and planning that emphasises how definitions of tangible built environment assets in terms of their community status are likely to be entangled with the 'intangible associations' of locality, including historical patterns of use [40]. An important consideration for us regards the notion of *interface* that define socio-spatial relationships between different users and functional scales: for example between shop doors and windows and the street, between the side street and the high street, and between the configuration of accessible central streets and their residential hinterland [41]. Regarded as a characteristic patterning of interfaces the suburban streetscape is realised not simply a static setting for this or that heritage object but as strongly implicated in the construction of the heritage asset itself, as part of a living community. The mapping of key interfaces that define the meaningful social space of community heritage, connecting the micro-morphological to larger scales of movement, contributes an important layer of description to assist in the definition, management and protection of everyday heritage.

It is true that such a spatio-morphological approach to heritage must acknowledge a degree of fluidity in its definition. This is because the status of tangible heritage is said to be at least partially contingent on the intangible associations arising from its historical embedding in everyday social practices that are likely change over time consistent with prevailing socio-economic and cultural norms. Even so, any assessment of broader heritage contexts can only benefit from engaging with a spatial-morphological approach which balances a necessary sensitivity to material or aesthetic dimensions with a specific focus on its role in constituting social identities, particularly within local communities. Yet, as we have shown in the case of Chipping Barnet, this fluidity should not be overstated since a key contribution of the spatial-morphological approach is to express how social meanings are constructed through the materiality of an historical built environment that is characterised by continuity as well as change. The point then, is less to relativise heritage to the point when it becomes indistinguishable from the shifting practices of everyday life, so much as to explain how heritage management that aspires to protect the heritage of living communities can benefit by engaging with the spatial-morphological description of arrangements of streets and buildings that sustain their identities as places.

London's suburban periphery continues to be a highly dynamic environment, comprising diverse spatial morphologies, topographies and socio-economic structures. Our case study of Chipping Barnet has shown how old spaces were re-used, adapted and modified in new ways, without, necessarily entirely displacing previous patterns of activity—and rarely all at once. This has important implications for understanding what a 'suburb' is and is not. By focusing on the spatial morphology of Barnet as a starting point, the idea of place is shown both to be less stable than traditional local histories can imply—but also not something that can be said to be eradicated simply because many people commute from there to work in London. Similarly, Barnet's continuing vitality can be, at least partially, attributed to the long-term adaptability of the historical street network and the wide array of smaller and larger premises this helps to support. Easy access between the commercial activity along the high street and other town centre activities, such as the library, museum and local college is a vital aspect of how Barnet works today. Moreover, looking beyond the tarmacked streets lined by somewhat prosaic building facades reveals traces of past activities not only in the buildings and land uses, but also in the properties of the network itself. For example, the extent to which pedestrian footpaths establish the high street as the centre for movement flows at a walkable distance from the centre's residential hinterland. Barnet is characterised not only as a place that *means* things to people who live there but also as something that is *done* in a corporeal sense, involving the comings and goings of daily life making use of the affordances of a spatial morphology with its origins in medieval England and its most recent elements less than half a century old. While these two aspects of its spatial culture are distinct, neither can they be entirely separated. They describe the dialogue of tangible and intangible aspects of suburban community heritage that serve to remind us that however potent and negotiable cultural images of the suburbs may be, they do not suffice to understand what is at issue in the description and delineation of their heritage as communities.

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Lines of Settlement: Lost Landscapes within Maps for Future Morphologies

Paul Sanders *, Mirjana Lozanovska and Lana Van Galen

School of Architecture and Built Environment, Deakin University, 1 Gheringhap Street, Geelong, VIC 3220, Australia; mirjana.lozanovska@deakin.edu.au (M.L.); lana.v@deakin.edu.au (L.V.G.)
* Correspondence: paul.sanders@deakin.edu.au

Abstract: The value of archival documents quite often extends beyond their original purpose, as evidence contained within these artefacts, whether written or drawn, can provide veracity for new lines of heritage inquiry. Many settlements in the 'new world' were set out by land surveyors whose drawings charted the accurate placement and alignment of new streets and block perimeters laid upon drawings of the extant topographical landscape features. The paper discusses three settlement maps of Melbourne, Australia, through the lens of Michel de Certeau's idea that maps are an instrument of power are not just about recording; maps are actually about appropriating and producing regimes of place. In the Australian context, the settlement drawings, prepared under the direction of the colonial administration, inadvertently depicts *Country* that had been under the custodial care of the First Nations peoples for millennia, and through the intentions of the settlement maps about to be irrevocably disturbed, altered or destroyed. We raise the prospect that urban and landscape design can reflect on the 'lost landscapes' of cultural significance, and discuss new ways of interpreting representation through an approach of design reconciliation.

Keywords: cultural heritage; mapping; surveying; indigenous place values; colonisation; Michel de Certeau; urban morphology; lost landscapes; design reparation

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1. Introduction

The objective of this paper is an examination of how the heritage context of colonial settlement can be re-evaluated through a contrary viewpoint to the conventional approach of urban morphology that seeks to understand urban development from its genesis, represented in archival survey maps as the starting point. Instead, we observe that these maps are also evidence of an end point of a cultural landscape, an unintended artefact of this particular heritage.

Urban morphology is the study of the structure of a city's form [1,2] from its 'formation to subsequent transformations' [3] (p. 3). The study of urban morphology is concerned with the physical and spatial layout of urban structure and the processes that give rise to them [4]. Particular attention is given to the plots, blocks, streets, buildings and open spaces which are all integral to the study of the 'history evolutionary process' of specific parts of a city under consideration [5] (p. 67). By recognising that 'the past provides the key to the future . . . the spirit of a society is objectivated in the historico-geographical character of the urban landscape and becomes the genius loci' [6] (p. 6).

There are several factors for the colonial settlement of Australia, from the earliest British interests in the latter 1700s that led to the founding of Sydney, Hobart and Brisbane as penal colonies and locations of defence. These were soon followed by Perth, Melbourne and Adelaide as new centres of free settlement, investment, speculation and trade [7]. At the outset of each settlement, the colonial authorities relied heavily on the ingenuity of the surveyors to assess the aspirations of the colonial authorities against the landscape characteristics and attributes of the site under consideration to support the decision to establish each particular settlement. While the configuration of Sydney and Hobart aligned to the topography and were somewhat loose in geometric pattern, the other major cities were conceived as orthogonal street grids of varying proportions and allotment subdivision. These schematic boundaries, once established and either sold at auction or designated for public function, would maintain as the morphological template for future development. Arnis Siksna undertook comparative analysis of the size of several Australian and American city block formations, his study revealed that the relationship of 'block size and form have crucial and predictable effects on subsequent evolutionary patterns' [8] (p. 24).

However, can there be other readings of survey and settlement maps of colonisation? While these maps are in themselves heritage artefacts as historical archives, can they be viewed as markers in a specific, dynamic, and even drastic time of change? Are these maps instruments of the control and power that affected the change? Can we intriguingly examine the mapped evidence from a perspective of its preceding time, as the end rather than the starting point of built transformation, as a depiction of the 'lost landscapes' of cultural significance?

2. Australian Aboriginal *Country*

Country is an Aboriginal Idea. It is an Idea that binds groupings of Aboriginal people to the place of their ancestors, past, current and future. It understands that every moment of the land, sea and sky, its particles, its prospects and its prompts, enables life [9].

Landscape is central to Aboriginal spiritual belief systems, and each area defined by individual language groups is bound to deep understandings of how the physical environment has been shaped, and individual and group responsibility for its custodianship and protection [10]. Evidence suggests that humans first came to the region at least forty thousand years ago [11]. From this time, Aboriginal people have lived in accord with the ancient landscape and have adapted successfully to the varying weather conditions and the enormous changes in the nature and extent of their territory. Five and a half thousand years ago the water level in Port Phillip Bay was about two metres higher than at present. Port Phillip Bay was a lot larger than it is now and much of what is now the inner city of Melbourne was submerged under water. As the sea subsided to its current level, many parts of these inner areas became boggy swamps [11].

The surface features of the Melbourne area we are most aware of today—the shape of the bay, the vegetation and the course of the rivers, have all formed in the past five thousand years. The surface features carry a number of traditional songlines—so named because navigational instructions, geographic features and human-made route markers were coded in song, sung by Aboriginal people as they travelled [11]. The tribes and clans of the local Kulin Nation utilised these songlines to meet on occasions of plenty in spring and late summer, and these areas served an extremely important purpose for these meetings. Melbourne and its surrounds remain a junction for all the major songlines heading north and west out of the city [12].

An old river red gum 'scar' tree, thought to be at least 300 years in age, with its deep, elongated scar, remains a living, breathing representation of a time when the *Wurundjeri* people freely exercised their way of life throughout the area. Uncle Bill Nicholson (a Wurundjeri Elder) describes that 'the tree was cut with a greenstone axe, quarried about one hundred and twenty kilometres to the north of the site at a place called "*Willamorin*"—"Home of the Axe", a sacred ancestral place where axes have been quarried for tens of thousands of years' [12]. The large, long scar indicates that the bark taken would have been fired into shape and used for a '*koorong*' or canoe, a flat-based canoe which would have been paddled out into the wetlands.

Wattle and gum trees also covered the area south of the Yarra River. Part of this forest remained up to the 1860s but was lost as a result of the rapid growth of Melbourne, the last remnant being the Corroboree Tree at St Kilda Junction. This tree stands just a few kilometres from the city centre but is largely hidden from view despite the popularity of walking trails. The corroboree tree—or '*ngargee*' in the local Aboriginal language—holds the life and memories of the things that went before it. It was the point where people joined and moved through and celebrated the people of this land. According to Carolyn Briggs (an elder of the Boon Wurrung people), for hundreds of years it was a meeting place for boys who would then embark on initiation journeys. Women would also meet there before heading to special places on the coast to learn birthing secrets [13].

These are some examples of the intricate network of landscape features that contribute towards the manifestation of *Country*, where 'everything is alive and everything is embodied in relationships, whereby the past, present, and future are one, and where both spiritual and physical worlds of *Country* interact' [14] (p. 14).

3. Surveying for Settlement

Within a short space of time in the mid-1830s, British settlers had started to make dramatic changes in the area which John Batman, one of the first pioneers who had established a small holding on the banks of the *Yarra Yarra* River had called it 'the place for a village' [11]. Trees were be chopped down for houses and fires. Animals and birds were hunted for food in greater numbers than ever before. Crops were sown and sheep and cattle grazed. Domestic cats and dogs escaped into the bush. Nothing would ever be the same for the Aboriginal people of the Kulin Nations [11].

The attention of the colonial authorities was therefore drawn to the suitability of the location for the establishment of a town, and procedures were initiated to affect formal control of the area through a settlement survey and demarcation of streets and allotments for imminent private sale [15]. However, historical accounts as to the exact attribution of the official foundation of Melbourne has been the subject of some conjecture, with particular reference to the two principal surveyors, Robert Russell and Robert Hoddle, whom were consecutively engaged in the process of imposing its towns plan configuration.

Robert Russell, a 'pioneer surveyor', architect, and painter, had been appointed as Assistant Surveyor in 1836 to measure and chart the Port Phillip Settlement (prior to the naming of the Town of Melbourne). He was accompanied by two assistants Frederick Robert D'Arcy and William Wedge Darke [15,16]. Russell was 'instructed to observe and report upon all natural phenomena' [16] (p. 9), and was in charge of the landscape features survey (Figure 1) and undertook triangulation, with D'Arcy, an excellent draughtsman, who drew the maps [15,17].

Greig suggests that despite the lack of any specific detailed instruction in the official appointment letter from the Deputy Surveyor-General in Sydney that ordered the setting out of a township as part of his survey, the intent of the party of three surveyors was surely to 'lay out a town' to establish civil authority, in preparation for land sales [15] (p. 40). Russell had been placed under the direct instructions of the police magistrate Captain William Lonsdale, who understood the duties were for 'immediate measurement of a portion of the district, a survey for measurement of the lands' [15] (p. 36). Furthermore, Sir Richard Bourke (Governor General) had reported that the surveyors had been dispatched to measure off sections and portions of the land for periodical sale [15] (p. 37).

Figure 1. Map shewing the site of Melbourne and the position of the huts and buildings previous to the foundation of the township by Sir Richard Bourke in 1837 [18].

The township had most likely been plotted out following the instruction of Londsdale and under Russell's supervision 'on the very site occupied by the scattered huts formed the 'un-named village' of the original squatters' [15] (p. 41). Russell much latter made claim that he had made the survey of the site of Melbourne without official instruction [15] (p. 43). The appearance of a dotted and numbered square grid on Russell's feature map (Figure 1), which had been sent to London to be lithographed, suggests a preliminary settlement configuration based on his knowledge of the standard plan in the Sydney office for laying out a new township, a copy of which he had in his possession [15] (p. 47) [17]. Critically, the map is a record of detailed landscape features which are meticulously recorded from which the following aspects are illustrated and written: *Yarra Yarra* River, Falls, Fresh Water above the Falls, Batman Hill and Burial Hill (remains of early settlers and the site of a signal station) [19] (p. 79), areas of Tea Tree Shrubs, Salt Lake, 'Flat' terrain, various tracks and lightly wooded areas. Additionally, homesteads are drawn and labelled with the family names of the settlers and officials [18].

The site for the town is on the banks of the *Yarra Yarra* River, a few kilometres upstream from the large sheltered bay of Port Phillip. The advantages of this selected site were many. In the 1830s and early 1840s, at the time of British arrival, the water of *Birrarang* (*Yarra Yarra*) were home to fish of all sorts and even dolphins. The waters coursed through low, marshy flats, densely grown with reeds and scrub, whilst on both sides of the river immense cordons of she-oak, gums and wattles tree forests grew. Headed into the river from the bay, saltwater mangrove swamps once spread. Beyond this, stretching as far as the eye could see, were rolling pastures covered with native grasses [20].

Four kilometres from the mouth, another river enters from the right. It is this river that British settlers first called Freshwater, before being given the name *Yarra Yarra*, in the mistaken belief that that was the name for the stream, in fact it was called *Bay-ray-rung*. The river then curves around a once prominent hill that was to be known as Batman's Hill. This hill had a natural covering of she-oak and grass. About one and a half kilometres further upstream, on the northern side were the tops of hills covered with gums [11]. East of Batman's Hill the river originally formed a natural basin, wide and deep, and become known as 'The Pond'. Immediately beyond the 'The Pond' was a set of rock falls consisting of a row of basalt boulders (The Falls) which formed rapids and retarded the spread of salt water further upstream. The *Yarra Yarra* River was therefore a freshwater stream beyond this point. It was the main source of drinking water until it becomes polluted [20]. Generally, the original vegetation comprised of tall and mature eucalyptus on both sides. In some areas there are trees that bear scars which show where bark has been removed by the local Aboriginal people [11].

Progress of Russell's work had been slow as he was hindered by several mitigating factors. Despite these claims, there was doubt as to his ability and efficiency in the task, and subsequently Bourke summoned from Sydney the Senior Surveyor Robert Hoddle to accompany him on an official visit to the settlement in February 1837 [16,21], to directly oversee the prompt implementation of a town layout. It is Bourke who officially confirmed the suitability of the area selected by Batman and the other first settlers as siting for a new town to which he named Melbourne [22] (p. 219) [23] (p. 94). 'Hoddle was ordered to go over afresh the ground already marked out by Russell' [15] (p. 46), and lay out a central grid [21] (p. 24). Bourke 'fixed the limits of the town, and the direction of the streets' [23] (p. 89), to which he also affixed European names [17] (p. 56). Only the *Yarra Yarra* River retained an Indigenous Australian reference on the official first map of Melbourne. It is noted that Hoddle, overseeing the management of Melbourne's immediate expansion, named many early suburbs with local Indigenous Australian names, for example: *Prahran*, *Tukulreen*, *Jika Jika* and *Borondarra* [23].

Therefore, as Melbourne's first Surveyor general, Robert Hoddle confirmed the settlement grid with the alignment of streets and subdivision of allotments within the street blocks. The Melbourne layout is indeed unique mainly for 'the "little" streets that were placed between the city's cross avenues to allow ease of rear access' [7] (p. 18). Hoddle authored a map 'Town of Melbourne' (dated 25 March 1837) for the intention of the first land sales [17], which shows the positioning of the grids aligning with the reach of the *Yarra Yarra* River and extremity of Salt Water terminating in the natural falls, and offset from the protrusion of Batman's Hill, from which there is a settling out line (Figure 2). The river and hill are the only landscape features recorded on this map. The grid was apparently 'superimposed onto the land with no consideration for the natural features of the site' [7] (p. 11).

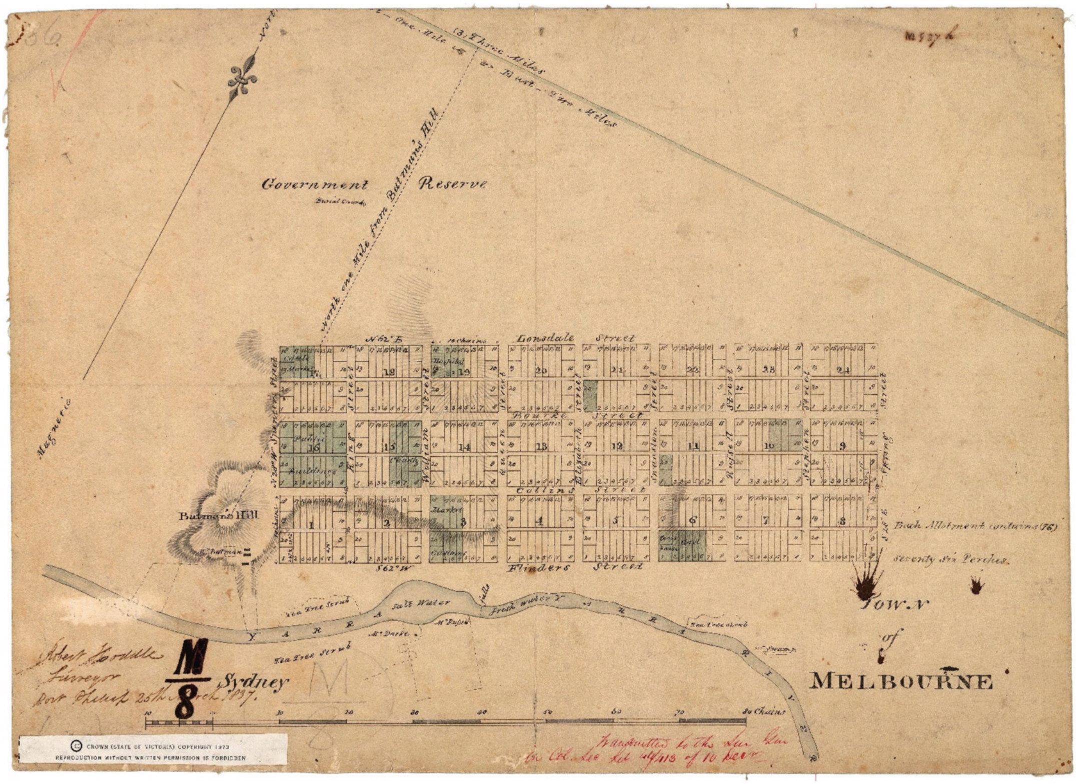

Figure 2. Town of Melbourne [cartographic material]/Robert Hoddle, Surveyor, Port Phillip, 25 March 1837 [24]. According to Selby [17] the map was drawn prior to receiving material from Russell; hence, it is void of the full landscape features except for the inclusion of Batman's Hill and ridgelines, *Yarra Yarra* River (indicating the position of the falls), scattered settlers homesteads, and a few notations of vegetation.

Hoddle subsequently gained popular recognition and attribution for making the first plan of Melbourne [17] with oversight to Russell's earlier work perhaps as a consequence for his perceived unsatisfactory progress [15]. The pervasive narrative being that Russell had made a topographical features survey of the 'ultimate site of Melbourne upon which Hoddle subsequently drew the familiar grid plan' [16] (p. 9), and whom designed the layout of streets and allotments for the new town [17]. Hoddle's letter (10 April 1837) states 'from Mr Russell I could only obtain a plan of the settlement executed by himself and Mr D'Arcy on which I drew a plan of the town of Melbourne' [17] (p. 57). Figure 3 is the superimposition, Hoddle's arrangement of named streets and numbered allotments overlaid onto Russell's landscape features survey.

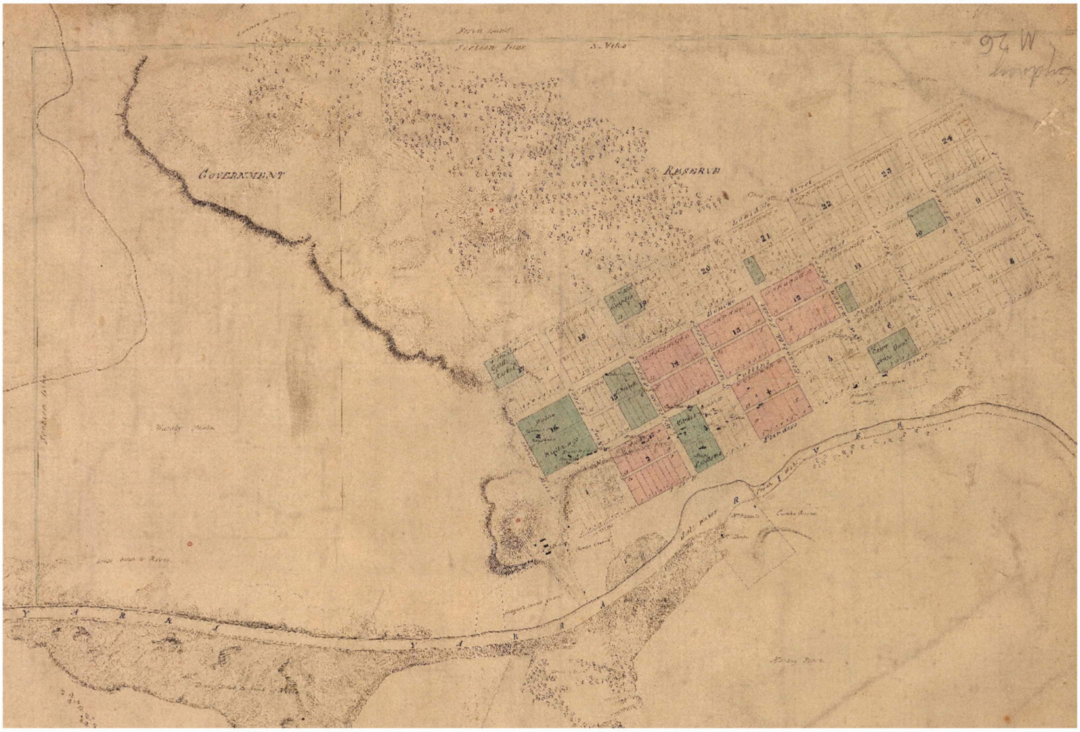

Figure 3. Town of Melbourne and Plan of the Settlement—Port Phillip. 1837. Part section. Public Records of Victoria—Historic Plans Collection [25].

Despite this debate, our interest is in a reading of the two maps as being: Figure 1, Russell's map of extensive detail of landscape features, onto which the township is lightly indicated, and, Figure 2, Hoddle's map which conversely sets out a settlement geometry in bold lines, with only Batman's Hill and the *Yarra Yarra* River with Falls as topographic features to aid the positioning of the grid. 'The old falls on the Yarra really determined the position of the city' [15] (p. 47). Yet, these were to be the prominent landscape features that would be expendable in the execution of infrastructural development of the fledgling town. A further collective understanding of the three maps is that they can all be viewed as instruments of power in the process of colonisation and dispossession, a theme which will be explored further in the next section.

4. Unwitting Evidence within Maps as Instruments of Power

Michel de Certeau's idea that maps are an instrument of power represents a very important set of thoughts and way of thinking about maps that has subsequently been taken up by architectural thinkers [26,27]. In his seminal work *The Practice of Everyday Life*, de Certeau talks about maps as instruments of power because maps centre power in place and implement a geometric schema for understanding space [28] (p. 124). Relating this understanding to the context of maps during colonization makes evident that the survey of the land was a way of appropriating the land. Speculation inherent in the map or plan was perceived as a constructed future superimposed onto the existing land, altering both its physical and socio-cultural topography [27]. The map materialises that speculation, and makes it more real than perhaps the intention because the map draws the vision in a pragmatic sense. The map thus pre-empts the change, alteration and transformation in relation to an existing reality. The map operates in a dual sense as projection of a yet unrealized future and as a representation of existing realities, and the cartographic or visual tools and methods tend to delineate what is drawn and what is not represented [29]. As a method of a projected future on the surveyed environment the map surpasses the moment of that reality and shapes forthcoming realities. Maps and cartography, like land surveys, are not neutral.

The end result is a record of a spatial environment upon which is a manifestation of time: time and the historical moment are frozen within the paradigm of a map, disclosing a spatial environment distinct from the flow of time and a sense of the unknown of what was to come. Colonial appropriation thus occurs across both space and time as axis but also as intersecting forces. For example, a map may represent a grid (even though this is something that does not yet exist in the early 1800s in Melbourne) but not necessarily the pathways or sites of inhabitation of the Indigenous peoples. From this perspective we can see that maps were integral to the larger scope of colonization as an appropriation of territory and as selective representation of realities [27]. Maps delineated the spatial order about the future of society. These were visions that projected onto particular sites and both imagined and articulated a transformation of that site into place. The maps of Russell and Hoddle actually determined a particular future for the site as a place for the city of Melbourne.

De Certeau discusses maps as instruments of power that produce regimes of place. Investment through the process of mapping and cartography constructs the place in question into a node or centre, and this action is not neutral but a determined strategy of colonial power. De Certeau connects spatial strategy, with maps and with place such that these three elements go together, and are organized in such ways as centres of authority and the law [28] (pp. 34–44). In that sense politics does not exist outside of maps, and colonization cannot exist without mapping. The map is a critical instrument and a tool deployed to deliver the strategies and processes. Important to de Certeau's theory is the contrasting of place and space. While the regimes of place are produced by maps and strategy, and they become strategic places of authority and power, so place is linked to authority power, law and strategy.

Space, in de Certeau's theory, is a loosened activity. Space is not unmapped, but it is not strategic to the map, and difficult to map, and historically it is much less mapped in official documents [28] (pp. 115–120). For example, one can imagine a picture (drawings, paintings) and this is also shown in early colonial photographs, of the co-existence of the Indigenous people within the 'places' established in the early times of colonization [30]. They co-existed within the places in a way that de Certeau calls tactic, whereby, the Indigenous people navigated the then newly imposed spatial order of the place and the strategic order of laws, boundaries and structures (Figure 4). Indigenous 'tactical' coexistence within these regimes of place was not represented on the official maps, or was officially omitted from the mapping of the place. Tactic is linked to what de Certeau defines as space, spatial co-existences that are interwoven within place. From this perspective a tactic can be considered 'out of place,' and that is exactly de Certeau's point, that these are spatial navigations within the regime of place which use that place differently to its intention.

Figure 4. Melbourne from the falls, 30 June 1837 [31]. In this image, the 'first picture of the settlement' [16] (p. 8), Russell depicts local Indigenous Australian inhabitants crossing the falls on the *Yarra Yarra* River, a significant landscape feature as a natural bridge. Across the river are early settler huts and tents, in the distance are the native woodlands.

The intention of the colonisers' settlement did not account for the co-existence, and in addition, the customs and activities of the Indigenous people. On the one hand, maps are instruments of power used to produce places that are strategic for the political intention and agenda, and in this case settler colonization. On the other hand, activities that do not fit into the scope or colonial vision of maps, and a regime of place as strategy, are those tactics and spaces that are temporal 'actions of the weak' [28] (pp. xvii and 119). Importantly, such tactics, de Certeau argues, can redefine place temporarily as a very different space [28] (p. 37). This presents a potential of the spatial realm that is outside the gaze and power of the regime of place. Within the first few years of settlement, Aboriginal peoples were almost entirely displaced from the Melbourne area [22]. Nonetheless many Indigenous communities and individuals also co-existed within the same spatial environments, navigating the implanted order, authority and strategy of the newly constructed place. Therefore, 'continuing aspects of Aboriginal cultures with expressions in values of place have persisted ... and evolved through many transformations and adaptions until the present day' [32] (p. 1).

Russell's maps and painting represent the concerted efforts of a landscape surveyor to record the extant condition around the site of colonial settlement. They are also artefacts of historical time—capturing the 'lie of the land' as it was perceived and recorded by Russell in 1837. In this sense, and for architectural historians/archaeologists, such documents can serve as evidence for other readings of history making. Figure 4 depicts the Indigenous people crossing the *Yarra Yarra* River at the point of the falls, continuing a time- honoured act of daily life within the fledgling surroundings of occupation. Within a short space of time, such landscape features will be irrevocably decimated in service of the rapid construction of colony. This painting is therefore a record of a 'tactic' in de Certeau's sense of the division between strategy and tactic. It captures firstly the extant co-existence of Indigenous communities within the scope of colonizing instruments of documentation and representation. Secondly, it illustrates a site that has been identified as significant for the Indigenous communities of the *Bun Wurrung* and *Woi Wurrung* peoples of the area [11]. A third aspect is that it indicates that indigenous presence, both—the act of indigenous people crossing and the site of the falls—co-exists as tactical non-strategic space within the regime of place that materialised as the new grid of Melbourne.

Therefore, it is possible to compare the two maps allocated as Russell's map against Hoddle's map (Figures 1 and 2) by identifying the prominent landscape features as a significant part of Russell's map that are suppressed within Hoddle's, to the extent that only the river and hill were recorded as a reference point for the positioning of the grid. Russell's map is an active intention and illustrates a comprehensive, observational and detailed approach in its record of the existing terrain and vegetation as necessary for its role in surveying the terrain for colonisation. Yet, it is an inadvertent record of Aboriginal *Country*, an unwitting record of features of local places that (we now know) are significant to Indigenous history and therefore critically evidence that it was un-ceded colonization, and that the establishment of colony was not terra nullius, as was claimed by the colonisers. Hoddle's map is the intent and blueprint for radical change. Between the two maps is a decision to omit these landscape sites in the transfer from an observational map of the land (Russell's map) to the next level of the map as strategy. It is one in a series of procedures that determine the power and authority of the colony. Such map redrafting—and the imprecision of the transfer—illustrates how the determinants of the making of the colony are at work in this otherwise perceived empirical exercise. Maps are subjected to the cartographer's gaze, and what the cartographer wants to see, in addition to the strategic and political objective. Hoddle's map presents the erasure of sites of the land that belonged to the inhabitants of the land, drafting a contract of 'wishful' but colonial determined terra nullius. These maps were both created as instrument of power, but they can now be used against their intention as historical artefacts, that open up a different lens on the history of this place. We can now appraise the recorded lost landscape features, for example the *Yarra Yarra* Falls and Batman's Hill, evident in the archival settlement maps, and renew an understanding of their original significance.

5. The Destruction of Cultural Heritage Places of Significance

Several known important sites of significance within the bounds of Melbourne's initial settlement were to be destroyed in the face of the expanding town. There was little or no appreciation for cultural places, or the thought of preserving their inherent landscape features. We highlight and discuss the two important landscape features that were prominent in Hoddle's survey (Figure 2), 'that map of the allotments, with only Batman's Hill and the Yarra marked on it, is our first map' [17] (p. 56).

5.1. Yarra Yarra Falls

In 1835, when Europeans settled at the site of what was to become Melbourne, there was a set of rock falls across the Yarra River. These falls prevented salty, tidal water mixing with fresh river water. Melbourne was chosen for settlement largely because fresh water could be obtained from the Yarra above the falls [19] (p. 6).

The rocks presented a natural crossing for Aboriginal people of the area (see Figure 4), and was a location of great importance, not only for its physical attribute as a natural bridge, but it provided a place for local clans to meet for 'law, social, and ceremonial purposes' [33] (p. 11). Immediately below the falls the salt water had opened up a wide and deep basin, suitable for anchorage of settler ships (see Figures 1, 2 and 5). The rocky crossing was latter dammed to improve the fresh water supply, but contributed to major flooding problem and was subsequently blown up in 1860 to allow ships to navigate further up the river [33]. The location of the former falls is now the site of Queens Bridge.

Figure 5. The City of Melbourne, Australia in 1885 [34]. Part detail. Batman's Hill is prominent to the edge of the city grid. Additionally, note that the falls are evident to the immediate left of the railway bridge, preventing the sailing ships from further passage upstream.

5.2. Batman's Hill

The hill adopted the name from John Batman who had arrived in 1835 as one of the first pioneers [15] (Greig, 1919) to set up a 'headquarters for exploiting the surrounding land' [7] (p. 11), and established a homestead and farm on the slopes of the hill. Batman had claimed to have purchased the land from local Aboriginal people; however, the colonial authorities considered the first settlers as illegal occupiers of Crown Land. Consequent to the surveying and planning of Melbourne discussed earlier, Batman's Hill was appropriated for various civic functions, the house as a superintendent's office, and as a grandstand for horse races [7]. In 1847 a powder magazine was constructed on its western slope and navigation beacons were erected to take advantage of the hill's prominence [35].

A contract to excavate and remove Batman's Hill was signed in November 1863 to make way for a new railway station, and so the entire landscape feature, along with the early settlement buildings were completely levelled. Figure 6 is a somewhat dramatic scene, depicting the manual labour of the removal of the hill, possibly drawn as a record of colonial advancement, but can now be viewed as evidence of a cultural landscape desecration.

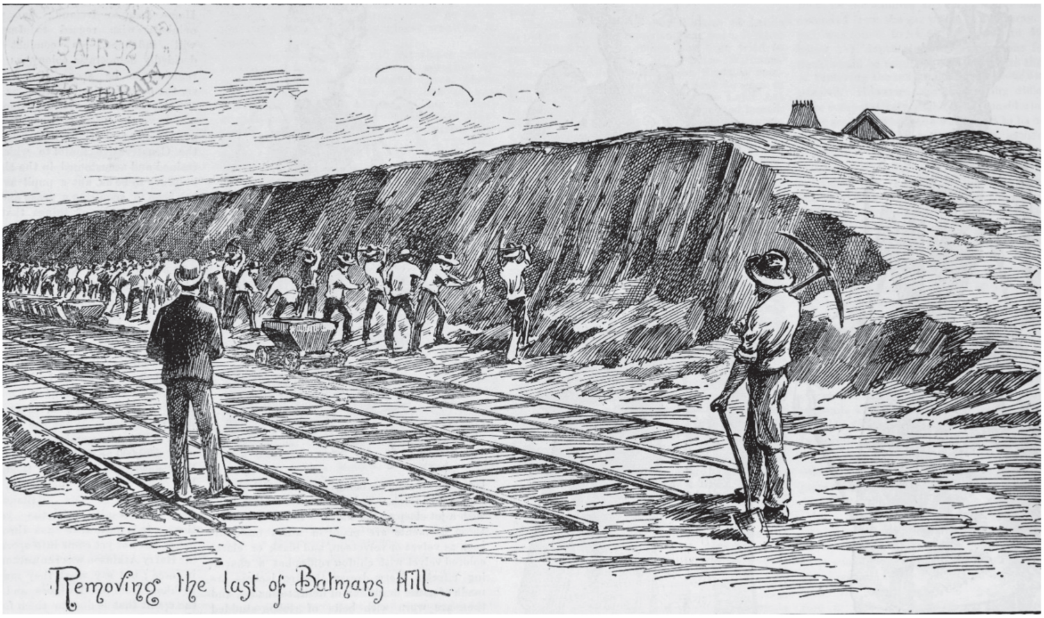

Figure 6. Removing the last of Batman's Hill. Extract from *Batman's Hill—past and present* [36].

6. Reparation through Design

> *We are becoming increasingly aware of the difficulty and continuing legacy of Australia's history as a settler society . . . [that] occurred with minimal understanding of our environmental context and no knowledge of its prior occupation* [37] (p. 29).

Australia, as is the case with other colonised countries, is still in the process of coming to terms and re-examining the veracity of conventional accounts of its history, heritage and culture. Until relatively recently knowledge of a 'pre-European history and ecology has been lacking' [37] (p. 30). Acts of reconciliation have included various political statements of recognition of past injustices and atrocities, in the form of formal apologies of the national government to the Indigenous Australians. However, the design professions and educational institutions have been slow to embrace momentum to affect significant change in current practice. New paradigms have nonetheless been provoked by several of Australia's Indigenous architects.

Kevin O'Brien has developed a radical proposition called *Finding Country* that emerged from his Masters of Philosophy thesis at the University of Queensland. A series of design studios have subsequently been undertaken where project participants are asked to execute the hypothetical removal of 50% of a selected urban grid. What follows is a contemplation of not what has been removed, but what can now be seen, an engagement with 'a palimpsest to erase a certain part of the text of the city to reveal a presence that had been covered over and ignored' [38]. A negotiation is thus required with the lost landscapes of *Country* before a new architectural insertion can be made. A tapestry map from a *Finding Country* studio project was exhibited as a collateral event at the 2012 Venice Biennale, at which O'Brien ceremonially burnt the drawing 'in an act of symbolic renewal and as a statement of positive intent' [38] in homage to the customary burning of landscape by Aboriginal people for renewed growth.

> *The Aboriginal map of Australia reveals a continent with many Countries and many spaces. The prevailing spectrum of architectural positions, bookended by decorated sheds and metaphysical decks, continues to bring Aboriginal Country into decline. If the*

> *opposite position is considered it is possible to find something lost. Cities historically enter states of decline, frequently associated with some form of catastrophe. Others end in a whimper. It is not unreasonable to imagine an opportunity for the recovery of Country through decline* [9].

Jefa Greenaway and colleagues Janet McGaw and Jillian Walliss have instigated a creative research student project at the University of Melbourne that engages with Indigenous place-making through three research methods of: Deep Listening, Mapping Place and Time and Critical Spatial Practices [37]. The project re-examined Russell's 1937 map (Figure 1), and identified the several important places of cultural significance, including The Falls and Batman's Hill. The outcome of the project was a number of creative works that included a spatial performance called *The Falls* involving participants recreating a waterfall by pouring bottled water from a bridge at the location, a temporal recreation of the lost landscape feature. This work thus appropriates the maps as 'informational tools' of significant landscape sites which it then re-performs towards a communicative and community act, as a corporeal and signifying revision of historical erasure. Such use of maps may join methods of oral histories, and further archival historical documents, to build a very different map of the embedded memories of the sites the place of Melbourne.

O'Brien and Greenaway have been active in both private architectural practice while also formally appointed within leading Australian universities to advance critical thinking, research and teaching on the advancement of Indigenous agendas in architecture. Universities play a crucial role in accelerating awareness and change in society, in the context of applied research into Indigenous environments. Paul Memmott as an anthropologist and architect, for many decades has been instrumental in leading as Director The Aboriginal Environments Research Centre (AERC) at the University of Queensland [39]. The centre has been responsible for extensive research projects and publication outputs. David Jones and colleagues [14] have collated and published a comprehensive guide for tertiary educators that sets out a carefully researched and informed overview that includes: an understanding of *Country*, protocols for respectful engagement with Indigenous issues, and introduction to Indigenous cultural heritage whereby 'all tangible and intangible aspects of a landscape may be important ... as comprising their 'living heritage' whereby the 'spiritual relationship [with landscape] is an important aspect of Indigenous cultural heritage' [14] (p. 23).

7. Discussion

There can be multiple readings of the same document, but these readings may be counter to each other and framed by a very different historiography. Survey maps were deployed as instruments of power establishing strategic places in the formation of cities such as Melbourne. The British olonial authority was made manifest in the projection of the strategic place as the grid within the colonial settlement map. Importantly, the strategic place is intrinsic to the map as a vision even prior to the actual laying out of the city. As a drawing artefact, it also generates a colonial imaginary, a visual paradigm about that site. One risk of visual documents is their reading as evidence, rather than as artefacts to be subjected to analysis and interpretation, as this subsequently generates a retrospective historical order that appropriate the colonial agenda as a neo-colonial historiography. Further, visual documents including artistic paintings and drawings participate in the processes of establishing place as a strategic centre. Such works need to also be subjected to analytical enquiry in order to avoid the replication of colonial bias.

A further reading, is how topographic features maps unwittingly provide evidence of the original cultural landscape that had the inescapable fate of destruction by virtue of the morphological intent of the surveyor's settlement configurations. Their lines of settlement became lines of dispossession. The maps also can be read as tracing the existence and livelihoods of Indigenous peoples alongside the strategic agenda for colonisation. The maps featured in this paper illustrate sites that were, and are significant to the Indigenous communities of the *Bun Wurrung* and *Woi Wurrung* peoples in the vicinity of Melbourne.

In the 1800s these communities navigated within this new order, new authority, and new law, by tactically using the interstitial spaces in this map, or by using them in an interstitial way. De Certeau calls tactics those very activities which are temporal uses of places, and this sense of how places may be extracted from their deployment as strategic creates the spatial sense of place. This possibility and openness is defined by the term space, and in de Certeau's sense is in contradistinction to place [28].

8. Conclusions

We have established that in the process of surveying for colonial settlement, the maps that were created in preparation for the establishment of new towns inadvertently depict Indigenous cultural landscapes that were under imminent threat. The scrutiny of such historical drawings from the viewpoint of looking back in time to the origins of the urban transformation process is the basis of urban morphology research. However, a reversal occurs when considering the topographical landscape surveys as a representation of a terminal moment of the physical features and forms of that location. This paper identified the cultural heritage significance of landscape features that were embedded within these drawings, represented in a moment in time before being erased. Therefore, these maps were instruments of power in the dispossession of land from the Indigenous Australian people. Nevertheless, a reparation process in architecture, urban design and landscape architecture is underway in Australia through creative strategies of design and performative events, that provide a glimpse of lost *Country*.

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heritage

Article

Sustaining Heritage Patterns in Mining Towns of the North American West: A Historico-Geographical Approach

Wendy R. McClure †

College of Art and Architecture, University of Idaho, 875 Perimeter Drive MS 2451, 83844-2451 Moscow, Russia; wmcclure@uidaho.edu
† This author is a member of ISUF.

Abstract: Urban morphology provides essential methodologies to inform processes for heritage preservation and design intervention in historic places. Among principal research methods used by urban morphologists, the historico-geographical approach is particularly helpful for interpreting formative and transformative processes and for identifying key elements that define the physical structure of historic contexts at a town or neighbourhood scale. This article will discuss applications of an adapted historico-geographical approach to analyse heritage patterns in 19th-century mining towns located in mountainous regions of the western United States. Profiled case studies are part of an ongoing study intended to inform design and revitalization processes by architects, planners and community stakeholders in the region.

Keywords: urban morphology; historico-geographical; town plan; preservation; design guidelines

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1. Introduction

Historic mining communities in the North American West that have been adapted as destinations for mountain recreation and cultural tourism are challenged with often conflicting goals to preserve their inherited mining-era contexts while accommodating growth and development interests. Citizens and civic leaders seek strategies to sustain place identity in the face of growth and change. Most community preservation efforts, as guided by architects, primarily focus on restoring or repurposing historic buildings. Underlying planning patterns that also shape inherited contexts may not be adequately understood. Urban morphology provides essential methodologies to inform processes for heritage preservation and design intervention in historic places.

Discussion is informed by studies of residual mining-era heritage patterns in towns throughout the United States (US) Mountain West using urban morphology methods. Findings are intended to contribute to a broader understanding of western mining towns as a distinct typology and, more specifically, to inform planning and preservation policies intended to sustain their mining-era place identity. Particular emphasis will be placed on three representative communities that achieved full maturity during the mining era, including Park City, Utah (UT); Telluride, Colorado (CO); and Wallace, Idaho (ID). All three towns sustained silver mining operations as their primary source of employment for at least 100 years between the 1870s and 1980s. Following mine closures during the latter half of the 20th century, each community's revitalization plan aspired to build a future on opportunities afforded by its historic built environment and mountain setting. Strategies for economic realignment included transforming mining-era downtowns into hubs for mountain recreation, downhill skiing and cultural tourism. Capacity to preserve the integrity of mining-era contexts in the face of development has varied depending upon policy-makers' understanding of their authentic spatial character and underlying structure.

2. Research Methods

Urban morphologists investigate the historical development of the physical components that shape built environments. These analyses are based on three guiding principles: first, urban form is constructed of three fundamental elements: buildings and their related open spaces, plots and streets; second, urban form can be understood at different levels of resolution, ranging from individual spatial elements such as building/plot configuration to their assemblies within a region; third, urban form can be understood historically [1] (pp. 3–10).

Among principal research methodologies used by urban morphologists, an historico-geographical approach as developed by geographers Jeremy Whitehand and his mentor M.R.G. Conzen, are particularly helpful when applied to analysis at the town or urban neighbourhood scales. M.R.G. Conzen's studies of small cities and towns in the United Kingdom closely examined street systems, plot patterns and building patterns, both individually and as an ensemble, in order to interpret the spatial structure of the urban ground plan. Using methods of plan analysis, M.R.G. Conzen identified distinct periods of town development for each context. Applications of the Conzenian approach for plan analysis, as demonstrated by J.W.R. Whitehand, Michael P. Conzen and Kai Gu, provide a basis for cross-cultural comparisons of urban development in Chinese and European cities. Methods used to identify and interpret heritage patterns in mining communities represent an adaptation to the North American context [2,3]. The overall objective is to identify over-arching spatial characteristics that serve to distinguish 19th-century mining towns of the US Mountain West as a distinct town typology. The focus of the study is primarily on finding similarities in their physical form. Adaptations of Conzenian methods are required for several reasons: systems for land subdivision in the US West differ from those used in Conzen's study towns in the United Kingdom; the relative importance of each spatial element's contribution to the overall town plan varies between the two contexts; and resources used for town plan analysis are specific to the US context. A brief outline of the research process used for this on-going study follows.

1. Plan analysis. Examination of archival territorial maps, plans, city plats and documents housed in federal, state and county collections provide valuable information regarding processes for town formation and expansion during the mining era. Founding town plans and subsequent platted additions illustrate the overall progression of formative and growth stages. A review of town plats also provides scaled information about several key elements shaping town form, including the organisation of streets, blocks and plots, and their transformation over time.
2. Building uses throughout most of the mining era were recorded on color-coded fire insurance maps produced by the Sanborn Company between the mid-19th to mid-20th centuries to help underwriters assess risk. Sanborn maps, which were updated every few years until the mid-20th century, show plot dimensions, building footprints, number of stories, building use and construction materials. The practice was modelled after fire insurance underwriters in Britain who used mapping to illustrate fire risk to London buildings. It is noteworthy that urban morphologist M.R.G. Conzen and his German mentors created colour-coded maps to illustrate patterns of land utilisation, building types and number of stories [4].
3. "Metsker maps" featuring Pacific Northwest townscapes as prepared by the Seattle-based company beginning in 1901, are used to support interpretation of the historic townscape in relation to natural topography and to the township and range system, a US system implemented in 1875 for land survey of the western territories. The survey system's use of an orthogonal overlay on mountainous terrain reflects the government's determination to impose order on a vast wilderness. Use of the grid as a strategy for land subdivision continued to dominate western settlement patterns at each scale of resolution from regional to town plan until the mid-20th century.
4. Local history research. A review of local history collections housed in county libraries, historical museums and university libraries supports interpretation of socio-economic

and cultural influences. Correlation of historic trends with plat sequences supports identification of transformative forces and their potential manifestations in urban form. Birdseye perspective drawings and historic photographs of downtown districts housed in archival collections enhance three-dimensional understanding of key spatial elements.

5. Field documentation. The importance of field research cannot be underestimated. Although information about the physical dimensions and organisation of heritage patterns within contemporary contexts can be acquired using remote sensing tools, there are significant advantages to on-the-ground research. Immersion in the spatial environment being studied engages all the senses, enhancing an urban morphologist's ability to perceive the impact of scale and dimensions depicted in plans and by aerial views secured by remote sensing tools.

3. Mining Town Formation

In mining communities of the Mountain West, processes for town formation typically followed a similar pattern. Initial ore discoveries attracted a rapid influx of transient prospectors and placer miners to previously unsettled mountainous regions. Fortune seekers bent on taking rather than community-making set up informal camps composed of tents and crude wooden shacks along stream beds near mineral extraction points. Entrepreneurs and opportunists followed in their wake to establish market centres in support of placer mining activities.

Early settlements often paralleled the natural course of rivers and streams, which served as natural fixation lines for town formation. During initial stages of town development, rows of simple wooden houses and false front commercial buildings were constructed on canyon floors. Emerging townscapes were typically elongated in form and confined within narrow canyon walls. A spinal main street, serving as a humanly constructed fixation line, connected extraction sites at the canyon head to the principal route leading to urban marketplaces. The earliest regional transportation routes, established by indigenous people, included ancient trails leading over mountainous terrain. In some cases, mining prospects were sufficient to motivate private landowners to construct access via toll roads capable of handling teams of oxen, as was the case in Telluride [5].

Natural geography conducive to town development was a key factor in accommodating and sustaining permanent settlement. A majority of fledgling townsites in extreme mountain settings lacked ample room for growth and expansion. Burke Idaho (ID), near Wallace in Idaho's Coeur d'Alene Mining District, provides an example of former settlements that were shaped almost entirely by extreme geography and resource flow. In the case of Burke, the canyon floor was so narrow at 300 feet (91.4 m) across that it could only accommodate a single shared circulation corridor, including two sets of railroad tracks, flanked on each side by a mixed street wall of houses and commercial buildings. Congestion was intense, prompting old timers to joke that, to survive in Burke, dogs had to learn to wag their tails up and down instead of sideways. Burke progressed quickly from encampment stages following initial ore discoveries in 1884 to an official townsite in 1890 with over 300 stores, offices and saloons aligning its single street at its peak in 1910. Incapable of diversification, the townsite's population gradually diminished following World War II, in tandem with slowing extraction rates and a decline in silver prices [6]. Constricted townsites such as Burke were largely abandoned once readily accessible ore reserves were exhausted. Remnant structures of fledgling communities and terrain altered by placer/surface mining activities can be found throughout the Mountain West (Figure 1).

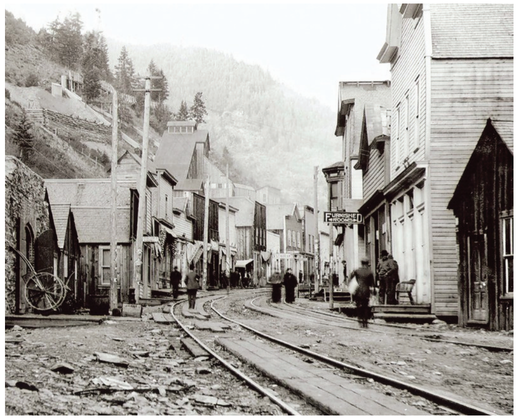


Figure 1. Main street Burke. Mining towns sited in narrow canyons were unsustainable after the ore ran out (Wikimedia Foundation).

Economic sustainability and progression to mature stages of town formation depended upon capacity to develop lode mining operations deep underground. Lode reserves attracted investment by mining corporations, providing stable employment for three to four generations. Following construction of transcontinental railroads across the Mountain West in the late-19th century, a mining community's ability to secure rail linkage to coastal marketplaces became an essential condition for successful corporate mining operations and long-term viability (Figure 2).

Figure 2. Town formation stages in Wallace. Early camp (green), founding town plat (red), miner's cottage rows (blue) and mining-era expansion (yellow).

4. Case Profiles

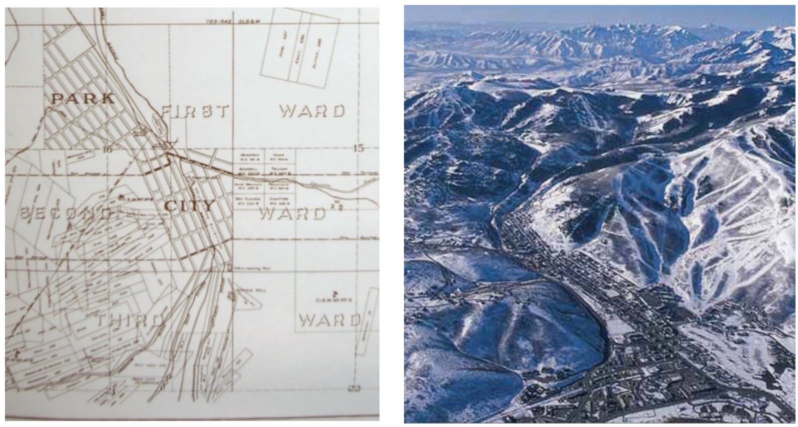
Historic background. Lode silver mining dominated the economies of Park City, UT, beginning in 1873; Telluride, CO, in 1877; and Wallace, ID, in 1886. Each community sustained corporate operations for at least a century. Corporate lode mining operations recruited waves of immigrant miners from throughout Europe and the eastern United States to work deep underground. Employment stability enabled multiple generations of miners to establish roots and engage in community-building processes in partnership with business owners, professionals and civic leaders. During early years, each townsite was accessed by mule along mountain trails or oxen teams on toll roads. Promising lode mining operations attracted railroad company investment by the 1890s. Rail service fuelled growth and prosperity by assuring expedient connection to urban markets. The combined factors of economic sustainability, railroad linkage and more favourable natural geography enabled each town to progress through characteristic stages of mining town development and to achieve full maturity during the peak of its mining era. A comparative discussion of similarities and differences in their urban form follows.

Townscape. Natural geography played a significant role in shaping each community's distinct urban form. All three settlements were established in river canyons of varying widths, flanked by steeply sloping hills or mountains. Formative processes in each circumstance occurred within influences exerted by distinct topographical outlines acting on conventional planning concepts, defined by M.R.G. Conzen as "morphological frames" [3,4] (p. 251; pp. 103–109). Though to varying degrees, natural geographic conditions were generally favourable to growth and expansion throughout the mining era. Historic townscapes also represent a palimpsest of humanly constructed environments. According to M.R.G. Conzen, when reflecting on his own studies of towns in the United Kingdom, "historical townscapes are palimpsests, bearing the stamp of their period of origin as well as subsequent periods" [3] (p. 50).

Mining townscapes also bear the indelible signature of human intervention and pollution of natural environments resulting from extraction processes, as evidenced by excavation trenches, polluted waterways, tailing deposits and treeless hillsides. Postmining clean-up often involves "capping", a process of covering mining tailings to isolate contaminants using soil and shallow root vegetation. Environmental clean-up sites are frequently located at the historic edges of town. As shown in Figure 3, capped mining tailings in Telluride form a fringe belt of park-like but polluted, undevelopable land.

Figure 3. Town edges in Telluride. Remnants of corporate mining operations and capped mining-era pollution continue to form town edges.

Town plan. Contrary to historic accounts depicting mining communities as spontaneous and unplanned, progression beyond encampment stages was generally guided by a deliberate town plan. The ideal mining town plan was configured as a gridded network of streets and alleys bisected by a principal commercial street. However, each orthogonal planning template, when imposed upon local terrain, manifested in a unique urban form. Park City's town plan reflects the most severe degree of topographic constriction of the three study towns: its original plat measured less than 500 feet (152.4 m) across a sloped canyon floor and could only accommodate four paralleling streets near the canyon head; blocks are elongated, measuring 425–450 feet (129.5–137.1 m) in length and approximately 100 feet (30.48 m) in depth Figure 4a,b.



(**a**) (**b**)

Figure 4. (**a**) Early plat of Park City. Street and block system conforms to canyon floor (courtesy of Summit County). (**b**) Aerial view of Park City showing mining era townscape and contemporary sprawl (courtesy of Robert Bruce).

Wallace's townscape within an ascending river valley was shaped by moderately restrictive geographic conditions. Its well-proportioned rectangular city blocks proved capable of fostering positive growth and expansion throughout the mining era. Telluride's setting within a generously proportioned box canyon measuring 1.6-km in width accommodated a founding plat comprising equally sided blocks subdivided into narrow, regularly sized residential and commercial plots.

Railroad company planning influence on mining town expansion during the late-19th century is exhibited in all three settings. Telluride's 1891 addition to the founding plat provides the clearest example. In lieu of the original plan's equally sided blocks, planners for the Rio Grande Southern (RGS) railroad company platted rectangular blocks that are elongated in a two-to-one ratio in the direction of rail travel. The advent of rail service fuelled growth in remote mining communities such as Telluride, generating a need for developable plots. The rectangular block configuration accommodated more efficient land subdivision with less land allocated for cross streets. Blocks of the expanded town plan are subdivided into equal 25-ft × 100-ft plots (7.6 × 30.5 m), with an exclusively north–south orientation facing the tracks. The newly configured blocks increased exposure and associated land value for the RGS railroad by maximizing plot frontage along the rail corridor. Furthermore, the subtle shift in block form and plot orientation reflects the railroad corridor's significance as a new fixation line for community development. Railroad additions to town plans characteristically remained compact, enabling walkable access to the railroad depot and to the town centre from residential neighbourhoods (Figures 5 and 6).

Figure 5. Plat sequence of Telluride. Mining era's original 1878 plat, 1891 railroad addition, 1898 East Telluride addition and discontinuous contemporary development.

Figure 6. Town view of Telluride. Mining-era heritage patterns, including streets, blocks, plots and building orientation retain legibility.

In addition to blocks, mining town plans are primarily defined by their street networks, plot configurations and land uses. The town plan's spatial character and scale is further defined by street cross-sections, siting of buildings in relation to street frontages and plot lines, and the unusually small scale and simplicity of common building types. An expanded discussion of each principal element follows.

Streets and Alleys. During early development stages, each side of a spinal main street was flanked by a street wall of simple wooden gable end and false front commercial buildings. Street dimensions in mining towns reflected their geographic constraints. Typically, corridor widths are narrower than other town typologies in the US Mountain West. Park City's Main Street width is particularly narrow, at 50 feet (15 m). By contrast, Telluride's main street, Colorado Avenue, spans approximately 80 feet (24.5 m). City founders boasted that Colorado Avenue, the city's principal commercial street, was wide enough to enable an ox cart driver to turn his team completely around, considered a luxury in mining towns [7]. Canyon widths also determined whether secondary networks of alleys could be accommodated. Telluride, in particular, features a comprehensive system of linked 25 ft wide (7.5 m) alleys that historically provided access to carriage houses, barns and city services (Figure 7).

Figure 7. Colorado Avenue in downtown Telluride. Colorado Avenue once supported the flow of miners and wagon loads of extracted ore. Today, the street connects recreationalists to surrounding mountains.

Plot Patterns. In general, surface land subdivision and ownership patterns in mining towns are independent of underlying mining claim ownership. Although land surveyors sought to standardize plot size, surface plot patterns vary according to limitations imposed by natural conditions. Irregularly shaped blocks in Park City are subdivided into single plot depths at the point where the canyon narrows. Rectangular blocks and plots in Wallace are sandwiched between the Coeur d'Alene River and mine entries at the face of steep mountainous terrain. Telluride's geographic setting could better accommodate land subdivision into regularly sized plots in both commercial and residential neighbourhoods. Wherever possible, buildings in all three towns are consistently sited in relation to plot lines and street frontages serving to reinforce the legibility of plot's boundaries (Figures 8 and 9).

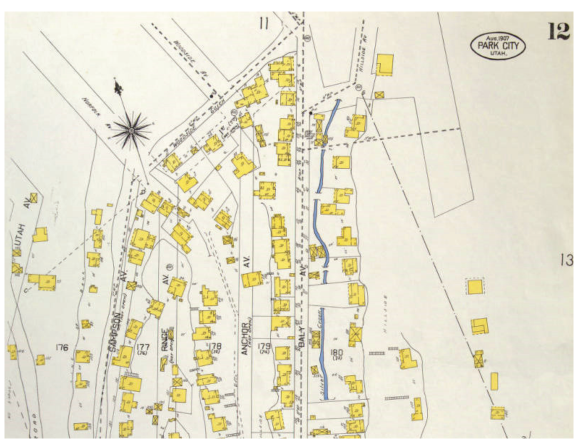


Figure 8. Early residential area in Park City. Sanborn map showing irregular plot boundaries and miner's cabins above the canyon floor. (Library of Congress digital collection).

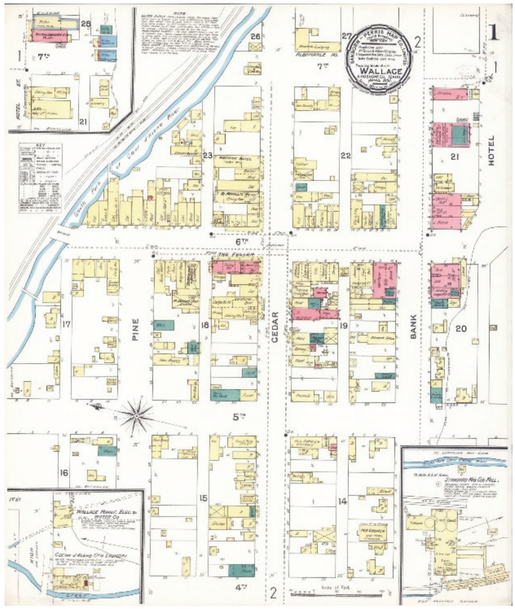


Figure 9. 1898 Sanborn map of Wallace. Wallace's blocks were rectangular and paralleled the course of Coeur d'Alene river and mountainous town edges (Library of Congress digital collection).

Buildings. The first residential and commercial buildings were constructed of wood, a readily available material. Their simple, rustic architectural character reinforced mining towns' perceived images as "rough and rowdy" places. Sanborn maps indicate disproportionate numbers of saloons and "female housing" compared to other building typologies in early commercial centres. Store fronts historically formed a continuous street wall of simple, wooden gable end and false front single-story buildings (Figure 10).

Figure 10. Restored 19th-century wood false front facades along Main Street in "Old Town", Park City.

Early residential neighbourhoods featuring simple wooden shacks developed along paralleling streets or, in cases where the canyon floor was too narrow, aligned steep hillsides above commercial centres. Since developable land was at a premium in mining towns, small-scale buildings served as a defining spatial characteristic throughout the mining era. In the cases of Wallace and Park City, rows of small miners' houses accessed solely by staircases erupted on terrain too steep to accommodate platting of city streets. Residential neighbourhoods that developed during corporate mining years featured simplified vernacular renditions of late-19th century architectural styles. Ideally, as is the case in Telluride, gable ends were aligned parallel to the long axis of plots in a regularly spaced pattern. Maturing streetscapes conveyed a sense of stability and order compared to early settlement years (Figures 11–13).

Figure 11. Early single-room miner's shacks in Telluride were small in scale and randomly placed on plots.

Figure 12. Miner's cottage in Wallace constructed directly above downtown on terrain too steep for street access.

Fire as an agent of change during the mining era had the most significant impact on a community's building typologies and materiality. While the town plan, including the organisation of blocks, streets and plots sustained devastating fires, early wooden false front commercial structures were vulnerable. In 1898, a devastating fire consumed Park City's entire downtown and surrounding residential neighbourhoods. Rebuilding efforts were supported by donations from nearby communities, mining companies, local banks, businesses and railroad companies, which shipped in construction materials free of charge. Fearing the advent of winter, initial rebuilds were hastily constructed of local pine. Several replacement buildings, including hotels, banks and mining company offices were constructed of more substantial materials, including brick and stone. A new opera house celebrated the community's renaissance and efforts to overcome its rowdy reputation [8]. Similarly, in 1890, a fire in Wallace levelled the district's entire inventory of the town's original wooden commercial buildings. A significant portion of the destroyed buildings included saloons and female boarding houses, as shown on Sanborn maps. By 1890, Wallace had become the banking and political centre of the Coeur d'Alene Mining District. Rebuilding efforts provided opportunities for stakeholders to reshape the community's decadent image and to project a sense of permanence and prosperity associated with a rising class of corporate mine workers and managers. The introduction of rail service in 1890 supported their efforts to upgrade the local building stock by affording access to urban suppliers of fire-resistant materials. Urban architects were commissioned to design iconic new union halls and civic buildings. Former single-story wooden false-front commercial buildings were replaced with more substantial 2–4 story brick and cast-iron buildings featuring eclectic versions of popular turn-of-the-century architectural styles and detailing. The newly rebuilt commercial core miraculously survived the "Big Burn of 1910", which consumed over 3 million acres of national forest land and multiple towns in a tri-state region of the North American West in a matter of 36 h. A majority of Wallace's commercial centre, as reconstructed in 1890, persists today. Business owners continued to expand the commercial core with infill buildings representing simplified renditions of popular styles, including Art Deco and Art Modern, until the 1950s, when mining activities began to decline [9] (Figure 14).

Figure 13. Corporate mining-era housing in Telluride. Miner's cottages were small in scale, regularly spaced and sited with gable ends facing the street.

Figure 14. Intact mining-era streetscape. Wallace's 1890s downtown survived the "Big Burn" of 1910.

Successful corporate mining operations in all three towns generated a need for a hierarchy of housing types to support a growing population of miners and their families.

During peak mining years, residential neighbourhoods were segregated according to housing types, which included boarding houses for recent immigrants, simple single-story miner's cottages and larger two-story houses for corporate managers, professionals and successful entrepreneurs. Wealthy mining company owners typically lived in the upscale neighbourhoods of major urban centres and accessed their investments via railroad, as needed.

5. Economic Transition

In the US Mountain West, mining populations peaked in the early 20th century. Fluctuations in national silver markets after World War II undermined corporate stability, leading to cycles of high unemployment and gradual out-migration. Cessation of mining operations in Telluride in the 1950s, Park City in the 1970s and Wallace in the 1980s caused local populations to plummet. Telluride and Park City became virtual "ghost towns". In Park City and Telluride, mining-era buildings persisted in a state of preservation by neglect throughout the 1960s and 1970s, while remaining residents, motivated by strong place attachment, pursued strategies for economic revitalisation.

Mountain recreation and mining heritage became central to each community's recovery plan. Building on mining-era heritage of downhill skiing as a necessary means of winter travel, Telluride and Park City recruited developers to construct world class ski areas. Base lift stations were located in repurposed historic neighbourhoods to encourage strong physical and economic linkages between town centres and ski areas. Beginning in the 1980s, ski industries in both communities attracted wealthy outside investment and generated booming real estate markets. Park City hosted the 2002 Winter Olympics, helping to boost its global image as a destination for winter recreation. Both towns have extended their tourist seasons by promoting summertime mountain recreation and staging outdoor music festivals and theatre performances. Most residents with a direct connection to mining heritage have been displaced by high housing costs resulting from booming real estate industries associated with mountain recreation and tourism. Stewardship of historic fabric now depends upon immigrants who are drawn to mining town ambience and planning departments charged with protecting historic fabric [10].

Economic recovery in Wallace has been more modest and dependent upon federal funding for economic realignment and environmental clean-up of widespread pollution resulting from 100 years of mining activities. Towns within the Coeur d'Alene Mining District, including Wallace, were designated as "Superfund" sites by the federal government following mine closures in 1983 rendering them eligible for federal funding to finance environmental clean-up and economic restructuring. Sited along a major federal transcontinental highway, Wallace is located 11 miles (18 km) from Kellogg, ID, another recovering mining town in the Coeur d'Alene Mining District, which received federal funding to upgrade its ski area and construct a gondola base lift in town with easy access to the highway. Given its close proximity to Kellogg and its authentically preserved mining-era context, Wallace's city plan reinforces regional aspirations to become a destination for downhill skiing, outdoor recreation and cultural tourism. Wallace also benefits directly from the conversion of an abandoned Union Pacific and Northern Pacific rail line that was historically used to transport mining ore and passengers to the city of Spokane Washington. The 73-mile (117.5 km) scenic recreational bike trail links Wallace's historic town centre and other mining heritage sites as it follows the shorelines of natural rivers and lakes in the Coeur d'Alene River basin and Lake Coeur d'Alene. The trail bed, itself, represents a creative solution for environmental clean-up by sealing mine waste rock containing heavy metal pollutants and spillage under a bed of thick asphalt and gravel [11].

6. Stewarding Mining-Era Heritage in the Postmining Era

Community capacity to steward mining-era contexts has seen varying degrees of success depending upon policies regulating development. While none of the profiled towns have explicitly adopted a regulatory approach based on urban morphology, design guidelines enacted in Wallace and Telluride reflect a clearer understanding of key mining heritage patterns. A comparative summary of development regulations for each context follows.

The Wallace community successfully averted the complete destruction of its historic core by the federal highway department, which planned to construct a four-lane, high-speed segment of its transcontinental highway directly through downtown. Local preservation advocates, who sustained close ties with mining era culture and place identity, pursued designation of the entire town as a national historic district. Leverage afforded by the National Historic Preservation Act and community solidarity forced the Federal Highway Department to construct an elevated bypass on the district's northern edge, thus sparing mining-era heritage (Figure 15).

Figure 15. Wallace's preservation success story. Local preservation efforts prevented demolition of the entire historic core for a 4-lane federal highway. The elevated highway bypass can be viewed in the distance.

In 1987, the Wallace city council instituted design guidelines for restoration, alteration and new construction within the town's historic districts, which require certification by the historic preservation commission for project appropriateness. The guidelines, which primarily regulate architectural design, focus on reinforcing key elements of mining-era scale and form by limiting building height, size and massing of new construction to within 10 percent of existing buildings. "Site orientation, proportion and directional expression" are also regulated to conform to established mining-era patterns. Given the community's strong commitment to sustaining its mining heritage, Wallace persists as one of the most intact mining-era streetscapes in the Mountain West [12].

Park City is on the verge of losing its mining town identity, entirely, under the pressure of a robust real estate market. "Old Town", Park City's historic commercial centre, was designated as two national historic districts in 1978. Maintaining the city's historic identity is a stated goal in the "General Plans" implemented in 1985 and 1993. Both plans were based on vague interpretations of what "historic image, imagined or real" that the city supported, whether mining, rural ranching or mountain resort. Their inherent ambiguity is captured in the 1993 General Plan's introduction, which states "the features of community character are difficult to define with precision" [13]. Park City's "2014 General Plan" exhibits citizen appreciation for mining heritage and a renewed commitment to promoting a "cultural sense of place" [14]. Although individual buildings along several blocks of "Old Town's" main commercial street have been artfully restored, upscale resort development continues to transform mining-era streetscapes. While aspirational, the plan lacks adequate language to identify signature elements of mining heritage planning patterns and scale to help guide development. For example, Park City's Main Street, sited in a sloped canyon base, was historically framed by descending street walls and rooflines of two-story buildings. Development guidelines recognize this important characteristic of mining-era form; however, recently constructed tourist accommodations offset its legibility with taller buildings (Figure 16).

Figure 16. New infill along Main Street in Park City. Construction of tall infill buildings offsets historic perception of the descending MainStreet.

Mining-era houses along paralleling streets are overwhelmed by ski-related development. In some cases, facades of demolished mining-era cottages have been incorporated into large condominium complexes. New infill buildings dwarf adjacent miner's cottages. Townscape edges, which were historically defined by canyon walls and open hillsides, are losing legibility due to encroachment of new residential neighbourhoods featuring voluminous vacation homes sited on large plots along cul-de-sac streets. The intimate scale and clarity of mining-era heritage patterns is overwhelmed and obscured by suburban style form (Figure 17).

Figure 17. Park City townscape. Sprawling, suburban style development obscures former mining town edges.

Telluride, which also boasts a robust real estate market, has been more successful at preserving heritage patterns. In 1963, Telluride was granted national landmark status, which offers the highest level of federal recognition for historic places. Landmark designation paved the way to implement more comprehensive guidelines and standards to regulate development. The community's ability to preserve the clarity of mining-era form is enhanced, because development guidelines acknowledge the critical role that historic planning patterns play in defining place identity. They seek to protect the legibility of key elements of the town's plan, including the grid configuration of streets, blocks and alleys and building orientation on both plots and blocks.

Telluride's guidelines mandate that new infill construction and additions to historic buildings reinforce mining-era scale, a defining spatial characteristic. Additions to mining-era buildings are regulated to minimise volume and visibility from the street. Given the intense real estate development pressure in Telluride, coupled with an American proclivity towards building large second homes in resort areas, the guidelines have been remarkably effective in stewarding mining-era scale by preventing new construction from overwhelming the town's intimate, late-19th century ambience. New infill construction is required to reinforce existing neighbourhood patterns for building placement and orientation. As illustrated in Figure 18, new single- and multifamily infill housing feature prominent, regularly spaced gable ends and recessed connectors, which help to reinforce streetscape patterns. Cross-gable rooflines increase square footage and volume while reducing the impact of larger building footprints.

Figure 18. New housing in Telluride. Design guidelines require perceived conformity to mining-era scale, building orientation and spacing.

Most US cities and towns, including Park City and Wallace, have adopted Euclidian Zoning, a US system for conventional land use regulation that was introduced in 1926. Euclidian Zoning regulates development by dividing a town into districts according to allowable and prohibited land uses. The system has significant limitations as a planning strategy, particularly when used as the primary tool to regulate development in historic places such as 19th-century mining towns where a diversity of land uses and building typologies have traditionally contributed to their place identity. Telluride's design guidelines, as drafted by the planning firm Winter and Company, incorporate concepts to regulate physical form. Historic building typologies serve as the primary basis for determining the scale and massing of allowable development instead of their intended use. Telluride's policies represent an adapted version of a form-based code, a planning approach first developed by the architectural firm Duany/Plater-Zyberk. Form-based codes use a regulating plan to prescribe the massing and scale of buildings, their relationships to one another and to the public street. In the case of Telluride, a regulating master plan divides the town into "treatment areas", each representing neighbourhoods with distinct mining-era spatial characteristics and building typologies. Each treatment area is assigned allowable uses that are compatible with the predominant urban form. Guidelines for each treatment area are tailored to protect defining historic patterns and require new infill development to reinforce them [15,16]. The guidelines in some treatment areas have proven effective in addressing transformative pressures exerted by the downhill ski industry and tourism and less effective in others. The "warehouse treatment area" historically featured a mix of warehouses associated with the railroad, industrial buildings, miner's cribs and boarding houses. Given the warehouse district's diverse heritage of building typologies in both form and scale, regulating guidelines afford flexibility to accommodate a variety of infill development uses and building types. Larger footprint multifamily condominiums and hotels in the form of "warehouses for tourists", modelled after industrial and boarding house precedents, have been successfully integrated (Figure 19).

Figure 19. New multifamily building in Telluride. Successful integration of larger footprint tourist accommodations and multifamily housing in the "Warehouse Treatment Area".

A breakdown in historic continuity occurs in the "Accommodations Treatment Area", which houses large-scale ski-oriented multifamily developments at the edge of historic residential neighbourhoods. Although guidelines encourage preserving "the ghost of a street grid" in new treatment areas, its legibility is obscured by bands of development, which lack a sense of visual continuity or physical connection to the town's historic street grid when viewed from the canyon walls and base [17] (Figure 20).

Figure 20. "Ghost of a street grid" in Telluride. Guiding policies insufficient to sustain continuity of street and block patterns in new "Accommodations Treatment Area".

Reliance on partial historic precedents such as the "ghost of a street grid" or building typologies to guide planning policy in new development areas has proven to be inadequate to sustain historic continuity in Telluride. To address the reality of incompatible development, M.R.G. Conzen's concept of "plan-units" could be useful for planners and policy makers as a basis for codification. As defined by M.R.G. Conzen, a plan-unit represents any part of a town's plan that is morphologically different from its surroundings as defined by its plan elements, including streets, plots and buildings. Although Conzen's intention as a geographer was to identify existing areas within a town's plan that are morphologically distinct, the concept of plan-units could potentially be applied as a basis for prescribing new urban form. As an organisational strategy for additions to an historic town plan, plan-units can be customized to include specifications for street systems, orientation on plots and connectivity within the overall town plan. Use of planning concepts to shape the ground plan in new development areas of historic places that are based on a deeper, structural understanding of inherited patterns have the potential to yield more complex, complete and compatible additions to the inherited town plan [3,18–20].

7. Conclusions

Mining-era heritage patterns in profiled towns, as well as those in a majority of historic towns in the US Mountain West that have been adapted for recreational economies, remain at risk. Booming real estate markets continue to attract waves of fortune seekers in the form of land speculators and wild cat developers bent on exploiting natural and cultural resources. Community building processes are also supported by citizens, civic leaders and entrepreneurs who take a longer-term view of inherited resources. While a majority of community stakeholders no longer contain a direct link to mining culture, many appreciate mining town ambience and associated strong sense of place identity. Mining town conservation, while well-intentioned, is hampered by policies that fail to address key defining characteristics.

The following investigative questions can support processes for morphological analysis of historic contexts as a first step towards crafting more effective policies:

1. How does natural geography help to shape the townscape?
2. How do changes in archival plat sequences correspond to socioeconomic changes as revealed in local history collections?
3. What fixation lines, both natural and humanly constructed, historically guided town formation and transformation?
4. What are key elements and dimensions of the town plan? Examples include street configurations, blocks and plot patterns.
5. How can new infill development reinforce legibility of heritage patterns at the neighbourhood scale?
6. How can historic building typologies and their spatial relationships serve to inform a form-based approach to planning?
7. How can clarity of inherited urban form, such as city edges, density and connectivity, be preserved in the face of new development?

Applications of urban morphology methods to interpret heritage patterns in mining towns may also be of use to policy makers in other historic places. Use of an historico-geographical approach provides a more holistic view of key contributing elements that define inherited fabric. As a basis to guide regulating policy development and revitalization processes, urban morphology methods can enhance community capacity to sustain historic continuity by helping to identify signature heritage patterns that define "place".

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Article

A Preliminary Study on Industrial Landscape Planning and Spatial Layout in Belgium

Jiazhen Zhang *, Jeremy Cenci and Vincent Becue

Faculty of Architecture and Urban Planning, University of Mons, 7000 Mons, Belgium;
Jeremy.cenci@umons.ac.be (J.C.); Vincent.becue@umons.ac.be (V.B.)
* Correspondence: Jiazhen.zhang@umons.ac.be; Tel.: +32-(0)65-373111

Abstract: As the material carrier of industrial heritage, industrial landscape planning integrates industrial heritage, post-industrial, and industrial tourism landscapes. In this study, we define the concept of industrial landscape planning. As a subsystem of urban planning, we study industrial landscape planning by using the theories and methods of urban planning. As an example, we consider Belgium and identify the main categories of industrial landscape planning as industrial heritage landscape and industrial tourism landscape. We use an ArcGIS spatial analysis tool and kernel density calculations and reveal the characteristics of four clusters of industrial heritage spatial layout in Belgium, which match its located industrial development route. Each cluster has unique regional characteristics that were spontaneously formed according to existing social and natural resources. At the level of urban planning, there is a lack of unified re-creation. Urban planning is relatively separated from the protection of industrial heritage in Belgium.

Keywords: cultural heritage; industrial landscape planning; industrial landscape; urban planning; post-industrial landscape; industrial tourism; industrial heritage; spatial layout; spatial distribution; spatial structure

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1. Introduction

Throughout the history of urban development, a large number of industrial heritages have been left. As an important material carrier in the era of industrial civilization, industrial heritage represents the evolution of human civilization and cultural development. It is an important historical witness of humans entering industrial civilization from agricultural civilization. Industrial heritages are valued throughout the world due to their historical and cultural significance, as well as the knowledge, scientific and technological, economic, and artistic values they possess [1]. Among them, industrial heritage landscape is a special kind of cultural heritage in urban planning [2] as a concept that has been influential in the field of urban planning. With urbanism, the landscape of industrial heritage, which carries the industrial memory, is gradually disappearing and being destroyed. However, there are limited studies that have focused on industrial heritage landscape, especially its intrinsically logical relationship with the specific meaning of industrial landscape planning. To date, studies on industrial heritage in urban planning and cultural heritage have mainly focused on architecture [3], tourism management [4], sociology [5], cultural heritage [6], and other specific cases of transformation analysis and application [7–9]. Most studies on industrial heritage landscape have individually aimed at investigating regeneration [10], design [11], strategy [12], analysis [13], and other relevant fields [14,15]. Studies on industrial heritage in the field of urban planning and cultural heritage protection are relatively rich, and the scope of research is also deepening, however, there are no studies on the concept of industrial landscape planning. Additionally, there is a lack of specific application of the concept of industrial landscape planning in urban planning, and therefore, this needs to be further explored.

Before mid-19th century, the industrial revolution began in Britain, followed by Belgium as a traditional industrial country in Europe [16]. The industrial revolution promoted Belgian cities into the era of the modern industrial period. Along with an industrial upgrade, the development of industries in Belgium flourished, making Belgium the most developed industrial country, with abundant industrial category structures, a huge market, and a large number of industrial facilities distributed on the European continent [17]. In addition, the industrial revolution promoted expansion of Belgian cities and brought about reforms in urban morphology and scale. After an extraordinary expansion in industrial redevelopment and urbanism, extensive industrial heritages now exist in Belgium. These industrial heritages create challenges for urban development and carry the cultural context of a city, which is of great research value. However, limited studies have focused on industrial heritage conservation and renewal in Belgium [18,19], especially from the perspective of industrial landscape planning. As one of the material carriers of industrial heritage in Belgium, it is of great practical significance to strengthen the study of industrial landscape planning and to therefore strengthen the protection of the industrial heritage. In view of this, and based on the theory of industrial landscape planning, in this study we use quantitative geography and ArcGIS spatial analysis technology to analyze the spatial geography of the Belgian industrial heritage projects in the list of the European Route of Industrial Heritage, from the perspective of landscape architecture to reveal the distribution characteristics of its industrial landscape and types of industrial heritage manifestations, and then to describe in detail the formation background to provide a relevant reference for the protection and reuse of Belgium's industrial heritage.

2. Research Aim

In this study, first, we review the literature and analyze the topic of industrial landscape. Then, we describe the formation of industrial landscape planning; the internal and external connections between urban planning; and the range of industrial landscape planning in industrial heritage, post-industrial, and industrial tourism landscapes. We conduct a vertical and horizontal analysis of the relationships among the three. After this, we analyze and evaluate our findings in industrial landscape planning in Belgium.

3. Industrial Landscape Planning

Industrial landscape planning is included in the concept of landscape; therefore, in this study, we discuss it under this premise. Before the beginning of the industrial revolution, landscape was mainly regarded as an aesthetic object, which was the research object of landscape poetry, landscape painting, and landscape architecture, etc. [20,21]. After the beginning of the industrial revolution, with a significant increase in social material wealth, a unique cultural temperament, namely industrial culture, was formed. Under this premise, urban landscape that represents industrial culture became an industrial landscape [22,23]. The industrial landscape as a human activity traces the material bearing of the architectural heritage, this study mainly involves the semantic of landscape architecture contained in the term landscape.

The term planning refers to the development vision of integrating multiple elements in a specific field. The elements of the industrial landscape do not exist in isolation. The combination of these two terms constitutes the industrial landscape planning, which shows that from the perspective of time scale, it focuses on the long-term, from the perspective of content, it focuses on the strategic level, and the guidance of principle.

3.1. The Features of Industrial Landscape

Industrial landscape refers to the external environment of an industrial plant including a single building, which has more advantages than the indoor space of industrial buildings, such as broad vision, sufficient light, fresh air, as well as a continuous and changing natural landscape. The external spaces of industrial buildings can be regarded as second spaces for production and life, which are interdependent with the internal spaces and complementary to each other [24]. With the advent of the post-industrial era, the ecological concept of urban construction has been strengthened. The design of industrial landscape has remained at the enterprise plant beautification, environmental greening level, but it has also gradually become a type of landscape [25]. The quality of an industrial landscape environment is an aesthetic problem and is also related to the cultivation of sentiment, improvement of health, improvement of efficiency, improvement of product quality, and measurement of scientific management level [26]. In view of the destructiveness of industrial activities to nature, designers and researchers of industrial landscape reasonably plan and use landscape ecological design principles to design according to the production process of sustainable development and industrial building standards and to therefore reduce industrial production destruction of nature. This requires more in-depth design and research in industrial landscape in order to create a better urban living environment.

3.2. The Categories of Industrial Landscape Planning

3.2.1. Industrial Heritage Landscape

Initially, when landscape first appeared in the field of industrial heritage, it was a technical word [27], and industrial heritage landscape was understood to be the spatial practice activities related to industrial production as well as its process and results [28]. Similar to cultural landscape, an industrial heritage landscape reflects the relationships among industrial production facilities, such as machines, architecture, and nature. This triangular relationship that industrial heritage landscape has with industrial culture and civilization includes industrial production information and facilities and the entire industrial memory [29]. In this study, it mainly refers to the new functions, contents, and meanings that designers give to industrial cultural relics with historical, technical, socially significant, architectural, or scientific research value, and the characteristics of the transformed landscape are closely related to the times and social development [30].

3.2.2. Post-Industrial Landscape

Following the development of an industry, a post-industrial landscape appears when old industrial facilities are transformed or upgraded [31]. In this study, a post-industrial landscape generally refers to the a new landscape that is designed and constructed as the main elements of the landscape after the industrial production activities stop, and all kinds of industrial facilities, surface traces, and waste left on the industrial wasteland are retained, renewed, or artistically processed [32]. These industrial facilities cover all kinds of facilities related to industrial production, mainly including production facilities; storage facilities; transportation facilities; and other infrastructure, management, and public service facilities, including all kinds of workshops, warehouses, power transformation and distribution stations, boiler rooms, etc. [33].

3.2.3. Industrial Tourism Landscape

Industrial tourism landscape mainly refers to tourism facilities landscape with industrial facilities as the material carrier. At the end of the 19th century, American industrial enterprises took factory visits to appreciate the charm of modern industrial production as a means of publicity and it gradually became the rudiment of industrial tourism [34].

In the middle of the 20th century, with European countries stepping into the post-industrial era, industrial tourism, as a kind of "nostalgic landscape", transformed many industrial heritages of "rust belt" into Renaissance assets with tourism value [35,36], which has become an important way for European industrial cities to realize economic transformation and an urban renaissance. At the end of the 20th century, with increased interest in sustainable development, industrial tourism has been interpreted as a new green ecotourism [37].

In these industrial enterprises, industrial facilities have become landscapes and progressively evolved into tourism products, factories have begun to have dual economic benefits as secondary and tertiary industries and have therefore optimized the industrial structure of the city. In this study, the industrial tourism landscape mainly refers to the market demand for industrial resources to attract industrial resources into tourism landscape resources and the development of comprehensive tourism landscape products, most of which involves modern planning and design for the construction of new industrial facilities [35,37,38].

3.3. The System of Industrial Landscape Planning

Industrial landscape planning is a new concept, and currently, in academia, there is no clear consensus on its definition. In this study, based on a review and analysis of the relevant literature, we defined industrial landscape planning as a system that includes industrial heritage, post-industrial, and industrial tourism landscapes (Table 1) [39,40], which are elements that are not isolated from each other. For industrial landscape planning to function effectively, it should have the characteristics of systematicness, integrity, continuity, dynamic stability, versatility, and regionality. Systematic planning and orderly development and construction are necessary in order to achieve the function of industrial landscape planning to the greatest extent, and therefore, the natural landscape of an industrial landscape and social civilization simultaneously integrate the resources and space of a city. They are described as a whole planning system.

Table 1. The internal relationship of the industrial landscape planning.

Item	**Industrial Landscape Planning**		
	Industrial Heritage	**Post-industrial**	**Industrial Tourism**
Cause for emergence	Industrial production	Urban regeneration	Economic transition
Character	Conserve the appearance of the building, renew the internal	Conserve the essence part, rebuild the rest in the modern landscape	New cases are the main ones and renewal is the second
Core	Memory retention	Landscape priority	Market orientation
Foothold	Museums, exhibitions, art galleries, memorials, etc.	Children's Park, creative park, office building, Science Park, etc.	Factory visit, enterprise introduction, production process science popularization, etc.
State	Stopped production	No production function	Maintain production

3.4. The Relationship between Industrial Landscape Planning and Urban Planning

The methods and disciplines in urban planning are continuously changing. Beginning with the industrial revolution, urban industrial structures have been considered to be important elements in urban spatial structure planning. Following the disordered development of industries, natural and urban environments were rapidly damaged. Society has gradually realized the importance of eco-friendly space and landscape [41], and therefore, sustainable development in urban planning has become a trend. Sustainable development aims to reuse urban areas and to more effectively use building sites [42]. Industrial landscape planning is a form of sustainable development that has a set of overlapping goals, for instance, energy consumption, pollution reduction, protection of natural areas, etc. From environmental protection to the cross-disciplinary aspects of sustainable development, in the mainstream, each element in urban planning does not exist in isolation, including industrial landscape planning (Figure 1) [18,43,44]. Industrial heritage protection is related to urban context, and its development focuses on urban function and space. By studying the industrial landscape in overall urban planning and discussing protection and development from the perspective of industrial landscape planning, it is possible to achieve a sustainable industrial landscape and urban industrial context resources can be formed. To protect industrial heritage, we need to consider industrial landscape planning in the context of urban planning, and at the same time, urban planning must be taken into consideration; the two complement and can benefit each other. They need to function together systematically with integrity and continuity. Architects practicing industrial landscape planning should consider urban planning and vice versa. The two should be integrated through planning for orderly construction to create an industrial landscape in natural and human landscapes with organic unity.

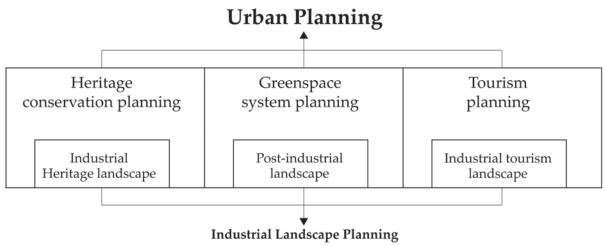

Figure 1. The internal logical relationship between industrial landscape planning and urban planning.

3.5. Exploring the Path of Industrial Landscape Planning

The purpose of industrial landscape planning is to conserve and rejuvenate the culture of industrial heritage; then, the concrete elements of industrial landscape can develop with harmony and sustainability. More specifically, first, existing industrial heritages are conserved. Second, the relationship between abandoned industrial facilities and present industrial facilities is coordinated to complete the integration of industrial heritage conservation and modern urban space demand. Third, effective industrial landscape planning with urban spatial planning results in an industrial landscape that inherits the culture of the industry and urban growth development at the same time (Figure 2).

Figure 2. The principle of industrial landscape planning.

The historical context of industrial heritage and its planning and protection is one of the important branches of cultural heritage protection. However, in specific planning, there are contradictions between protection and development. Therefore, a specific path in industrial landscape planning cannot be generalized and predefined but should be classified according to a specific situation. Planners need to evaluate current industrial heritage landscapes; to establish a comprehensive evaluation system of the historical, cultural, social, scientific and technological, artistic, aesthetic, location, and tourism values that they possess; and to therefore determine the value level of these industrial heritage landscapes. By combining spatial layout and the functional aspect of industrial landscape planning, an industrial heritage landscape with a higher value level can be protected and reused, whereas one with a lower value level can be appropriately transformed or demolished to provide spare construction land for a city.

4. Spatial Analysis for Industrial Landscape Planning in Belgium

The purpose of industrial landscape planning is to protect and revive the landscape culture of urban parks, so that the elements of industrial landscape can coexist harmoniously and develop sustainably in a city. The principles of industrial landscape planning are as follows: (1) to protect the present industrial heritage of a city; (2) to consider the relationships among industrial heritage, post-industrial, and industrial tourism landscapes; (3) and to complete the integration of industrial heritage protection and modern urban planning needs. Implementing industrial landscape planning with urban space planning involves continuous development of the industrial landscape, revitalized in the context of an urban park and, at the same time, carried out reasonably and orderly with the development and construction of a city.

Surveying and analyzing the details of an industrial landscape is the foundation for further studies on industrial landscape planning. Specific guidance for illustrating the layout of industrial landscape planning could include the following:

1. Surveys that follow relevant surveying methods, such as field exploration, basic data collection, and analysis.
2. An analysis that includes the development path of an industry, the variety of elements of an industrial landscape, etc.
3. According to background material collection, a summary of the features and challenges of the industrial landscape and an illustration in the industrial landscape status atlas.

4.1. Research on the Present Situation of Industrial Landscape Status in Belgium

Starting in 1802, the first industrial revolution process began in Belgium and resulted in an extraordinary growth of industry in Belgium during this period, which followed a fluctuating path of development with periods of acceleration, peak points, slowdowns, and the ending, demonstrating that the law of development is dynamic [45]. This feature has determined that the industrial abandoned sites in Belgium are separated broadly with a variety of conditions and categories. With the economic transformation and the prevalence of the concept of sustainable development, because of society's limited knowledge about the value of industrial heritage, a large number of industrial facilities have disappeared completely in the process of relocation and industrial upgrading [46]. Therefore, in Belgium, only a few sites remain and have been conserved and renewed properly based on the sites of the European Route of Industrial Heritage. In this study, we conducted a statistical analysis and classified the existing industrial heritages in Belgium for industrial landscape planning.

The survey results show that heavy industry holds the main position in the current situation of industrial landscape planning, which matches the industrial history in Belgium. Heavy industrial heritage facilities have been featured in the occupation of huge territories, closed spatial structures, etc. They are an independent functional part of a city zone, comparatively. After the sustainable concept was raised, these sites have become one of the main targets that should be improved and regenerated in cities [47]. According to the survey results, a limited number of heritages belonged to the range of the post-industrial landscape. Instead, most of the sites belonged to the modern industrial tourism landscape, and they were all built from industrial heritages. With the help of Google geographic coordinate picker and Google Earth, the industrial heritage of Belgium was calibrated, and we established a spatial database of Belgian's industrial heritage landscape. Combined with the relevant theory of industrial landscape planning, the spatial distribution map of industrial heritage in Belgium was generated (Figure 3). In this map, the site distribution of Wallonia is more than that of Flanders and that of Brussels (Table 2). The industrial heritage landscape is mainly distributed in Wallonia, which is also more than that in Flanders.

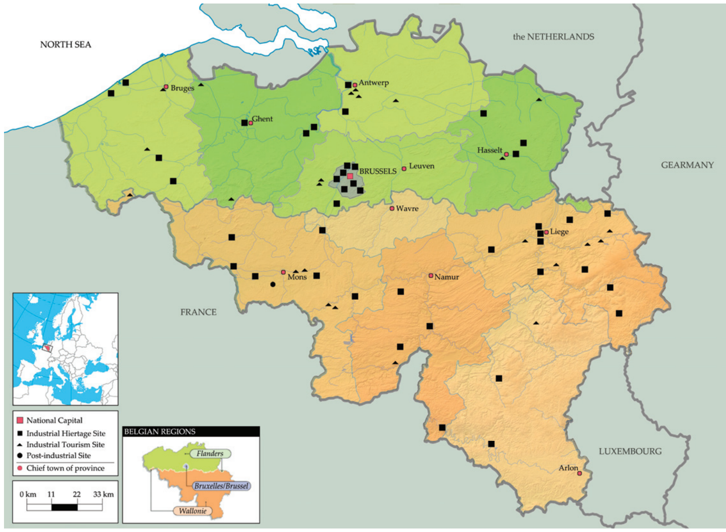

Figure 3. The industrial landscape distribution map of Belgium.

Table 2. The industrial landscape distribution in each region in Belgium.

Region	Number in Total	Industrial Heritage	Post-Industrial	Industrial Tourism
Flanders	24	13	-	11
Wallonia	35	21	1	12
Brussels	7	7	-	-
Total	66	41	1	23

4.2. Functional Planning of Industrial Landscape Planning in Belgium

Functional planning is a method of function transfer and industrial upgrade for industrial landscape [48]. It mainly focuses on the elements of industrial heritage in the categories, existing status, land territory, location, community status, etc. Specific industrial heritage landscape functional planning needs to be based on its actual situation, in line with the requirements of an urban master plan, green space system planning, and other upper planning [49,50]. The main paths are as follows:

- For the industrial heritage landscape, industrial heritages with large land occupation, abundant existing relics, and superior natural and community resources have a high class of possibility for transferring function. In this situation, a synthetic construction model is adopted, combining industrial heritage conservation and territory spatial planning.
- For the industrial tourism landscape, if the existing remains of the industrial heritage landscape resources are abundant and running well, the main types of remains are industrial buildings or facilities, which can transform their functions into indoor architectural landscapes such as cultural exhibitions and museums, tourism activities and production are running together harmoniously.
- For the post-industrial heritage landscape, industrial heritages of municipal public facilities such as stations, with special commemorative significance and quarries, which are mainly open-air industrial equipment heritages, can be transformed into parks and squares with a post-industrial landscape architecture form.

4.3. Case Studies of Industrial Landscape Planning in Belgium

In order to combine the principle of industrial landscape planning with the case study, this study selected three representative cases to verify the theoretical research according to the existing Belgian industrial landscape sites, aiming at the different characteristics of industrial heritage landscape, industrial tourism landscape, and post-industrial landscape and applies the results of theoretical research to provide guidance for the case study.

- The representative case of industrial heritage landscape is the Blegny-Mine museum in Liege (Figure 4) [51]. That is one of the four major mining sites of Wallonia recognized as UNESCO world heritage was transformed by the former Argenteau-Trembleur [52]. The feature of its industrial heritage landscape is this setting lies in the conversion into a leisure center and the preservation of the two pits from different periods, and one gives access for the visitors to the underground galleries on the levels −30 to −60 m [53]. These industrial heritage landscape facilities give visitors a special immersive experience.
- The representative case of industrial tourism landscape is the Tramway Lobbes in Thuin (Figure 5) [54]. That is a rural railway discovery center, with a locomotive exhibition and light railway system that served rural Belgium from the late 19 century. The rural railway system is still running not only for tourism but also for commuting, and tourists can take its tramcars through the picturesque wooded countryside, passing the notable church, gardens, and a belfry at Thuin [55].
- The representative case of industrial heritage landscape is the "PASS" Science Adventure Park in Mons (Figure 6). That is a modern science adventure park transformed by a colliery complex. Inside the park, all the industrial facilities were redesigned and renewed, the internal facilities were transformed into a science theme gallery for education, and external facilities were transformed into a landscape architecture park for leisure. Permanent and temporary exhibitions on scientific and artistic themes are located in ultra-modern buildings and grass plots, and special events are held on the site throughout the year. Compared with the Blegny-Mine, the post-industrial landscape of 'PASS' pays more attention to the creation of landscape architecture parks and theme parks for the purpose of leisure. The original industrial legacies are mainly material carriers for modern design, not for retaining.

Figure 4. The former mine passage is now an experienced facility in Blegny-Mine.

Figure 5. A railway system still in use for commuting and tourism in Thuin.

Figure 6. Open-air children's play facilities in 'PASS' Science Adventure Park.

4.4. Spatial Layout of the Industrial Landscape Planning in Belgium

An in-depth analysis of the spatial distribution characteristics and overall pattern of Belgium's industrial landscape provides a comprehensive understanding of the survival status of Belgium's industrial heritage and provides some reference for the protection and utilization of industrial heritage. In order to find out the mutual laws of industrial heritage in Belgium, this study obtained the spatial distribution characteristics of the industrial landscape in Belgium with the help of kernel density operation model in ArcGIS software (Geographic Information System Company, Environmental Systems Research Institute, West Redlands, CA, USA) (Figure 7).

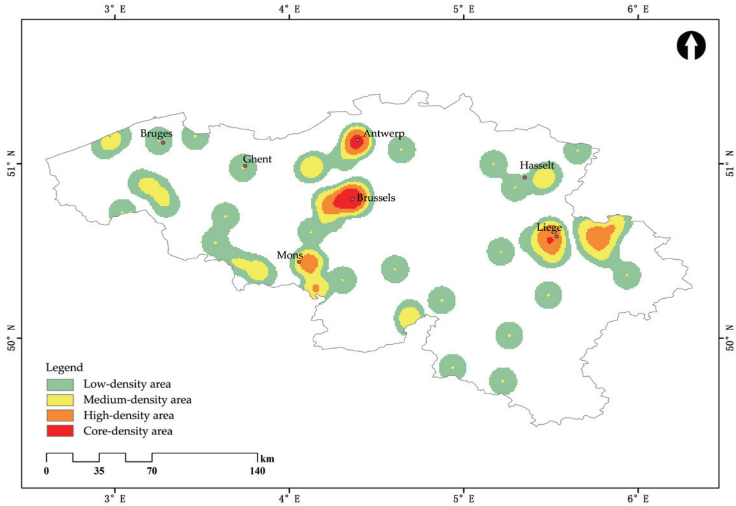

Figure 7. Spatial layout of industrial landscape in Belgium.

The spatial layout of industrial landscape planning should conform to the main direction of urban spatial development as well as the regional industrial spatial layout and should be considered in coordination with tourism planning and urban green space planning [56]. On the basis of the characteristics of the current industrial landscape distribution in Belgium, the spatial structure planning theory is applied to promote the development of surrounding areas and the overall upgrading of industrial communities [57].

Belgium is located in the northwest of the European continent; it is a country with abundant mountain and river resources. Due to its abundance of natural resources, it has an excellent natural environment for a heavy industry foundation [58]. When the first modern factory was constructed in Searing, the industry in Belgian expanded rapidly, especially, machinery in Liege, coal in Mons, textiles in Ghent, the port in Antwerp, and service in Brussels. With the introduction of the machine textile industry, the industry started to develop in the Flanders region; then, due to the development of the mining industry, the industrial center began to shift towards the Wallonia region. Finally, with the rise in manufacturing and processing manufacturing industries, the focus of development began to return to the Flanders region. The regional characteristics of industrial heritage are very obvious. Overall, industrial heritage appears in clusters in Belgium [59] and is consistent with the spatial layout of industrial landscape in Belgium.

However, due to the lack of unified planning, these industrial landscape resources are not effectively integrated together. As a result, Belgium, which has excellent industrial culture, has not formed such a famous cultural card as the Ruhr district in Germany.

5. Discussion

Industrial heritage, industrial tourism, and post-industrial landscape constitute the theoretical framework of industrial landscape planning, based on theoretical exploration. The three categories of the industrial landscape are different forms of industrial heritage protection. They are in the same time and space sequence, but the forms of transformation and reuse are different. Combined with case studies, this study finds that the distribution of the industrial landscape in Belgium is extremely unbalanced, which limits the brand building of the industrial culture. The existing resources are mainly belonging to the industrial heritage and industrial tourism landscape, and the post-industrial landscape is extremely scarce, which also reflects the lack of vitality of current urban construction in Belgium to a certain extent. From the perspective of industrial landscape planning, we propose three points of guidance for its application:

- The post-industrial landscape projects can be added to the core area of the city, which not only increases the open-air space for the city but also provides citizens with modern public parks for leisure. It retained the industrial culture, also in line with the concept of sustainable development of green development.
- The development of industrial heritage landscape projects in the suburbs can protect and utilize the abandoned industrial heritage, meanwhile stimulates the economic vitality of the surrounding communities with lower costs but gain higher benefits.
- The industrial tourism landscape projects in the outer suburbs can bring tourists an industrial tourism experience, while also minimize the negative impact of industrial production on urban life.

In terms of specific projects, Belgium is the country with the densest railway lines in Europe, and its railway system can be a significant advantage of its industrial culture. Unfortunately, this advantage has not been fully utilized at present. Although Belgium has a large number of industrial landscape resources, but its spatial distribution is relatively scattered. In future regional planning, we can take the landscape resources of the location into consideration, combine with various regions and various types of industrial landscape resources, balance the allocation of resources from the regional planning level, and create a cultural card of industrial landscape belonging to Belgium through comprehensive protection.

6. Conclusions

Industrial landscape planning plays an important role in urban planning and heritage protection, but there is no general and comprehensive understanding of it. In this study, we defined the concept of industrial landscape planning, discussed its internal and external relations with urban planning, and explored its application. We analyzed industrial landscape planning from macroscopic, systematic, and comprehensive aspects to identify industrial heritage, post-industrial heritage, or industrial tourism landscapes. The core issue was to deal with the protection and development. The different stages of development and different forms of presentation are interrelated and interdependent.

In this study, we considered Belgium as an example and provided an overview of its industrial landscape planning and spatial distribution characteristics, then did case studies with theoretical principles. Industrial landscape planning in Belgium is highly matched with its industrial development route. Most of the landscape projects of industrial heritage, post-industrial heritage, and industrial tourism were built on its located industrial resources. The scatter plots show strong regional aggregation and spatial distribution characteristics of four clusters. The main industrial heritages of each region are consistent with Belgium’s historical course; meanwhile, all of the natural and cultural resources are reflected in Belgium’s regional characteristics. However, the scatter plots also highlight the lack of a unified layout at the urban planning level for the protection of the industrial landscape in Belgium. Each cluster and each landscape type are relatively independent. It is necessary to take industrial landscape as a special type of urban planning from the macro, systematic, and overall perspective. For specific promotions, to enhance the brand of Belgium’s industrial culture and urban renewal and community building, we need to make a unified deployment of Belgium’s industrial landscape projects from the urban planning level, promote the post-industrial landscape projects in the core area of the city, promote the industrial heritage projects in the suburbs, and promote the industrial tourism projects in the outer suburbs, meanwhile focusing on key areas such as railway industry. This study only starts from the current situation of industrial landscape planning and provides a general description of functional planning, spatial structure layout, and context protection planning. Industrial landscape planning still needs more detailed studying and practice.

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heritage

Article

Urban Morphology of Zagreb in the Second Half of the 19th Century—Landmarks Guiding the Reconstruction of the Town and the Preservation of Identity after the 2020 Earthquake

Bojana Bojanić Obad Šćitaroci * and Mladen Obad Šćitaroci

Faculty of Architecture, University of Zagreb, Kačićeva 26, HR-10000 Zagreb, Croatia; scitaroci@gmail.com
* Correspondence: bbojanic@arhitekt.hr

Abstract: The research of the urban morphology of Zagreb in the second half of the 19th century was done with the intention of showing the importance of inherited urban morphology and the importance of urban identity factors at a time when preparations are being made for reconstruction after the 2020 earthquake. The research was performed on the basis of old maps and plans and previous research on urban development. The medieval town of Zagreb began to develop in a planned manner in the second half of the 19th century. The orthogonal street grid in the new town built in the 19th century and called the Lower Town—were the result of urban utopian times and the first written legislation on urban planning (1857), the first development plan (1864/1865), and a second development plan (1887/1889). The concept for the urban design of the Lower Town has three distinct themes: an orthogonal street grid, public parks and squares and public buildings. The series of public spaces, consisting of seven squares and the Botanical Gardens, became a landmark pattern in the urban morphology of Zagreb at the end of the 19th and beginning of the 20th century. This urban pattern, as a lasting value, remains the main landmark for any new architectural and urban interventions in the town historic part.

Keywords: urban history; urban morphology; urban form; urban design of 19th century; system of public squares and city parks; Zagreb; Croatia

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1. Introduction

The study of the urban morphology of Zagreb in the second half of the 19th century was done with the intention of showing the importance of inherited urban morphology and the importance of urban identity factors at a time when preparations are being made for reconstruction after the 2020 earthquake.

Zagreb experienced two major earthquakes—one on 9 November 1880, and the other on 22 March 2020. The consequences of both earthquakes were severe damage to residential and public buildings. The earthquake in the 19th century prompted the first modernization of the city in the way of a large expansion of the city (Lower City) according to the principles of urban ideals of the second half of the 19th century. The earthquake in the 20th century caused great damage to the Lower Town, which has not been thoroughly rebuilt since its inception, so now is the opportunity and obligation to carry out a thorough reconstruction and rehabilitation of the city from the late 19th and early 20th century.

Therefore, the aim of this article is to point out the main identity features of the historical fabric of the city, from which we must start in considering the modern concepts of preservation, restoration, rehabilitation, improvement and modernization. In doing so, the basic features of a historic city belonging to the Central European urban tradition and culture must be preserved. The aim is to point out the landmarks important for the rehabilitation of the historic town of the late 19th and early 20th century, which, after more than a century, needs to be restored and modernized, while preserving important features that make it a cultural asset and urban heritage.

Although it developed in the vicinity of the Roman town Andautonia, Zagreb is a medieval town and is first mentioned in 1093. In 1242 the town was decreed a free and royal free town. Up until the mid-19th century Zagreb was a small town, after which it began to develop rapidly into the capital of Croatia, which was then part of the Austrian (Habsburg) Monarchy. Since the Middle Ages and up until 1850, Zagreb had been developing on two adjacent hills—*Gradec*, which was the civilian city under King's administration, and *Kaptol*, the ecclesiastical and bishopric centre. On the whole, both *Gradec* and *Kaptol* have a planned urban structure and their layout is characteristic of medieval towns [1,2]. In 1850, they were joined into a single town, which provided conditions necessary for the planned development of Zagreb. (Figure 1).

Figure 1. Zagreb environs in the mid-19th century, before 1861. Black—existing town core and further constructed area, dark grey—public and larger private gardens and parks, white—main roads, gray (shaded)—river and streams.

In 1857 Zagreb had 18,000 inhabitants, in 1900 there were 62,000, whilst in 1921 figures rose to 100,000 inhabitants. The railway running from Vienna to Zagreb was built in 1862 and the first larger industries and banks appeared around 1870. Running water and the waterworks appeared in 1878, the first horse-drawn tram appeared in 1891 and electrical trams were introduced in 1910. The Academy of Sciences and Arts was established in 1866, the University was founded in 1874, and a new theatre was opened in 1895. After a major earthquake in 1880, Zagreb began to develop more rapidly and in a planned fashion.

There are four main districts with differing urban structures within the central area of modern-day Zagreb: (1) the medieval urban structure of a twin cities *Gradec* and *Kaptol* with villas and summer residences located on hilly terrain in the north, (2) the urban structure of the Lower Town between the historic core and the main train station, (3) the modern, urban structure which grew up as the town periphery which was transformed while unplanned construction began between the main train station and the River Sava, and (4) the new town—New Zagreb according to urban modernist's principles of the Athens Charter before World War II, as the second modernization of the city.

2. Materials and Methods

The research was conducted for the historical part of Zagreb. There are several legible and stylistic layers of the city, of which the medieval-renaissance layer (up to the 17th century), the baroque layer (17th and 18th century), the historicist layer (19th century) and the protomodern layer (at the beginning of 20th century) are recognizable in the fabric of the city. The basis for the research were old maps (for the periods up to the middle of the 19th century) and urban plans (from the middle of the 19th century onwards) [3]. The research also relies on published works that bring the results of more comprehensive research on the entire historical part of the city and the urban genesis of Zagreb. This method allows us to identify solid points within the tissues of the city, especially public buildings and public outdoor spaces (squares, parks, streets, promenades). We consider these points and spaces of public importance to be strongholds for future plans for the restoration, rehabilitation and revitalization of the town's historic space. Scientifically based research results will be able to be applied in the contemplation of contemporary interventions in the historic city.

The research presented in this article uses previous research on the historical development of Zagreb, which was conducted and published on the basis of systematic archival research. For the older historical periods of Zagreb until the middle of the 19th century, the works of Lelja Dobronić are referenced [1,2,4], and for the period of the second half of the 19th century and the first quarter of the 20th century, the works of Snješka Knežević are referenced [5–7]. Other papers focused on selected topics were also used [8–13].

Theoretical texts on public spaces and urban rehabilitation were used less for research in this paper because the aim of this research was to determine the essential components of the urban fabric and recognizable features of the historical part of Zagreb. It is precisely these character traits of the historic town that become the starting points for models and principles of restoration, but this is another topic that will be developed in the continuation of the research. From the theoretical aspects, two topics were highlighted: (a) urban forms (urban block) since the historical part of Zagreb is a city of blocks and (b) sociological aspect because each city is made up of people and way of life. We can renovate city blocks by respecting the historical structural features, but it is also necessary to modernize them and adapt them to modern needs [14]. City blocks and city fabric have been a constant of the city from ancient times to the present day, so it must be placed in the context of the general development of the city [15,16]. The sociological aspect is much more complex due to demographic changes and lifestyle changes, so this topic is not the subject of this research, although it is important and unavoidable for urban renewal in the context of sustainability of living historic cities [17]. From the point of view of traditional urban civic culture, an important aspect is the ambience and historical urban scenography, which is often referred to especially in public parks and promenades where it was important to be seen and seen by others [18].

To achieve the expected results, it was necessary to consider the context in which Zagreb lived in the first and second half of the 19th century—before the earthquake in 1880, and the context of the second half of the 19th century when begins the great expansion of the city and the first urban modernization.

2.1. Urban Circumstances in the First Half of the 19th Century

The development of Zagreb in the first half of the 19th century was not carried out according to any urban plans, which means there was no controlled urban expansion. Instead, the town developed spontaneously around the main town square located beneath the medieval towns of *Gradec* and *Kaptol* and there was intensified urban development along the access routes to the town. (Figure 2).

Figure 2. Zagreb until the mid-19th century: A—Gradec (the Upper Town), B—Kaptol (the Bishop's Town), C—Donji grad (the Lower Town), D—Harmica (the main town square).

From the end of the 18th century and up until the mid-19th century, public parks and gardens began to be laid out in peripheral areas and outside the borders of the medieval towns of *Gradec* and *Kaptol*. Maksimir Public Park was laid out in Zagreb's east environs by the bishops of Zagreb, from the end of the 18th and up until the mid-19th century [19], while the Bishop's Park was laid out east of *Kaptol* in Vlaška Ulica (at the end of the 18th century), and Ribnjak Park was laid out along the eastern rim of *Kaptol* (1830). Two public promenades appeared along the fortification walls of medieval *Gradec* in the first half of the 19th century—the North Promenade and the South Promenade, and additional large parks were laid out in the vicinity of *Gradec* around villas and summer residences [11]. (Figure 3).

2.2. Urban Circumstances in the Second Half of the 19th Century

In the second half of the 19th century, Zagreb began to develop in a planned manner over the area south of the medieval towns of *Gradec* and *Kaptol*. Today Zagreb includes *Gradec* (the Upper Town) and the area lying to the south of it, known as *Donji grad* (the Lower Town), which developed in the second half of the 19th century. This area was mostly privately owned, so that town authorities acquired the land gradually. A number of civil laws were introduced for its further development as were the first urban town plans, which led to its orthogonal design and "block-like" development (rectangular grid plan)—the first plan of Zagreb was produced in 1864/1865 [8] (Figure 4), and a second plan in 1887/1889 (Figure 5). An additional, supplementary development plan was produced in 1894.

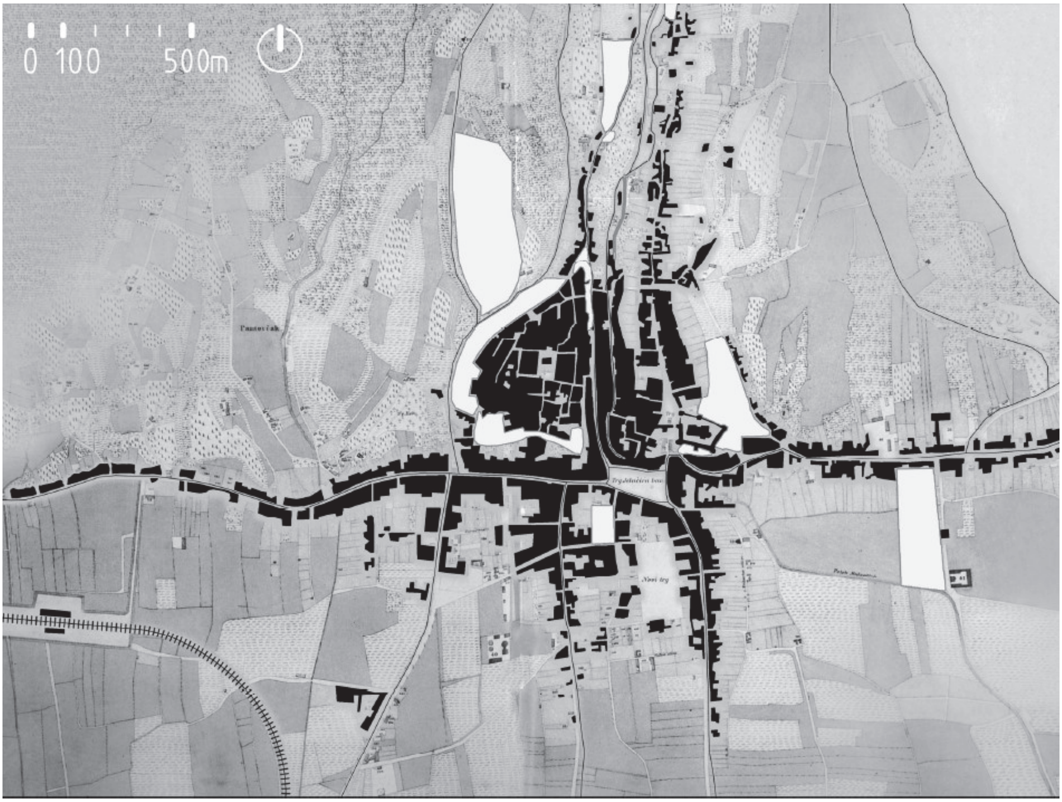

Figure 3. Zagreb urban and landscape context, 1864. Black—existing town and constructed area, white—public and larger private gardens and parks. Ground layer—landscape pattern (woods, fields, meadows, orchards, vineyards, streams).

The regularly shaped ground plan of Zagreb began to appear after legislations on the development of the town were passed in 1857 (Law on the Development of Zagreb). These provisions were the basis for the layout of Zagreb in the second half of the 19th century [6].

The aim of the first urban plan of Zagreb (1864/1865) was to develop and renovate the older parts of the town, and to harmoniously conjoin the newly planned areas with existing structures (Figure 4). The principle incorporated in the first urban plan (1865), which provided for a grid of intersecting streets placed at right angles, continued to be applied in the second urban plan (1889) and this design extended from the town centre and towards the east and west [6], but it also incorporated a slight difference—greater distances were envisioned between the streets (the surface area of the blocks was larger). The second urban plan was completed nine years after the earthquake. That plan was a response to rebuilding the city after the earthquake. A model of building a new city next to the existing historic city was applied. The New Town (Lower Town) took on the characteristics of the then modern Central European urbanism and marked the beginning of the first modernization of Zagreb after eight centuries of continuous existence of the city (Figure 5).

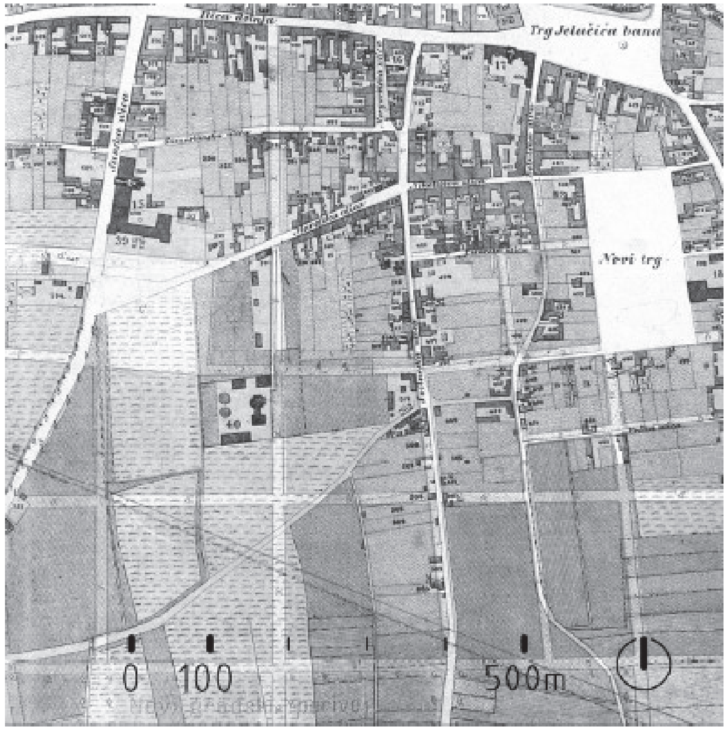

Figure 4. Central part of the Lower Town, cutout from the first urban plan (1865).

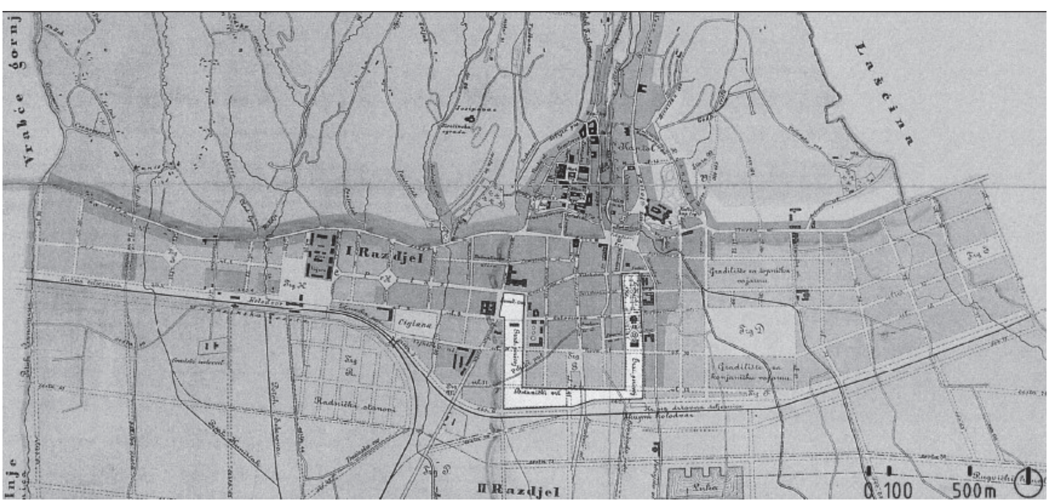

Figure 5. The Lower Town, cutout from the second urban plan (1889) in which the first squares/parks of the Lenuci Horseshoe are included (white).

Apart from the urban development plan from 1889, a new development scheme was established whereby the town was subdivided into three parts/zones with provisions for facilities, amenities and conditions for their development. In 1894 additional provisions for the centre ordained that building should have at least two storeys and be uniform in height; in addition, the height of buildings in relation to the width of the streets was defined, as well as the size of courtyards, etc. This well-deliberated urban planning with a clear urban matrix and vision continued to be applied well into the beginning of the 20th century (Figure 5).

2.3. The Framework and Concept of Squares in the Lower Town of Zagreb

The drafting of the second urban plan of Zagreb from 1889 was headed by the key town urban planner, Milan Lenuci. The concept for the urban structure and design of the Lower Town has three distinct themes: an orthogonal street grid, public city parks and squares, as a new element in the urban development of the town in the 19th century, and public buildings (a theatre, the Academy of Sciences and Arts, the Art Pavilion, the Main Train Station, the National Library and University Library, etc.). The U-shaped "Lenuci Horseshoe" is the name given to a series of seven parks (squares) including the Botanical Garden, which are incorporated within the urban block network (Figures 5 and 6). This urban development concept was drawn up in 1882 and designs were legally defined in 1889, although they were later gradually implemented up until the 1920s [6]. This series of parks and squares became a distinctive motif in the urban morphology of Zagreb at the end of the 19th and the beginning of the 20th century [11].

Figure 6. Urban structure of the second urban plan for Zagreb from 1889. Black—existing town core, light grey—planned city blocks, dark grey—public spaces (parks and squares).

After the earthquake in 1880 Milan Lenuci (1849–1924), an urban planner and engineer who studied in Graz (Austria) and was inspired by Viennese and Parisian models, played a crucial role in the construction of the new centre of Zagreb—the Lower Town. Lenuci was not the initial creator of the original concept of the Horseshoe, but was responsible for its urban design and execution [6]. The initial, as yet incompletely defined concept, was conceived before he assumed the role of city urban planner, but it was he who first formulated a planned design, which was included in the second urban plan. His merit lies in the fact that he persevered the planning of the Horseshoe which was completed despite numerous influences and interests that might have prevented its realisation. Whilst most of Lenuci's other ideas and projects for Zagreb were not realised, or at least not entirely, he undoubtedly laid the foundation for the urban development of Zagreb in the 20th century.

3. Results

To answer the question of the urban morphology of the Lower Town in Zagreb, the research is focused on recognizing the basic urban features of each city, especially the historic city, namely: urban grid, urban blocks, squares, streets and building typology.

The appearance of the Lower Town and its morphological characteristics were influenced by two urban plans (1865, 1889) and three successive instances of construction and approved regulations (Order of Constructions from 1857, 1887 and 1894). Despite urban regulations for each instance of construction (from the construction of new streets to the landscaping of open spaces), long and heated debates ensued, resulting in the coordination of differing interests.

3.1. Urban Grid—Map of the Town

The design of the town was based on rational urban principles and urban blocks/ islands built along the edges and the façades of these residential buildings shaped the town streets. Although the original concept was to adhere to the ideal of an orthogonal block system, this proved impossible as there was a need for it to be adapted to existing circumstances, which is why most blocks in Zagreb are irregular in shape and appearance and form unique and individual series, so that each block differs in size and shape. They are rarely square, but rectangular or trapezoidal in shape.

The origin of the orthogonal street network dates to construction regulations from the mid-19th century. Provisions for urban development from 1857 ordained that street be built and traced at a width no less than 13.30 m and that intersections be at right angles and at a distance between 76 and 95 m. These dictates defined the initial urban structure and the construction of blocks. The first urban plan from 1865 (Figure 4) was transposed onto the charted plan and design provisions from 1857.

It was not possible to achieve an ideal network of city blocks and streets as there were a number of limitations, of which the most important were: existing roads (old roads that led from the environs and into the city, which had been in existence since the late Middle Ages, and including more recently constructed roads), existing good quality construction along the main roads, inherited plot divisions (cadastral system), watercourses, privately owned land, the possibility of land acquisition for public needs, and others. Before the first urban plan most of the Lower Town was farmland and rural in character—arable land, pastures, orchards, gardens, vineyards, groves (Figure 3). The terrain sloped slightly to the south and was intersected by larger and smaller streams which flowed from the north and southwards from the mountain *Medvednica* (the *Zagrebačka Gora*) and towards the River *Sava* and the valley beyond. There were also numerous branches of the River Sava, which periodically flooded the adjacent terrain. The new town plan changed this rural-suburban landscape completely.

The realised network of streets, as a compromise between the desired ideal grid and adaptations to numerous constraints, determined the shape and size of city blocks and squares, and also the width and appearance of the streets.

3.2. Urban Blocks

As a result of adaptation to local conditions, almost no two blocks are of the same size and shape. Their ground plan is frequently rectangular and trapezoidal, and rarely square. The smallest town block is 1800 m^2, the largest is 44,700 m^2, and the average block size is around 13,000–15,000 m^2. All the blocks are enclosed and the buildings are placed on the property line along a street line. Exceptions are rare and are to be found along the western stretch of the Horseshoe where the buildings are removed within the interior of the block, allowing for the landscaping of small gardens between the building and street. The street façades are not uniform, neither in character, width, height, nor in design, as buildings were not built at the same time; land plots vary in width and belong to different owners, whilst corner buildings are architecturally highlighted.

The blocks are mostly residential, except for along the edges of the Horseshoe squares where the outer façades of the block include buildings intended for public purposes, such as courts of law, university buildings, churches, and others. The inner courtyards of the blocks were originally landscaped and were utilised mainly as gardens and orchards, either as private or shared space for tenants living in the surrounding buildings. In the first half of the 20th century, in places, the inner courtyard spaces of blocks incorporated residential buildings and crafts workshops and warehouses, and in the second half of the 20th century, kindergartens, schools, playgrounds and garages. The blocks did not have roads and access for vehicles was only possible in the form of passage through the building. (Figure 7).

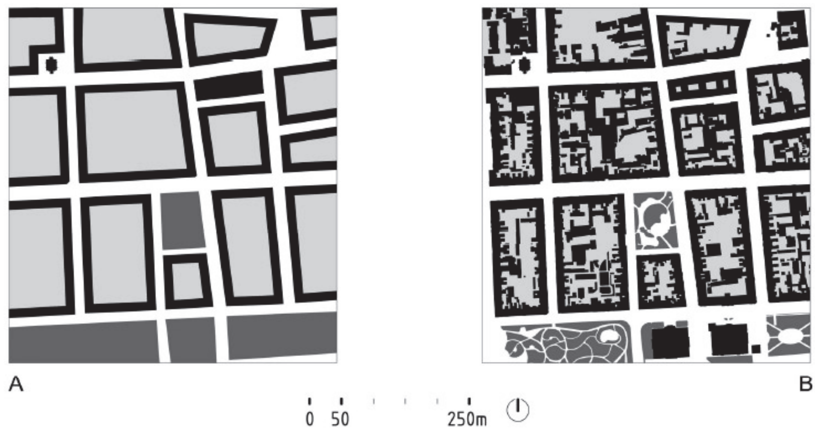

Figure 7. Urban structure of characteristic town blocks within the Lenuci Horseshoe. (**A**)—the envisioned historical city block with gardens and orchards in the 19th century, (**B**)—laid out spaces within the blocks at the beginning of the 21st century.

3.3. Squares

Squares in Lower Town in Zagreb have been historically researched, the genesis, sequence of construction and construction of buildings on the squares are known. Zagreb's squares are well documented in books and articles created as a result of many years of research of the Lower Town and Lenucci's Horseshoe [5–7,11,13,20].

All the squares in the Lower Town are newly planned squares, laid out in the second half of the 19th century (Figure 8). Until then, there was only one square in the Lower Town—*Harmica* (present-day Ban Josip Jelačić Square), located beneath *Gradec* and *Kaptol*, and utilised as early as the Late Middle Ages as a space for trading and for trade fairs. The first square in the Lower Town (New Square, modern-day Nikola Šubić Zrinjski Square), located 100 m south of the medieval square *Harmica*, began to be laid out on the basis of the first urban plan. Its rectangular shape (100 × 220 m) in pursuance of the Order of Construction from 1857 dictated its regularly shaped ground plan. This was the first in a series of squares in the Lower Town and the starting point of the eastern stretch of the Lenuci Horseshoe. The starting point of the western stretch of the Lenuci Horseshoe was University Square (present-day Republic Square), which began to be laid out after the introduction of the second urban development plan [6].

Figure 8. Modern-day urban structure of the system of squares belonging to the Lenuci Horseshoe. Squares: A. Zrinjski Square, B. University Square (today Republic Square), C. Academy Square (today Strossmayer Square), D. King Francis Joseph Square (today King Tomislav Square), E. South Park (today Starčević Square), F. Botanical Garden, G. Western Park (today Mažuranić and Marulić squares), H. Roosevelt Square, I. Svačić Square. Bulidings: 1. Main city square—*Harmica*, today Ban Jelačić Square, 2. The Croatian Academy of Sciences and Arts, 3. The Art Pavilion, 4. The central train station, 5. Hotel Esplanade, 6. The Botanical Garden, 7. The old National University Library (today Archiv), 8. University—faculty buildings, 9. University—Film Academy, 10. The Croatian National Theatre, 11. University—main building, 12. The Mimara Museum.

The Lenuci Horseshoe includes seven squares and the Botanical Garden. At the beginning of the 20th century two smaller squares (present-day Svačić Square and Roosevelt Square) were laid out. All these squares were laid out without any inherent urban tradition. Two of the squares (Zrinjski Square and University Square) were laid out at the site of cattle fairs, which means that the tradition of spaces where people gathered was continued. The remaining squares were laid out on the basis of the second urban development plan. All the ground plans are regularly rectangular in shape; none are of the same surface area and each is adapted in shape to conditions dictated by the micro-space in which it is located. Their surface areas range from 2.25 to 2.98 acres. Three of the Horseshoe squares, as well as two of the smaller lateral squares, are landscaped parks, whilst four of the Horseshoe squares are architectural squares with public buildings [6].

The squares of the Lower Town are preceded by squares from earlier periods, followed by numerous new squares created during the first half of the 20th century [21]. The system of squares as public town parks offers the town open spaces for leisure, entertainment, relaxation and free-time activities, a form of daily life outdoors (Figure 8). These spaces do not tend towards being pretentious, over-representative, theatrical or full of symbolism; on the contrary, each square represents space made to the measure of man in the spirit of Late Romanticism, Historicism and Art Nouveau. The transformation of Vienna and the design of the Ringstrasse in the second half of the 19th century was the inspiration for the Lower Town Squares project [18].

3.4. Streets

The network of streets is laid out based on the directions of the compass: running in a north-south and east-west direction, with minor deviations in view of existing roads and paths. According to their position/alignment two types may be observed: those roads that existed previously and newly planned town streets. Within the area of the Lower Town several access roads leading to *Gradec* and *Kaptol* existed even during medieval times: *Ilica* Street and *Vlaška* Street (accessed from the west and east) and *Savska* Street and *Petrinjska* Street (accessed from the south). These formerly planned roads in the Lower Town became important traffic thoroughfares. Of the three tree-lined streets (laid out running in an east-west direction) the most important is the urban avenue that connected the first railway station (in 1862; now *Zapadni kolodvor*, West Railway Station) and the city centre. University Square arose at the conjunction of the connection point of this avenue (now Gjuro Deželić Street) and the centre of the Lower Town, which is also the starting point of the western stretch of the Horseshoe. Street widths range from 10 to 22 metres. Tree-lined streets are the widest (around 22 m), and the rest are predominantly around 12 to 15 m. (Figure 9).

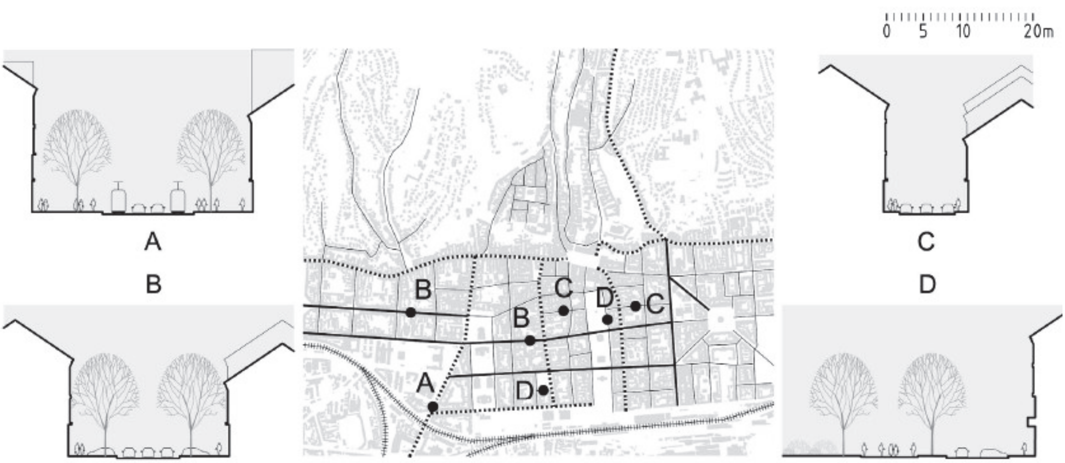

Figure 9. Characteristic types of streets in the Lower Town: dashed line—roads (once access roads into the town), bold line—avenues, thin line—other streets. A, B, C and D—characteristic cross-sections of streets. A—tree-lined streets with tram, B—tree-lined streets, C—streets without trees, D—street as part of the square.

3.5. Building Typology

The first and second urban plans dictated regulations for the construction of buildings. The provisions for urban development from 1857 ordained that building be constructed along the property line (edges of the streets), that they be conjoined and no lower than one storey. In the second urban plan (1889, Figure 5) the town was divided into three parts/zones (Figures 5 and 6). Zone I encompassed the area between the medieval cores of *Gradec* and *Kaptol* and the railway tracks and to the south. Buildings constructed in this zone had to be two to three storeys high. In Zone II, further to the south and between the railway tracks and the River Sava, plans foresaw the construction of single-storey houses and the establishment of "clean" industries, which also applied to the hilly Zone III, which lay to the north of *Gradec* and *Kaptol*.

In the Lower Town (i.e., in Zone I according to the second urban plan from 1889) there are three types of buildings: 1. residential buildings in blocks that make up most of the construction, 2. buildings predominantly intended for social purposes incorporated within the construction of residential buildings (courthouses, university buildings, and others) and 3. public building located around the Horseshoe squares (Figure 10).

Figure 10. Public buildings in the central area of the Lower Town.

Blocks are mainly divided into uniform elongated rectangular city plots, placed with their narrower side facing towards the street. Thus, the size of the building is determined by the width of the plot in relation to the street.

The most common type of residential housing is condominium buildings with flats for middle and upper-middle class citizens. As far as the ground plan is concerned, these are square, rectangular and L-shaped buildings. There are small flats on the ground floor and in the attic. Another type of residential building constructed for the upper classes is single-family palaces, which are, as a rule, positioned so that they overlook the Horseshoe squares. Buildings lying within the blocks were not originally planned and are not essential in the morphological sense. Public buildings are important for the urban concept of the Lower Town. The Lenuci Horseshoe was conceived and designed as a public space, a kind of urban stage with numerous public cultural, scientific and art buildings and universities—all the buildings important to national culture, except Parliament. These buildings located on the squares became visual landmarks and dictated the new urban benchmark for their environs because they were usually built before the surrounding residential blocks [6].

4. Discussion

This research focused on the central part of the Lower Town. The eastern part of the Lower Town was built later, after 1905 when Milan Lenuci drew up an urban plan. That part of the town is not covered by this research. It is a logical continuation of the former Lower Town, but it is already a protomodern era with new views and approaches.

Detailed plans and the design for Lenuci's Horseshoe were never produced; neither were a plan for their implementation which would define the structure and specific morphology (detailed allocation and urban and architectural design), or costs, the organisational implementation scheme, etc., unlike in the case of the Ringstrasse in Vienna or the Andrassy Avenue in Budapest. No public tender for the urban and architectural design of Lenuci's Horseshoe, or any part of it, was ever issued. Lenuci's Horseshoe remained incomplete up until the end of WW I, and so work continued in the years between the two World Wars—in the 1920s and 1930s. Despite minor changes to the initial plan, in essence, further construction of the Horseshoe continued according to the initial plans for the creation of a series of uninterrupted parks and squares with public buildings.

The concept for this framework of squares/parks in Zagreb was based on the Ring concept applied in many other towns and cities in Europe. Although the concept and inspiration for the model was the Ringstrasse in Vienna, the urban development of Zagreb was different. In Vienna, as in most other European cities, parks and squares with public buildings were laid out at the site of old renaissance/baroque fortifications. However, Zagreb did not have such fortifications. The idea was to separate the central part of the town, intended as a residential area, from the industrial zone of the town, including the train station (engines ran on coal and produced dense smoke). In addition, a series of squares/parks afforded enough space and the possibility for public and cultural buildings of vital importance for the town and state to be founded and built. (Figure 11).

Figure 11. Aerial view of the central part of the Lower Town in Zagreb with squares.

Zagreb's medieval settlements *Gradec* and *Kaptol*, located on hills above the Lower Town, retain their historical dimension and, in part, their mediaeval and renaissance fortifications. The town was expected to expand across the flat terrain beneath the two settlements. The model selected was that which was recommended for urban mono-functional areas, and certainly not one for city centres, which is an orthogonal grid. There are both advantages and disadvantages to a rectangular network. In no instance is the ground-plan layout for the old city walls in Zagreb semi-circular, which would make it difficult for a series of equally sized, regularly shaped squares to be laid out. The urban grid does not provide for individualisation of the urban environment, nor does it provide sufficient challenges for artistic imagination and opulence in design, as in the case of circular boulevards such as the Vienna Ring. The Zagreb Horseshoe does not encompass the medieval town; it extends and stretches across spaces that lead from the old city core and across what were once fields and meadows. (Figure 11)

Zagreb does not have a main new avenue, which would emphasise its urban axis, like Andrassy Street in Budapest, Unter den Linden in Berlin and Corso Sempione in Milan. Gjuro Dezelic Street in Zagreb has all the characteristics of an avenue, but it is small compared to the urban impact of the Lenuci Horseshoe. It is discernible, but does not dominate the urban fabric of the city.

The Lenuci Horseshoe is not a boulevard, although it includes certain elements typical of a boulevard. The Horseshoe is not an avenue but it is a sequence of squares, forming a horseshoe shape. The Horseshoe is not a ring, although it could also be interpreted as such, despite not being round in shape.

The Horseshoe includes public buildings located within the squares, whereby it differs from Vienna and other cities. The Horseshoe was not established at the site of earlier town fortifications. It was created as an original conception in the spirit of the European urban aesthetics of the late 19th century. Milan Lenuci was well-versed in the typological models of European cities which definitely provided inspiration and served as a role model for Zagreb. However, due to the urban, landscape and topographical context, as well as other forms of constraint, a distinctive urban blueprint for Zagreb was created, which differs from other similar European cities.

5. Conclusions

Zagreb's Lower Town from the second half of the 19th century is the expression and result of "urban utopian times, a period which believed in Harmony and Beauty, and which was based upon an idealised concept of the Town" [6]. We can consider it the revival of the ideal city of the late 19th century. The Lenuci Horseshoe, consisting of seven squares and the Botanical Gardens, is the most valuable urban enterprise from the 1880s in the whole of Croatia and it opened the doors to similar, although less demanding, enterprises in other Croatian towns.

The urban grid of Zagreb's Lower Town and the squares/parks of the Lenuci Horseshoe are an embodiment of the urban principles of the 19th century, which are also to be found in other European cities. However, other urban solutions, which differ from those for other cities, were found for Zagreb. Therefore, Zagreb may be relevant in the study of the urban morphology of cities dating to the second half of the 19th and early 20th century.

The research indicated the following:

- Urban grid is based on an orthogonal network that deviates from the rules due to existing plots (cadastre), ownership, existing roads and part of the existing construction along the existing roads in the fields. The urban grid is part of the identity of the city, a historical matrix that must not be changed (enlarged or fragmented) if we want to preserve its authenticity.
- Urban blocks show diversity and a reluctance to uniformity. Almost no two blocks are the same, although the experiential general impression is of a "urbs quadrata". By keeping the street traffic network, we also keep the urban blocks. Towards the street the urban blocks remain unchanged in terms of the position of the buildings and the architectural front. Changes are possible in the interior of blocks where different types of interiors are found—from a few original gardens and orchards to the construction of apartment buildings, service buildings and public buildings (schools, kindergartens, etc.), often high-density construction. The interior of the blocks remains preserved for new modern functions and modern construction or for a modern interpretation of the original landscape of the block.
- Squares and parks as public spaces are an indicator of the high urban and architectural culture of the time when they were created in the late 19th and early 20th century.

Over the centuries of existence, some have undergone minor changes, which allow the restoration of the original appearance if desired. It is precisely these public spaces that are the important factor of identity and individuality by which Zagreb differs from other Central European cities of the former Habsburg Monarchy.

- Streets are appropriate widths for the age in which they were formed, often with tree lines. Today's use with numerous car parks changes the former cross-section and appearance, as well as the partial function of the promenade. Therefore, one of the main issues is the removal of cars from the streets and their placement in garages inside the block.
- Buildings significantly affect the experience of the city, its function and aesthetics, especially public buildings (Figure 10) whose construction followed due to the impossibility of construction in medieval Gradec (Upper Town). Public spaces and public buildings located in the middle of park squares are the most impressive contribution of the realized urban concept. Without public buildings and public spaces, as symbols of urban and social culture, the city would be deprived of recognizable ambiences with a predominant monotonous housing construction. They have priority in rebuilding the city.

These five essential components of a historic town should not be excluded when considering, planning and checking a comprehensive renovation—whether it is the rehabilitation of a damaged city, revitalization of neglected parts of the city, modernization of outdated technical and communal infrastructure or modernization a Lower town that has not been thoroughly rebuilt since its origin a century and a half ago. Therefore, the main question is how to read the historical inheritance of Lower town and draw ideas and possible preservation insights for modern reconstruction from it.

In the next decade, large-scale works are expected in Zagreb on the reconstruction of the city that was damaged in the 2020 earthquake. Zagreb needs an urban rehabilitation of the historic city from the end of the 19th century and modernization, which can be understood as the third modernization of the city. An important role in this is played by the inherited urban morphology, which indicates the identity features of the urban fabric of the city.

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Functional and Morphological Transformations of the Urban Block—Contribution to the Expected Modernization of Zagreb's Historical Core

Sanja Gašparović *, Tihomir Jukić and Ana Mrđa

Faculty of Architecture, 10000 Zagreb, Croatia; tjukic@arhitekt.hr (T.J.); amrdja@arhitekt.hr (A.M.)
* Correspondence: sgaspar@arhitekt.hr

Abstract: The paper explores the possibilities of the structural and functional transformation of blocks in the historical center of Zagreb as a part of modernization after many years of neglect as well as earthquakes in 2020. The research aims to determine how the existing block tissue corresponds with the needs of today's residents and the possibility of its improvement. The historical circumstances in which the blocks were formed and underwent the most significant changes and modern processes that affect the state and value are determined. There is a special focus on the interior of the block (courtyards), as well as on the spaces on the ground floors of street facades, where numerous, unexplored changes can be observed. The findings provide starting points for desirable structural–functional transformations of blocks and stem from the synthesis and interpretation of knowledge from four interrelated parts of the research. The characteristics of blocks have changed during city development stages, as depicted by an analysis and graphic interpretation of historical maps and urban plans (1864–2021). Influences of modern processes on changes of the city are determined on the basis of the synthesis of previous research from different interdisciplinary points of view; a detailed analysis of the structural–functional changes is conducted on the example of three selected blocks. Transformation models for three selected blocks are proposed.

Keywords: Zagreb; urban block; urban transformation; urban reconstruction; urban planning; historical core

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1. Introduction

The historical urban network of Zagreb, a pillar of urban planning, consisting of Lower Town, Upper Town and Kaptol, bestows the city with its architectural and cultural identity. Like other lived-in historical districts, this complex and dynamic spatial system is exposed to constant changes associated with social, political, and economic conditions. Research on the Lower Town formation indicates different stages in its development. The second half of the 20th century is characterized by processes and pressures that have left significant ramifications on the structure and function of the city center's identity, as well as the quality of life of its inhabitants. In recent decades, the neglect and degradation of the urban block tissue has become increasingly visible. The condition into which the city center has lapsed, especially after the devastating earthquake of 2020, indicates the need for modernization.

At the beginning of the 20th century, there was a broad international impetus for the reformation of urban blocks. The reformed perimeter block was considered a suitable model for the metropole at that time—the formation of a solid street facade, but at the same time, the realization of large, green, and bright courtyards. A large number of shapes were designed, including spacious courtyards, inner streets, and courtyards oriented toward the surrounding streets, with lower interior buildings and so on [1].

Among the numerous comparative European examples of historical block construction, we single out the Amsterdam's extension toward the south as one that shows the evident negations of the nineteenth-century city planning. The Berlage plan of 1917 deliberately ignored the orthogonal grid and rural plot division of the previous planning period and organized a new city quarter with its own structure, defined by large scale blocks and an internal communal green space [2,3].

Another example of urban block reconstruction originates from the 1910 Groß Berlin competition, which played a significant role and represents a milestone in the discussion on urban planning. A science-based, multidisciplinary, theoretical, and cross-scale design approach resulted in several original competition solutions for urban residential ensembles. They included park network systems and the opening of courtyard blocks as a reaction to a typical 19th century block, characterized by compactness and high density with open spaces that had no greenery, but were rather often used for crafts and workshops, thus creating the matrix of slum and congestion [4–7].

Models of reconstruction applied with the Berlin urban block structure were a subject for consideration for decades after. Of particular note is the Interbau 1957 exhibition and later the 1984 IBA, with dominant goals being to provide sun, light and greenery, rather than insist on continuity and tradition. The 1970s were especially marked by dynamic discussions on urban renewal, involving Heinrich Klotz, Rob Krier, Charles Moore, Wolfgang Pehnt, Aldo Rossi, Peter Smithson, and Jamess Stirling. Dilemmas about the existing city block construction were related to the principle of renovating—repairing, changing, or replacing—the existing blocks. Some of the basic concepts of the restoration of Berlin at the IBA 1984 were as follows: identifying the citizens of Berlin with the city; maintaining the historical planning structure as a permanent basis for the development of a "future for our past"; and urban renewal in the context of characteristic parts of the city relevant to its identity and at the forefront of its restoration. In the realization, this all led to the renewal of the existing block structure and the formation of new replacement blocks, even where they did not exist in such a form. The urban block as a historical city form is affirmed in several variations (open block, closed block, block in block and divided block). The city space is enriched with new and renovated streets and squares and the emergence of new park categories—parks in the block, city parks, and regional parks [8–10].

Most European cities have begun processes of long-term systematic transformation of their central historical parts some thirty to forty years ago and are now in their final stages. The functional and structural transformation of the urban block is an essential component of many of these cities' improvement models.

In the early 1970s, Rotterdam's city administration launched a major urban renewal project. In contrast to cleaning and demolishing neglected parts, the reconstruction of the center (*Stadsvernieuwing*) and residential areas was planned with the participation of citizens. Activities were carried out in order to reduce population density, ventilate blocks and upgrade public facilities and the communal infrastructure. Instead of narrow and long blocks and dark streets, designated areas for gathering and socialization were created both in blocks and in public spaces—communal gardens, passages and children's playgrounds [11].

From the realization of the first superblock in Barcelona in 2016, a new concept of urban order has sprung up. The new model of innovative urban and transport planning strategy aims to reclaim public spaces for people, reduce motorized transport, promote sustainable mobility and active lifestyles, provide urban greening and mitigate the effects of climate change. The scheme transforms nine city blocks into the so-called 'superblocks', where traffic is only allowed around the perimeter, and priority is given to pedestrian areas, low-speed zones and recreational green spaces. A recent study suggests that there are potentially significant benefits to be delivered from this ambitious plan [12,13].

Finally, as a counterpoint to the efforts to reaffirm the role of the urban block during the 20th century, it is important to point out the theoretical model of complete block dismantling, influenced by Le Corbusier's urban thought of building new and reconstructing existing cities. It is based on a concept that denies the historical city and the impact of the specificity of a particular location in the city. This model was brought to absurdity by his concept for Plan *Voisin*, which envisages the demolition of the historic part of Paris and the creation of a new composition started from scratch by eliminating ties with historical quarters. The traditional parts of the block are dismantled and reorganized into a new unit resembling a vertical block [14].

The focus of the research is the city of Zagreb, which, unlike the mentioned cities, has only just begun thinking about a systematic reconstruction process without a comprehensive plan and/or strategy following a long period of neglect [15].

Urban renewal should consist of a set of planning measures and terms for a functional and qualitative change of degraded areas. It refers to various processes (urban regeneration, reconstruction and revitalization) related to social, structural, functional, cultural and environmental changes of a certain part of the city. Planning the urban regeneration of the historical city should provide a comprehensive vision of development, with consideration of each new urban architectural project in light of preserving the identity of urban heritage [16]. In the context of city modernization, it is important to emphasize the urban environment as a living tissue. Architectural heritage can be reutilized respecting its core values, but also the needs arising from social, cultural, spatial, economic and other requirements of our time—adaptive re-use of the built heritage [17]. New urban planning and architectural interventions in the historic core of the Lower Town need to bring new potential that will contribute to the conservation of city identity [18]. In addition to the basic principles related to the criteria of integrity and authenticity of physical structures, the intangible components, such as the purpose and the use of space, are important, especially in terms of the role of housing and quality of life [19].

Research Question and Aims

The conducted research aims to determine the extent to which the existing block tissue is in line with the modern needs of residents and the possibility of improvement. The objective is to determine the historical circumstances of the formation of the Lower Town block structure as well as the genesis of their most significant structural and functional changes, with identification of its development stages. A special focus is placed on pinpointing the causes and effects of negative transformation processes.

Unlike other conservation research, which is mainly focused on the architectural heritage of the outer perimeter of the block, the focus of this study is the changes in the interior of the block (the enclosed central courtyards), as well as the ground floor spaces of street buildings. Both spatial aspects, neglected in previous research, are an integral part of the block and are significant for its definition. In addition, these are spaces where numerous changes take place without any identification of their causes or control/management models.

The findings should serve to define the starting points of desirable structural and functional transformations of specific block structure parts as an integral element of the city core reconstruction and its modernization in the coming period. Although conducted and tested in the case study of Zagreb, the research can serve as a methodological approach for the reconstruction process of other urban areas.

2. Materials and Methods

Research was conducted using quantitative and qualitative methods by synthesizing different specifics—bibliographic, cartographic and photographic materials as well as field data. The exploration of spatial characteristics and urban processes was conducted in two different scopes/scales, as follows.

For the area of the whole Lower Town, the boundaries are defined by the last planning document prepared for the subject area (Development Plan of Lower Town, 1989), including 168 blocks over a total area of 350 hectares and the area of three blocks (A, B, C) selected according to the established criteria (Figure 1).

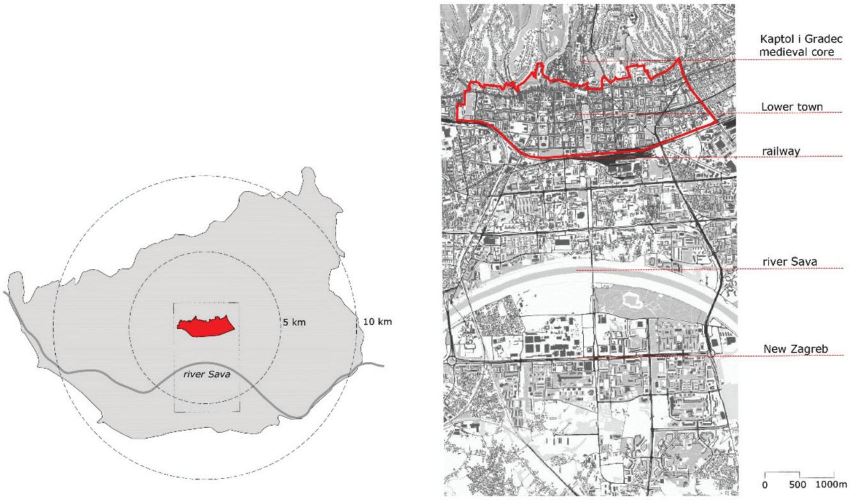

Figure 1. Research area: Lower Town within today's city limits/scope of the Master plan—*Generalni urbanistički plan* limits (**left**). Location of Lower Town in the central city area—relation to the most important city development stages and spatial features (**right**).

The research consists of four interrelated parts:

(a) The characteristics of the blocks through the development stages of the Lower Town are determined by an analysis and graphic interpretation of historical maps and urban plans of the city of Zagreb (from 1864 to 2021) [11,12], as well as a synthesis of scientific and professional papers on the historical city development. The most significant stages of city expansion are identified, spatially mapped and graphically interpreted. The presented space–time sequences provide the basis of defining criteria for detailed case study blocks selection reference.

(b) The recent processes' impact on the structural–functional changes are determined by the synthesis of previous interdisciplinary Lower Town research (architecture and urbanism, art history, sociology, demography, economics) with field data. Processes with negative effects on the block, which were not previously spatially explored, are identified together with spaces that carry the potential for improving the quality of life and preserving the city's identity.

(c) A detailed analysis of the structural–functional changes is conducted by comparing selected examples of three blocks (A, B, C). The case study method is focused on two previously unexplored spatial aspects:

- Stages and characteristics of physical changes of the blocks' enclosed courtyards, as determined by a comparative analysis and graphical interpretation of cartographic materials from different periods of the city's development (1964–1989–1923–1934/35–1968–1998–2021) and a detailed field survey (Figure 2, Table 1).
- Changes in the usage of street buildings' ground level spaces, as determined by a comparative analysis of data selected in 1974 and a mapping of the data on the condition, type, location and number of commercial spaces from a conducted field survey in 2021.

(d) Guidelines for urban block renewal are proposed in the form of a transformation model based on a synthesis of the previous three parts of research: historical stages of city development, impact of modern processes on city changes and detailed analysis of structural and functional block changes.

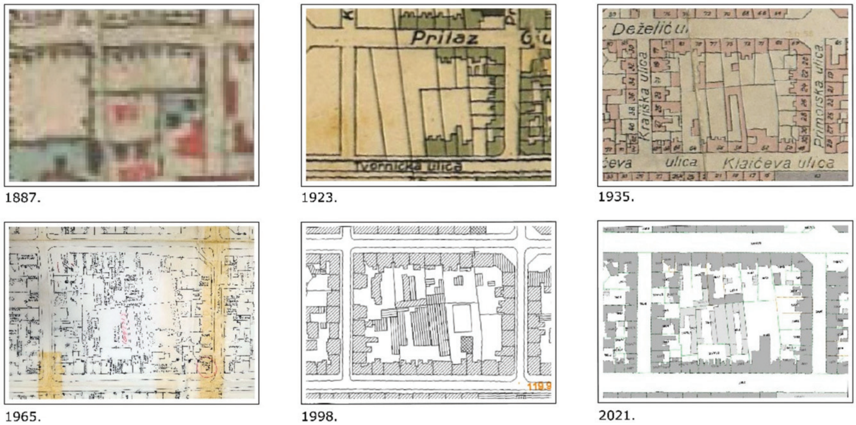

Figure 2. Selection of the most expressive cartographic materials from different periods of the city's development used in comparative analysis and graphical interpretation of structural functional block changes.

Table 1. Cartographic material used in the research (NSK—National and University Library in Zagreb, Zg Geoportal—Zagreb spatial data infrastructure, DGU—State Geodetic Administration).

Cartographic Material	Year	Type	Scale	Source
Nacrt Zagreba, Albrecht, D.	1864	Regulatory basis	1:5950	NSK
Nacrt grada Zagreba	1889	Regulatory basis	1:11,520	NSK
Nacrt Zagreba, Heinzel, V.	1923	Regulatory basis	1:10,000	NSK
Nacrt grada Zagreba	1935	City plan	1:5000	NSK
Treća katastarska izmjera	1965	Cadastral map	1:1000	DGU
Digitalni ortofoto (DOF)	1968	Digital ortophoto	-	ZgGeoportal
Croatian base map (HOK)	1998	Base map	1:5000	ZgGeoportal
Google maps	2021	Satellite map	-	google.com
Digitalni katastarski plan	2021	Cadastral map	-	ZgGeoportal

The starting points of urban planning for desirable transformations of structural and functional blocks are proposed by synthesizing all four interwoven parts from previous research and usage of logical argumentation methods, combining deduction and induction.

3. Results

3.1. Urban Block Characteristics through the Development Stages of Lower Town

The study of the city center block development is closely connected to the history of modern Zagreb, which began in the middle of the 19th century, when Lower Town was formed. Unlike many other European historic cities, such as Vienna, where the inner city was the heart around which the city spread radially, Zagreb's Lower Town emerged as a new planned part of the city development on the south side of the historic core.

3.1.1. Formation of the Lower Town during the Second Half of the 19th Century

The initial phase of Zagreb's modernization and urbanization, initiated by the construction of the railway and the city's expansion along the main traffic routes, was determined by the First and Second Building Orders and Building Development regulations in the middle of the 19th century [20]. The Second Building Order from 1857 prescribed the manner of forming streets, squares and buildings' facades. The rectangular shape of the new squares was determined by omitting the block as well as the conditions for mostly straightforward tracing and right-angled streets crossing. The minimum width of streets, the position of buildings' facades and other urban planning terms that contributed to the image of a new, more modern city, were also determined [21]. Lower Town urbanization began in the 1860s with the formation of main development axes and the transformation of an irregular rural structure into a uniform elongated rectangular city plot with a proper distribution [22–24].

The first regulatory document for the development of the city was adopted in 1865 and was the most important plan and strategy for the transformation of Zagreb into a modern city. It spatially and substantively defined Lower Town—its role of connecting historical settlements with the suburbs, unifying the urban standard and achieving urban consolidation. The regulations required planned and orderly construction, so the basic typology of the future city, created by the transformation of the building plot of mercantilist construction of non-homogenized shapes and sizes into standardized building parcels, remains a permanent effect of the plan (Figure 3). Various procedures by which the system of urban blocks was established stem from that document—corrections and rectifications of construction directions, corrections of street axes, the laying out of the so-called green horseshoes—rings of lower city gardens and others [22,25,26].

Figure 3. The first regulatory basis of the city, 1865. Area of planned Lower Town block structure is marked in light pink, situated south of the historic medieval core.

3.1.2. City Modernization after the 1880 Earthquake

The devastating earthquake of 1880 was a new turning point in city development. At that time, economic relations gradually passed from the craft phase to the pre-industrial phase, the new middle class of merchants and builders formed, and the city entered a period of rapid growth that lasted until the beginning of the World War I.

The new Regulatory Basis of 1887, covering a much larger area, used zoning for the first time in planning—the division of the city into three areas of different functions and different levels of elaboration (Figure 4). The first zone included the central urban area of Lower Town, where the first development was expected and for which the regulation was set. Special provisions determined the height of construction—two-story buildings, and three-story buildings on squares—and banned the accommodation of "unclean" factories. Detailed regulatory bases were announced for all roads and streets. The previously planned ring of parks (the green horseshoe) grew into a lavish spatial framework for edifices celebrating national culture; monumental public buildings combined with residences for wealthy citizens, adorned by extensive park landscaping, which created a unique historic *Gesamtkunstwerk* of the founding era [20,22,27]. By the end of the 19th century, Zagreb became a modern European city.

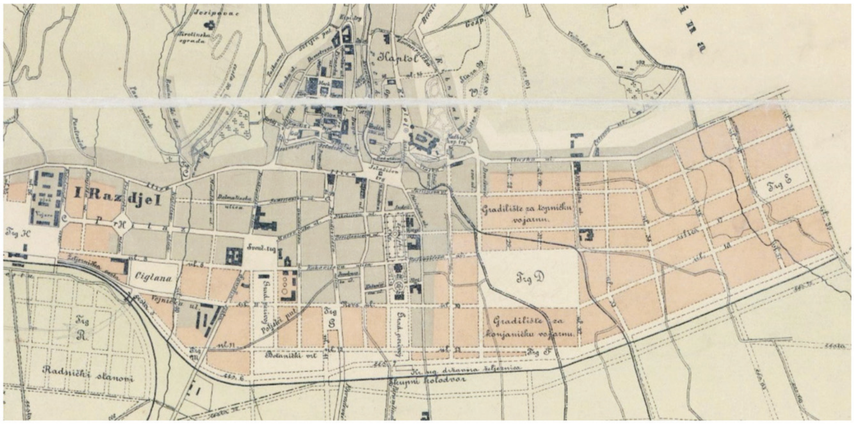

Figure 4. Regulatory basis of the city, 1887.

At the end of the 19th century, several amendments to the Building Regulations were approved, additionally regulating block construction by determining the permitted heights of buildings and the area of unbuilt courtyards. Houses for lease were mostly built at that time, often with the owner's apartment joined with smaller auxiliary buildings. The increase in the number of central functions bears testament to the growing importance of the area.

3.1.3. Lower Town Industrialization in the First Half of 20th Century

The beginning of the century is characterized by strong urbanization and the process of industrialization initiated by the railway construction at the end of the 19th century. At that time, Zagreb was becoming one of the strongest industrial centers in Southeast Europe. The accommodation of the industrial buildings started in the first phase on the outskirts of the city and along traffic routes (mostly along the railway). Gradually, the city also gained a number of industrial plants, incorporated into the urban fabric, in the growing lower city center [28,29].

Certain parts of the city had greater or lesser advantages for further expansion. The biggest, but also the most intensive, changes took place in peripheral parts, where some segments changed their use and structure several times until their final inclusion in the urban fabric [30].

The annexation of the settlement along the eastern city border almost doubled the city area. Alterations in the approach to urban planning and the construction of a drainage channel enabled the introduction of diagonal streets and the formation of triangular and pentagonal blocks. In that way, it was possible to build free disposition corners as a generator of specific urban accents of the city [20]. The eastern part of Lower Town was formed latest, mostly according to the 1923 Draft Plan of the City of Zagreb and was completed only after World War II.

In the following decades, the planning focus shifted to new regulations and the expansion of the city toward the south, across the river Sava. In 1930–1931, a large international competition was announced for the development of the "general basis for the construction, expansion and regulation of the city of Zagreb. The new regulatory basis from 1953 defines Lower Town as a commercial and residential urban space and protects the existing physical structure of buildings. New building interventions are planned as an additional filling based on the established block grid.

3.1.4. Stagnation and Degradation of the Lower Town Identity in Second Half of 20th Century

At the time of the City Center Development Program in 1968 and the proclamation of building southern Zagreb, the Lower Town area underwent an extreme stagnation period, marked by growing traffic problems and an unchanged physical and functional structure [31–34]. The need for substantial restructuring and certain physical rehabilitation is recognized in order to achieve architectural and urban modernization with technical and spatial upgrades aimed at establishing the physiognomy and scale of a millennial city center.

Since the 1960s, Lower Town has seen population depletion and a decline in housing function—important indicators of change in the spatial and functional tissue of the city. Moving industry to city outskirts has become a tendency combined with a concentration of new central activities, indicating the increasing attractiveness of the area. Trade and various businesses (especially in clothing, footwear, furniture, technical goods, etc.) emerging in the commercial zone, together with cultural, entertainment, administrative and other institutions, and the rapid growth of activities related to tourism is evident [35].

At the same time, planners warned of the need for a systematic urban policy for the distribution of new city services (tourism, shops, crafts, etc.), with special attention paid to spaces within city blocks. The outdated way of occupying blocks' interiors, in which contents of heterogeneous building groups dominate (warehouses, storage rooms, garages, small-scale production, crafts and industrial buildings) is pointed out and characterized as one of the basic factors of the so-called blocks "congestion" [36]. However, among many such buildings, which no longer belong to the modern city center and hamper the spatial potential of the city, it is important to single out those that do have heritage value and bear testament to the early 20th century economic prosperity of Zagreb as well as the modernization processes of the time [37].

In recent decades, Zagreb, like many other cities, has increasingly fallen into the general entropic climate of globalization and transitional integration. The conflict between traditional and modernizing identity can be seen in various aspects of space. It is especially present in the transformation of commercial street spaces (shops). Since 1990s, there has been an obvious trend, present throughout Central and Eastern Europe, visible in the emergence of hundreds of new global brands and services, with traditional craftsmen increasingly losing their place in the market flooded by a river of well-known branded stores [38]. Zagreb has long been known as a city of craftsmen and traditional crafts (watchmakers, hat makers, shoemaker, umbrellas, etc.). Until recently, they were one of the important features of urban identity, possessing strong charisma. The potential danger of their complete decline, if they continue succumbing to globalization, shall lead to them no longer reflecting traditional Zagreb, which is, in fact, one of their primary roles [39].

One of the most noticeable trends that have marked the past ten years is a significant increase in tourist activity. It is evident in the growing number and vast array of tourist accommodation, as well as varied adaptations of city spaces (restaurants, souvenir sales, events in public space, etc.). A significant increase in the number of housing units offered through Airbnb has led to an increase in real-estate prices and leases in the center. Gradually, it is expected to lead to a violation of privacy in residential buildings, changes in the quality of housing and the eviction of permanent tenants [40,41]. In addition, numerous adaptations, additions and extensions accommodating the demands of tourism lead to structural changes of questionable quality. A significant share of tourist accommodation in buildings in the enclosed space of the block is evident. It is, therefore, important to view tourism in light of its impact on the quality of housing and in the context of the process of transformation and conversion of buildings in the block, often of smaller urban-architectural and construction values [41].

In addition to all the above mentioned processes, the devastating earthquake of 2020 has put into question the sustainability of the future development of the historic city center and is the impetus for a new step forward in quality reconstruction and revitalization. Like a complete renewal after the earthquake of 1880, when modern Central European city was formed, Zagreb is once again given such an opportunity today. The approach to the new stage of modernization of the city requires the planning of integral interventions that go beyond the reconstruction of individual buildings but requires an approach that looks at the wider space, including blocks, areas of common urban character, and city districts—the historical center as a whole [19].

3.2. Structural—Functional Changes of Selected Blocks

One of the greatest spatial potentials for the improvement and modernization of Lower Town, recognized since the 1970s, are the enclosed courtyards within city blocks. Their current redevelopment and neglect pose a limitation in terms of functional organization and urban security (disabled access, evacuation routes, passages and fire access) and quality of life in the block (reduced amount of natural light and ventilation, deteriorating microclimate conditions, lack of space for tenants, etc.). Changes in economic, social and political conditions in recent decades have imposed the need to reconsider the construction and design as well as the use of buildings inside the blocks in order to improve the quality of life and establish an identity that befits the city center.

Unlike the buildings around the perimeter of the block, for which the purpose and time of construction are well known, the block's interior remains in obscurity. The aim of the research at the block level is to determine the period of construction, purpose and current usage, terms and possibilities of transformation/improvement.

3.2.1. Criteria for Selecting Block Examples

Although there are numerous differences among a total of 168 blocks, almost each and every one of them possessing unique features, for the purposes of this research, three reference examples were selected according to the following criteria:

- Blocks from all three development stages of the city determined by the analysis of planning documentation (Figure 5).
- Blocks from the area of the city in which a deficit of activities important for the quality of everyday life is determined [42].
- Blocks of predominantly residential use (excluding the strict center in which business activities predominate in relation to housing) (Figure 6).
- Blocks with accessible enclosed courtyards (road and/or pedestrian access) (Figure 6).

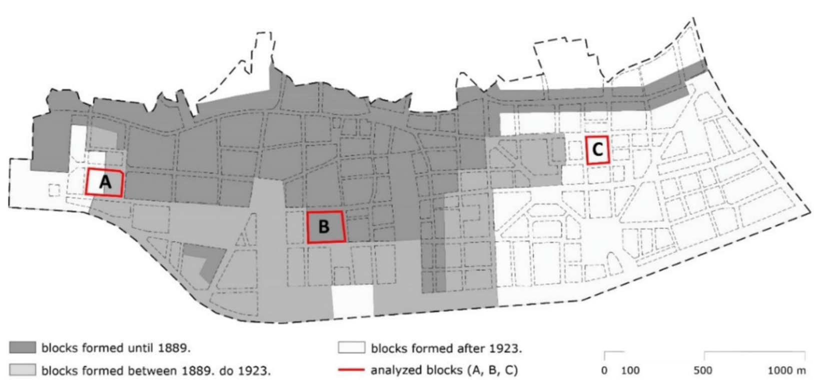

Figure 5. Graphical interpretation of the stages of temporal and spatial development of Lower Town blocks with the markings of the three blocks selected for a detailed structural–functional analysis, created by the author.

Figure 6. Selection criteria for reference blocks—spatial block characteristics: passageway, usage, location in the city, created by the author.

3.2.2. Structural Changes in the Construction of the Interior of the Block

The conducted analysis of block structure based on the comparison of cartographic materials (1887–1923–1934/35–1968–(1998)–2021) has allowed for the identification of the most significant stages of physical changes of the blocks' enclosed space (Figure 7). It can be concluded that the original building concepts, especially in the older parts of the city (block A, B), imply predominantly unbuilt inner courtyards. The increase in the share of buildings, inside the blocks, was noticeable in the period from the 1930s to 1968, which can be related to the rapid development of the city's industrialization in that period. Block courtyards are mostly filled with auxiliary, crafts and production buildings since the view of the interior of the block was, almost regularly, reserved for less representative "second-class" rooms in the apartment [36].

The period from the 1990s to 2021 is characterized by individual reuse (conversion of former ancillary buildings into residential, commercial or tourist accommodation), renovation of buildings or minor additions and extensions. Based on the analysis, it can be concluded that in recent times, there have been no significant new constructions in the interior; therefore, the existing ones are of substandard quality and do not belong to a modern city center.

According to the scale and usage, buildings inside the blocks can be divided into three basic types (Figure 8):

(a) Small-scale buildings in the function of the accompanying facilities of perimeter housing units (garages, common storage rooms for tenants, smaller craft workshops, etc.). Partly reused and adapted according to individual initiatives of owners without significant architectural and urban value or contribution to the improvement of conditions and quality of the block as a whole.

(b) Buildings of larger scale, originally in the function of production, various trades, workshops and warehouses, mostly out of function and in poor construction condition. Only a small number of former service buildings possess the significance of urban planning or architectural heritage (such as part of block C—ice factory).

(c) Buildings of larger scale (former production plants and warehouses) that have been reused and are currently in function.

Figure 7. Graphical interpretation of blocks A, B, C's structural changes from 1887 to 2021, based on different cartographic depictions, created by the author.

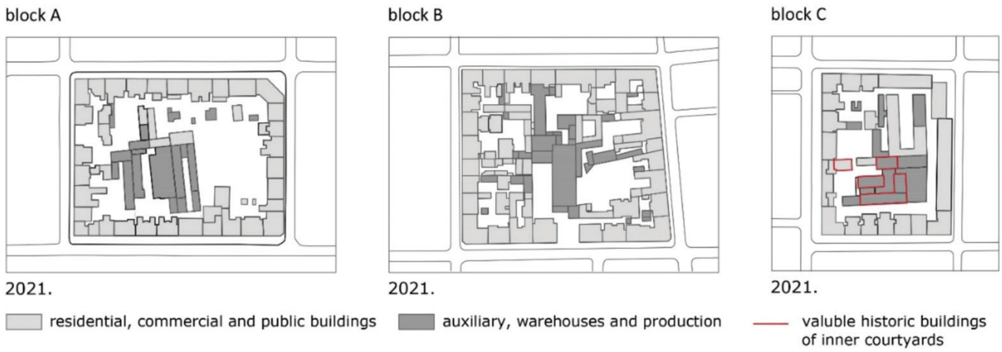

Figure 8. Share of auxiliary and service and commercial buildings in the built block structure according to the data in the digital cadastral plan [43], created by the author.

3.2.3. Street Ground Floors Usage Changes

A detailed survey on the number and typology of the Lower Town functions was conducted in the 1970s. At that time, a significant share of evenly distributed shops and services of a local character established mainly across ground level facades was determined. A significant presence of craft and small-scale production facilities (small areas), located mainly in the interior of the blocks accessible from the street, was identified [36]. Recent participatory art projects as well as initiatives by citizens and the professional public have been warning increasingly about significant changes in the character and representation of spaces and activities for everyday life, as well as a large share of neglected and unused commercial spaces on the ground floors.

A comparative analysis of the data from 1974 and 2021 (field survey) for the three selected blocks indicates a trend in change, which is reflected in the number, type and position of non-residential premises on the ground floors of street buildings (Figure 9, Table 2). The obtained findings show that the total number of facilities on the ground floors street level in the observed period decreased by an average of 38%. The largest decline in the number of premises of different use was recorded in the western part of the city, for which a lack of social, cultural and sports facilities were previously identified [42]. A distribution of commercial spaces that was even and continuous across most block facades was replaced by their sporadic position and reduced density. Some facades, or even streets, have almost completely lost their public character (block C). There are significant reductions in certain types of commercial spaces, especially shops of daily consumption (blocks A, B) as well as various types of services (blocks A, C).

A reduced number of crafts and small-scale production sites is an indicator of a significant functional transformation of the city center, caused largely by the growing impact of tourism. The gradual extinction of crafts and services that were once a recognizable sign of the city's identity (watchmakers, production and repair of shoes, fountain pens, tailors, carpenters), no longer competitive in globalization, is especially significant. In addition, the reduction in the number of everyday consumer stores has a direct impact on the quality of life in the historic part of the city. A once planned positioning and concentration of commercial spaces in buildings, at the corners of blocks, as well as along passages to inner courtyards, played a significant role in establishing the character and attractiveness of the street and its connection with the inner block space. Their closure, neglect or inappropriate reuse greatly affects the stated desirable interrelations and indirectly results in the loss of urban identity.

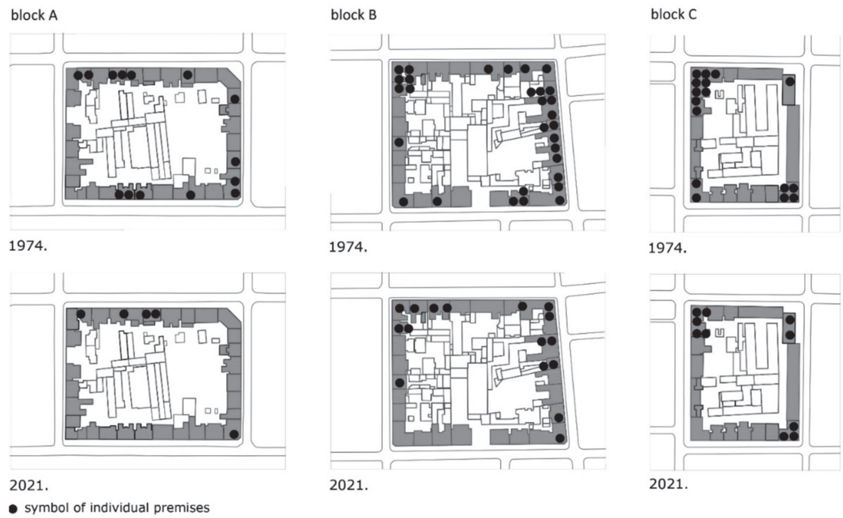

Figure 9. Comparative analysis of the number of commercial spaces on the street ground floors of blocks A, B and C in the period of 1974 to 2021.

Table 2. Comparison of commercial space types at the street ground floors of blocks A, B and C in Table 1974. to 2021.

Type of Premises		Block A		Block B		Block C
Everyday stores	**1974**		**1974**		**1974**	
	2021		2021		2021	
Specialized stores	1974	-	1974		1974	-
	2021		2021		2021	
Crafts and production	1974		1974		1974	
	2021	-	2021		2021	
Services	1974		1974		1974	
	2021		2021	-	2021	
Business space	1974		1974		1974	-
	2021	-	2021		2021	-
Culture and art	1974		1974		1974	-
	2021	-	2021	-	2021	-
Health care	1974	-	1974		1974	
	2021		2021		2021	-
Catering	1974		1974		1974	
	2021	-	2021		2021	
		Total No. 1974. = 13 Total No. 2021. = 5		Total No. 1974. = 30 Total No. 2021. = 16		Total No. 1974. = 16 Total No. 2021. = 10

3.3. Guidelines for Urban Block Renewal—Models of Structural-Functional Transformation

For the three detailed blocks analyzed, guidelines for structural–functional transformation in the form of conceptual models (rather than design solutions) were proposed. They are focused on the possibilities of improving inner courtyards and streets (street facilities) and are based on knowledge from previously conducted analyses (historical development, modern processes, changes and the current state of space). The criteria that require a different approach to the transformation of each block are as follows (Table 3):

- Accommodation in relation to the city center (predominantly business and tourist purposes).
- Accommodation in relation to the distribution of accompanying facilities in the city.
- Block size.
- Proportion of buildings out of order or in poor construction condition inside the block.
- Dominant purpose and way of using buildings in the interior.
- The share and character of green areas in the interior of the block.
- Share of protected buildings (cultural—historical value) inside the block.
- Traffic context—the character of the streets and the share of parking in the block and streets.

- Pedestrian character of the street and the share of retail units on the ground floor.

The goal is to respond to the needs of each part of the city and achieve the recognizability of each individual block.

3.3.1. Model of Transformation of a Block into a Public Park (Example Block A)

Block A is located in the western, oldest part of the city, away from the business and shopping center. The neighborhood is predominantly residential, with a relatively small share of public green areas, sports and recreation areas, children's playgrounds, etc. The largest share of buildings in the interior is out of order or in inappropriate use (garage of a number of private companies with a negative impact on housing). The existing open areas are neglected, untidy and burdened with the parking of tenants' vehicles.

It is proposed to remove buildings of unsuitable condition and manner of use from the interior of the block as much as possible, with possible retention of certain buildings in public function or their relocation to more appropriate facilities and locations. The inner courtyard becomes a predominantly green area differentiated into a border zone of private gardens and a central zone of a public park with sports and recreational facilities, children's playgrounds, etc. Affirmation of public entrances and an emphasis on the availability of indoor parks should be achieved through new facilities on the ground floors of peripheral buildings—especially in positions that flank/mark the entrance to the block purposed suitable for improving the quality of housing in the block and neighborhood, such as shops, services, and communal facilities for tenants (Figure 10).

3.3.2. Transformation Model of a Block into a Shopping and Service Center (Example of Block B)

Block B is located in the central part of the city in the contact zone of the narrowest business and shopping center and also the area with the largest share of tourist rentals. It belongs to the category of the largest blocks, high density of construction of the inner courtyard and a significant share of larger buildings of the former production function, partly already converted into a supply center. The existing open areas are neglected, untidy, unconnected and burdened with tenants' vehicle parking and shop users.

It is proposed to remove part of the auxiliary buildings that are out of function and to form a strong move of public open areas—passages/square/park through a block that affirms trade, service and catering facilities in the function of tenants and tourists. New pedestrian entrances to the block are introduced and emphasized by street bars in the function of preserving the city's identity (traditional crafts in the function of tourist promotion). The new dynamic inner street has the potential to connect with the inner courtyards of adjacent blocks into the city's expanded pedestrian zone system. Arranged private yards/gardens ensure the distances and privacy of the residential parts of the block (Figure 11).

3.3.3. Transformation Model of a Block into a Socio-Cultural Center (Example of Block C)

Block C is located in the western, newest part of the city, removed from the business and shopping center. The neighborhood is predominantly residential with a relatively small share of social and cultural facilities.

It belongs to the category of medium-sized blocks with a significant share of built parts of the interior, some of which are protected as urban–architectural heritage (city ice factory), out of function and in neglected condition.

It is proposed to remove part of the existing buildings without special value and to renovate and convert all protected and some larger buildings as the social center of the residential area. New facilities of flexible character (culture, art, arts and crafts fair, specialized market, etc.) use repurposed buildings and newly formed open public space, which extends to the area of streets transformed into a pedestrian zone with an increased share of greenery. Activation of the street and the entrance to the block is achieved by new facilities on the ground floor, which, by their nature, complement the new offer of the neighborhood and include the local community (Figure 12).

Table 3. Spatial characteristics of three analyzed blocks based on the field research.

	Blok A	Blok B	Blok C
Location			
City area	Western part	Central part	Eastern part
Formation period	1889.–1923.	Before 1889.	After 1923.
Streets bordering the block	Dezelićeva Primorska Klaićeva Krajiška	Hebrangova Preradovićeva Žerjavićeva Gundulićeva	Martićeva Vojnovićeva Beršćenskoga Bauerova
Building Characteristics			
Block dimensions (outer perimeter: AXB)	175 × 130 m	188 × 150 m	110 × 138 m
Block area (m^2)	22,760	28,097	15,214
Area of the built part (m^2)	12,275	18,634	9799
Area of the unbuilt part (m^2)	10,485	9463	4989
Built share	54%	66%	64%
Number of block buildings	55	96	30
Average number of floors	P + 2	P + 2	P + 5
Use and Purpose			
Total number of apartments in the block	261	284	380
Apartments in the perimeter building (No)	253	255	374
Number of tourist accommodation	3	15	4
Number of ground floor premise (2021.)	5	16	10
Number of ground floor apartments	54	44	41
Predominate use share			
Residential use	15.9%	23.5%	11.3%
Mixed use	46.2%	48.0%	50.6%
Office/Work	16.9%	14.8%	32.8%
Social use	11.8%	1.6%	1.3%
Auxiliary/Storage	7.4%	10.8%	4.0%
Accessibility			
Number of block car entrances	9	17	3
Parking			
Number of street parking spaces	86	51	116
Number of block parking spaces	71	105	27
Open Spaces			
Unbuilt area of the block (m^2)	10,485	9463	4989
Area of green surfaces (m^2)	7889	4521	3939
Area of residential gardens (m^2)	3510	3866	941
Pedestrian areas, 'squares' (m^2)	0	0	0
Park area (m^2)	0	0	0
Sport and recreational area (m^2)	560	0	0
Road surface, access and parking	3469	4217	1417
Children's playgrounds	0	0	0

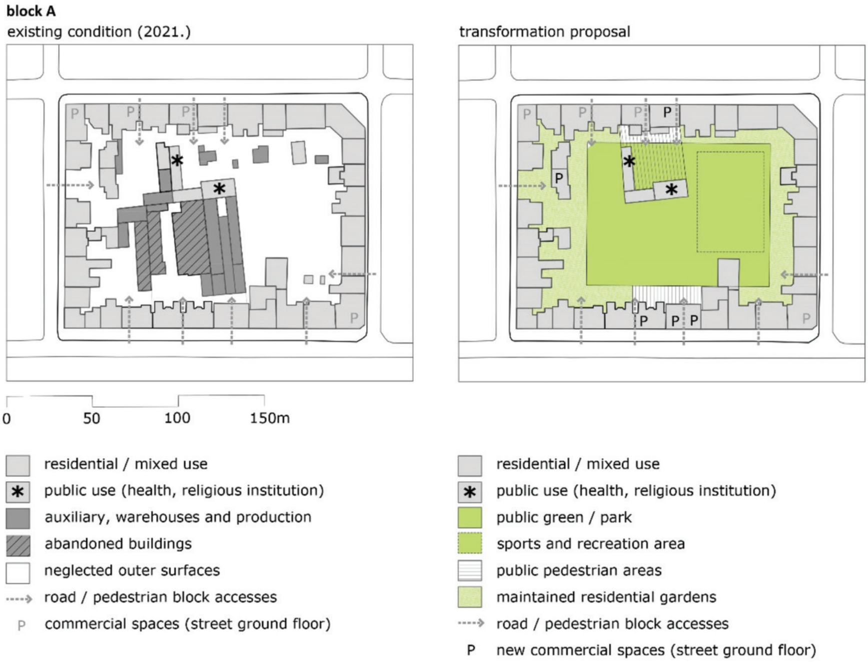

Figure 10. Model of transformation of a block into a public park (example block A).

Figure 11. Transformation model of a block into a shopping and service center (example block B).

Figure 12. Transformation model of a block into a socio-cultural center (example of block C).

3.3.4. Prerequisites for the Realization of the Proposed Models

In order for the proposed models of block transformation to be realized, it is necessary to meet certain planning preconditions at the city level:

- Modify the concept of parking in the center by relocating public garages to the outskirts.
- Implement the concept of a superblock by excluding individual streets from the motor traffic system and grouping several blocks into a 'pedestrian' whole.
- Implement the concept of urban green infrastructure by connecting existing and newly planned green areas into a networked system.

It is also necessary to establish city policies aimed at incentive and subsidy systems for the use of public transport, stimulating certain trades and services, arranging and maintaining inner courtyards and gardens, city policies (subsidies and incentives), capacity control and distribution of tourist accommodation, etc.

It is necessary to develop planning mechanisms for the implementation of block renewal plans as a whole (as opposed to interventions on individual buildings).

4. Conclusions

The research deals with the transformations of the block structure of the historic center of the city of Zagreb. The focus is the historical development of the city and the contemporary processes and pressures that affect spatial changes in the face of expected urban renewal after years of neglect and recent devastating earthquakes. Unlike many studies focusing on the architectural heritage of the envelope (outer perimeter) of the block, the focus of this research is on changes in the interior of the block (in courtyards), as well as on the ground floors of street facades as two aspects that have been insufficiently explored for decades but are an integral part of the block and play a significant role in its direction. Literature on this topic is extremely scarce, and the last comprehensive research of the Lower Town was done more than 30 years ago. Therefore, the conducted research represents a significant contribution to improved knowledge about the changes and processes of the Lower Town, necessary for making informed decisions when planning urban renewal.

Other research contributions can be divided into three basic units as follows:

Spatial units of the city have been identified for which it is possible/desirable to design a particular urban renewal project.

Processes have been identified, whose consequences and the manner of planned control have to be incorporated into the concept of complete reconstruction of the city.

Three conceptual models of transformation of selected blocks are proposed as an illustration of the necessary individualized approach to the reconstruction of each individual block/neighborhood.

The research confirmed that it is not possible to establish a single principle of renovation for the Lower Town space. The established basic development stages of the city (before 1889, between 1889 and 1923, after 1923) influenced the creation of three significantly different areas recognizable by construction features and living standards (facilities, block size, construction features—earthquake resistance, etc.). Therefore, the process of integral reconstruction should begin in a specific way in individual city parts divided by historical urban development boundaries. A similar approach to improving social welfare was applied in Barcelona during the 1980s by differentiating zones of different characteristics for which particular urban renewal projects were designed, such as Ciutat Vella [44].

Although the focus of the reconstruction of the city immediately after the earthquake is focused on repairing structural damage to individual buildings, the analysis of the processes that characterize the city in the second half of the 20th century pointed to negative trends in space (depopulation, 'congestion' of blocks, loss of historical identity and globalization, reduction in the number and type of content on street ground floors, and uncontrolled tourism), which significantly affect the reduction of quality of life and therefore, have to become a part of the measures taken for the purpose of complete, planned and long-term reconstruction of the city. Like the concept of reconstruction and revitalization in Milan, it has to be an integrated approach between construction, energy efficiency, and environmental sustainability for the deep renovation of the historical area [45]. The relationship of people, space and architecture as well as the relationship of political power and space all together ultimately influence the choice of the model of urban renewal [46].

Given that the Lower Town area is today considered an area of extremely well preserved and particularly valuable historical urban structure and is the tightest protection zone of the cultural and historical ensemble of the City of Zagreb, radical changes, such as dissolving and/or increasing the dimensions of the outer block perimeters, as was done in Rotterdam in the 1970s, are not applicable. In the Zagreb case, it is more realistic to expect urban renewal by implementing small-scale projects that are able to regenerate the quality of life in neighborhoods and are based on the concept of transformation of public urban spaces. One such successful example is the 1991 Barcelona remodeling model, by which 43 markets that make up the network throughout the city were renovated and built. The positive effects of this model are visible in the social structure of the neighborhood, the suppression of oligopolistic trends and the economic promotion of the city [47].

Preserving and improving local urban identity is one of the most important premises of urban renewal. By avoiding uniform solutions and with targeted city policies, the features of local identity and social behaviors that grant Zagreb its local city identity and reflect inherited values can be encouraged. Like in other successful community-based renewal projects (Gracia and 22 @ in Barcelona), these features are mostly related to open public space and are as follows: festivals, public food markets, playground spaces, limited vehicular traffic, space calibrated to pedestrian scale, numerous public plazas, etc. [48]. The proposed models of the transformation of the interior of the blocks (A, B, C) illustrate the principle of an individual approach to reconstruction with the aim of achieving recognition and meeting the real local needs (of the block and the neighborhood). They are based on the change of the conceptual role of the block yard, which should take over the role of a site for the socialization of tenants, through upgraded public open and green spaces, teeming with activities in the function of improving everyday life in Lower Town. Of particular importance in this context is the share of green areas of the block whose value was recognized in the early twentieth century in Berlages' plan for Amsterdam, when the interior of the block saw an interpretation of housing conditions in a traditional house by providing private gardens on the ground floor and grouped collective gardens in the center [14]. The proposed conceptual sketches differentiate the newly established public and green areas according to the size, type and manner of use and consider them a part of a fully designed system at the city level (urban green infrastructure).

The role of the street in modern sustainable planning is changing substantially. Following up on the example of the Barcelona model of superblock, it is proposed to discourage car traffic in the city center and transform individual streets into pedestrian or shared space zones. Their additional activation is possible by reaffirming the neglected spaces and opening new stores in the street ground floors of blocks, while taking into account the offer of content. With targeted city policies, it is possible to preserve some of Zagreb's traditional crafts with incentive systems, but also to meet the modern needs of residents and tourists. Outdoor terraces, as an extension of the use of the premises on the ground floors of buildings, have a very high potential to activate the streetscape. Their impact on morphological and social attributes of public space is reflected in the occupation of a large number of pedestrian areas, contributing to convivial feeling of security and safety in the neighborhood. Numerous cities, such as Barcelona, have recently seen an increase in the number of terraces in public space under the influence of multiple factors, such as tourism growth, the implementation of anti-tobacco law, prioritization of pedestrian realm in public space and, more recently, COVID-19 restrictions [49].

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Urban Morphometrics and the Intangible Uniqueness of Tangible Heritage. An Evidence-Based Generative Design Experiment in Historical Kochi (IN)

Alessandro Venerandi [1,*], Ombretta Romice [1], Olga Chepelianskaia [2], Kavya Kalyan [2], Nitin Bhardwaj [2], Vija Viese [2], Sebastián Ugás [2], Shibu Raman [3] and Sergio Porta [1]

[1] Urban Design Studies Unit, Department of Architecture, University of Strathclyde, Glasgow G1 1XQ, UK; ombretta.r.romice@strath.ac.uk (O.R.); sergio.porta@strath.ac.uk (S.P.)
[2] UNICITI, 31400 Toulouse, France; olga.chepelianskaia@uniciti.org (O.C.); kavyakalyan12@gmail.com (K.K.); design.nitinbhardwaj@gmail.com (N.B.); vija.viese@gmail.com (V.V.); sebastianugas@gmail.com (S.U.)
[3] Welsh School of Architecture, Cardiff University, Cardiff CF10 3NB, UK; ramans@cardiff.ac.uk
* Correspondence: alessandro.venerandi@strath.ac.uk

Abstract: Asia is urbanising rapidly. Current urbanisation practices often compromise sustainability, prosperity, and local quality of life while context-sensitive alternatives show very limited impact. A third way is necessary to integrate mass-production, heritage, and human values. As part of UNICITI's initiative, A Third Way of Building Asian Cities, we propose a scalable and replicable methodology which captures unique morphological traits of urban types (i.e., areas with homogenous urban form) to inform innovative large-scale and context-sensitive practices. We extract urban types from a large set of quantitative descriptors and provide a systematic way to generate figure-grounds aligned with such urban types. The application of the proposed methodology to Kochi (IN) reveals 24 distinct urban types with unique morphological features. Profiles, containing design-relevant values of morphometrics, are then produced for a selection of urban types located in the historical district of Fort Kochi/Mattancherry. Based on these, figure-ground design demonstrations are carried out in three sample sites. Outcomes seem aligned with the urban character of their respective types, while allowing distinct design expressions, suggesting that the proposed approach has potential to inform the design in historical/heritage areas and, more broadly, the search for a Third Way of Building Asian Cities.

Keywords: sustainable urbanisation; liveable urbanism; urban morphology; evidence-based design; Asian cities

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1. Introduction

Recent economic growth in Asian countries has resulted in rapid urbanisation in the region. Many cities are both rapidly expanding in size and population. These cities hosted 0.3 billion urban dwellers in the late 1950s, 2.1 billion in 2015, and are projected to host 3.3 billion by 2050 [1]. This unprecedented growth comes at the cost of significant vulnerabilities. The United Nations (UN), for example, estimates that 31.2% of the urban population of Central and Southern Asia currently reside in slums [2]. In addition, Asia is the most climate vulnerable region in the world. Summer temperatures are estimated to rise 6 degrees that could result in a rise of the sea-level by 1 m to affect most Asian cities, increasing the risk of floods and storm surges along the coastlines. Urban development also adds to these vulnerabilities due to the high greenhouse gas emissions associated with the use of conventional concrete, cement, brick, and steel materials [3]. The Global Infrastructure Basel Foundation estimates that more than 75% of the infrastructures that will be existent in 2050 are yet to be built, and a large part of them will be built in Asia [4]. Aforementioned challenges are likely to exacerbate further if the business as usual (BAU) way of building cities continues, in which case Asian urbanites will be locked into a low quality and unsustainable life conditions for decades.

The housing industry in Asia currently offers two main ways of urban expansion. The first features mass-produced building materials and neighbourhood designs out of corporate-centred urbanisation processes (Figure 1, left), targeting the expanding market of the urban middle/upper-middle class. As a result, Asian cities are overwhelmed by identical, standardised urban and building patterns repetitively iterated to cover most formally urbanised land independently from local social, economic, cultural, and environmental contexts [5].

Figure 1. Downtown of Mumbai (IN), example of BAU way of building (**left**) (source: [6]), and vernacular huts in Kutch (IN), example of niche, sustainable and local context-tailored building solutions (**right**) (source: [7]).

This BAU way of building is associated with higher carbon footprints and shorter lifespan of buildings. Every year, the world emits over 30 GT of CO_2 and nearly 40% of it are related to buildings, of which nearly 1/3 comes from manufacturing of conventional building materials such as iron and steel, cement, aluminium, and glass (estimate based on data from [8]). The operational energy consumed to run these buildings is also very high due to the incompatibility of the materials with the local context. Lighting, heating, ventilation, and air conditioning in glazed commercial buildings represent over 70% of the total consumed operational energy [9]. BAU buildings also last for less time. The average lifespan of a traditionally built building (bricks and wood) is at least twice that of a typical modernist building (reinforced concrete and glass curtain wall): 120 years versus 60 years [10]. The loss of place identity and sustainability associated with the BAU way of building cities goes hand in hand with the loss of economic competitiveness as qualified/talented individuals tend to settle in places with character and more liveable urban environments [11]. Related to this, the BAU way of building cities is also detrimental to urban liveability. According to The Economist Intelligence Unit, which measured liveability in terms of quality of life, mental and physical health, safety, walkability, public transport, and cultural and natural environments, and produced a ranking of the world's most liveable cities, two Asian cities (Osaka and Tokyo) feature in the top ten, however they are both located in the only developed country of the continent (Japan) [12].

The second current way of urban expansion relies on sophisticated, sustainable, locally sensitive, and context-tailored designs (Figure 1, right) for the cultural and social elites. This, however, represents a very small portion of the overall built-up stock. Finding a third way to build both fast, well, and affordable, is crucial and non-deferrable if a viable alternative to the lose-lose choice between unsustainable/insensitive/malfunctional urbanism and slum ghettoisation is to be factually found. Such Third Way of Building Asian Cities should meet today's infrastructure and housing needs of building fast and affordable in dense urban environments and, at the same time, the need to building unique, sustainable, and liveable cities made of places that recognise and treasure the spiritual and cultural identity of local communities as embedded in the spatial structure of tangible urban heritage. Most importantly, it should re-activate the interrupted cycle of continuous renovation and formation of the urban heritage of tomorrow, by consciously integrating in new planning policies and practices of the collective wisdom that historically was a natural part of the granular, local processes of city production. This is the mission of a non-for-profit initiative, A Third Way of Building Asian Cities, launched in September 2019 at the 55th ISOCARP World Planning Congress in Jakarta (ID), by UNICITI, a French think-tank and consultancy (https://www.uniciti.org, accessed on 31 August 2021).

This paper presents a contribution to phase 1 of the aforementioned initiative, which was initiated in December 2020. It aims at identifying viable alternative solutions that can help build a unique, sustainable, and liveable urban fabric in Asian cities today. In line with this initiative, we propose a replicable methodology, named Urban MorphoMetrics (UMM), that captures the morphological uniqueness of homogeneous urban areas and helps to design new masterplans with the advantage of a controllable awareness of it. More specifically, UMM: (i) identifies homogeneous patterns of urban form in cities, i.e., urban types (UTs hereon) via a rich description of current urban form, based on hundreds of numerical spatial descriptors (morphometrics); (ii) extracts from each UT its own numerical form code by distilling a sub-set of six main morphological features, which are relevant to city planning and place design; (iii) operationalises these profiles to inform the formation of evidence-based design codes (DCs hereon) in designated areas. UMM, is specifically designed to pair up richness of information with XL-scale of application, potentially fit to cover the whole of Asian cities. It is also of great relevance for urban heritage planning as it permits to capture the morphological essence of places and generates figure-grounds respectful of this essence, while not being replicas. More broadly, UMM allows to capture the "collective wisdom" embodied in historical/heritage urban types and shapes an urban future in line with it. This not only implies understanding and measuring the built heritage of the past, but also building tomorrow's heritage, that is, urban areas to which future residents will attribute values of identity, attachment, and use, which largely stay unchanged through time.

While UMM must be applied to the whole of Kochi to function, including UTs that are not in historical/heritage context, a proof of concept of UMM is presented in this work through its application to the historical district of Fort Kochi/Mattancherry. Here, we demonstrate that despite working in very challenging environmental conditions and with a largely sub-optimal base of input data, the UMM seems to demonstrate a significant ability to capture relevant features of the city of Kochi, which is the base for the development of an innovative generation of evidence-based design codes (EBDCs). We obtained 24 different UTs, characterised by distinctive morphological traits. Morphometric profiles are then extracted for three specific UTs, located in the historical district of Fort Kochi/Mattancherry. Moreover, figure-ground-only design demonstrations are generated for a selection of blocks within each selected UT. Design demonstrations—not to be confused with proper masterplan proposals—are abstract design exercises enacted as part of UMM's development. In this context, they are aimed at exploring the ability of UMM-based numerical design guidelines to lead a plurality of professionals towards design outputs which would be distinguishable from each other and yet visibly reflect the intangible "uniqueness" or "distinct character" of any UT, including historical ones. These exercises are to be considered successful if this intangible balance of unicity and typicality is achieved, insofar: (i) a radically reduced set of six only descriptors are plugged into the demonstration; (ii) figure-ground of building envelopes (rather than real building footprints) are actually designed, and (iii) demonstrations consistently achieve both terms of the balance across different UTs and, within each UT, across proposals by different designers.

The remainder of this paper is structured as follows: in Section 2, we illustrate the UMM methodology through which we identify UTs, obtain morphometric profiles, and operationalise them to generate figure-ground design demonstrations. We then present, in Section 3, the study area (the city of Kochi), its main geographical characteristics and urban development. In Section 4, we describe in detail the input dataset and urban form descriptors generated from it. We then show, in Section 5, the resulting numerical taxonomy of Kochi, the detailed morphometric profiles, and the figure-ground design demonstrations for three of its UTs. The paper finishes with a discussion of the results and conclusions in Sections 6 and 7.

2. Methodology

The methodology is illustrated in two parts. First, starting from a large set of morphometric descriptors, we identify the UTs at city-wide scale and produce their morphometric profiles (statistical elaborations of all descriptors applied to each UT). The second part uses these profiles to inform the figure-ground design demonstrations. Whilst these tests are purely conceptual at the moment, we explore their potential for applicability in real-life scenarios.

2.1. Morphometric Taxonomy and Profiling of Urban Types

The technique for the classification of UTs used in this paper is a development of previous work by Fleischmann et al. [13], specifically designed for this application. We thus summarise next its main features and illustrate with more detail advancements proposed and applied in this specific work. The morphometric taxonomy is the quantitative classification of morphological patterns starting from single measurable descriptors of urban form. Each descriptor measures a single dimension of the physical city (e.g., building footprint, coverage ratio, block size), while their combination detects recurring morphological patterns in a specific study area. Descriptors measure a variety of dimensional and relational aspects of basic components of urban form, at the very local scale of the components themselves and for local areas, accounting for spillover effects typical of spatial phenomena [14]. While previous studies (see, for example, [15,16]) selected one or very few descriptors to test specific but narrow research questions, this approach is based on the idea of comprehensiveness as well as richness of information, retaining the largest number of morphometric descriptors utilised in urban morphology that could operationally fit our technical framework, augmented with a few new ones allowed by our method alone, to comprehensively describe the urban form under examination [17].

The morphometric taxonomy relies solely on two georeferenced vector datasets: building footprints and street network. From these, morphological cells (a quantitative version of the cadastral parcel or plot) are created via a Voronoi tessellation-based partitioning of space [18], reflecting the zone of influence around each building; 74 primary characters are then computed for each cell across the entire study area, allowing to numerically quantify morphometric elements (street segments, building footprints, and cells) in any urban fabric, by capturing the relationships between them and their immediate surroundings. The entire list of primary characters can be found in Fleischmann et al. [13]. As mentioned above, a crucial aspect of this approach is accounting for the local context: four different statistics, or "contextual characters", are thus computed for each primary character over aggregations of cells around each cell and attributed to it. The interquartile mean is the average computed on the values between the first and third quartile of the distribution. The interquartile range is the range in values of the central 50% of the distribution. The inter-decile Theil index, a measure of local inequality, and the Simpson index, a measure of heterogeneity of values, are both measures of diversity. Full formulas for computing these statistics can be found in Fleischmann et al. [13].

Having computed the contextual characters, a cluster analysis is performed to synthesise this rich description and generate a taxonomy of UTs for the area under examination. The morphometric taxonomy presented by Fleischmann et al. [13] is based on the use of the Gaussian Mixture Model (GMM), a probabilistic version of the k-means clustering. However, the purely statistical nature of this technique, to a certain extent, jeopardises the result as, by not considering the spatial structure of the data, it introduces noise (i.e., misclassified buildings) in otherwise homogeneous UTs. For this reason, a different technique, i.e., agglomerative hierarchical clustering (AHC) [19], which imposes a spatial structure on the definition of the UTs is used in this paper. More specifically, AHC is a hierarchical technique of cluster analysis, which builds a tree (dendrogram) of clusters (UTs) starting from the single observations (buildings) up to a main branch, following a merge strategy based on the reduction of the sum of squared differences within all clusters. A third order connectivity matrix is used as a connectivity constraint to impose a spatial structure on the clustering (only nearby clusters can be merged together). The optimal number of clusters (UTs) is identified via the computation of the silhouette score, a common heuristic technique used for validating consistency in cluster analysis [20]. Since it is possible that the output of this method identifies UTs with too large variations in terms of urban form, successive rounds of clustering and silhouette scores can be performed on a selection of UTs to better differentiate sub-patterns. A final dendrogram, crucial to evaluate levels of similarity across UTs, can be built by recomputing the hierarchical tree starting from the cluster centroids of each UT.

Once the optimal solution is reached, morphometric profiles of UTs are built from six primary characters: cell area (CA), coverage ratio (CR), building footprint (BF), building elongation (BE), alignment to surrounding buildings (ASB), and mean distance between buildings (MDBB). These are selected due to the easy readability of their units (e.g., m^2, percentages) and because they provide enough spatial information to generate coherent figure-grounds in sample sites, within specific UTs. Furthermore, they are often used in design codes and guidance, such as the National Model Design Code recently proposed by the UK Government [21]. Importantly, morphometric profiles are offered for each UT in one table, reporting for each of the six primary characters: (i) 15 intervals of values identified through natural breaks' discretisation at the level of the entire study area, and (ii) the percentage of buildings falling in each of these intervals. This form allows designers to smoothly translate analysis outputs in (ranges of) design instructions.

2.2. From Morphometric Profile to Figure-Grounds

The development of figure-ground design demonstrations involved four professional urban designers of the UNICITI think-tank. They helped to conceptualise, test, and validate the workflow through a series of experiments. None of them had previously taken part in the development of UMM: they effectively acted in the role of end-users. This was intentional, as our aim was to test the applicability and effectiveness of UMM to professionals without any background knowledge. In particular, at this stage, we wanted to assess to what degree four different designers, working under an extremely reduced framework of six characters only, could come up with figure-ground proposals which: (i) were all different from each other, and yet (ii) all retained the typical "character" or "feeling" of the UT of reference.

A full illustration of the results of the exercise is provided in the Results section. The workflow developed by the UNICITI designers entails the following steps:

- *Selection of the sample site*. This is usually a brownfield, or an area designated by local authorities as developable, within specified design constraints to be integrated in this workflow. The iterative testing carried out by the UNICITI designers showed that the method works well at the meso-scale, that is, an area comprising a few blocks (at least 100 buildings), considering smaller areas would mean that intervals with small distribution percentages would not be represented. Having selected the site, this step requires the computation of its area (A) in m^2.
- *Computation of number of buildings (for the sample site and intervals of the six primary characters)*. Using the cell area (CA) intervals and distribution in the morphometric profile, the total cell areas per interval (TCA) is calculated by multiplying the median value of each interval (M) by the corresponding distribution percentage. The total number of buildings for the sample site is computed by multiplying the site area (A) by 100 (the total of all intervals) and dividing this value by the sum of TCAs. The number of buildings in each interval, for each primary character, is computed

by multiplying the distribution percentages for each interval by N and dividing this value by 100.

- *Generation of the building envelopes*. To avoid uniformity in figure-grounds, a random set of x values, where x is the number of buildings in each interval computed at the previous step, is generated for each interval for BF and BE. The generated building footprints and elongation values are then randomly matched. Both operations of random number generation can be achieved in Excel via the RAND function, or through ad hoc websites (for example, https://pinetools.com/random-number-generator, accessed on 31 August 2021). The longer dimension (LD) of each building is computed by calculating the square root of the ratio between BF and BE. The shorter dimension (SD) is calculated by dividing BF by LD.
- *Design considerations*. Several considerations must be made on the UT around the sample site before laying the buildings on the ground: (i) function and spatial distribution of buildings (i.e., clustered or sparse) and their relations with open spaces; (ii) whether buildings tend to abut on the streets with their short or long sides; (iii) whether the street network tends more to a grid or a tree-like structure. Such considerations are purely qualitative and are made from remote via a quick visual inspection of commonly available map repositories.
- *Generation of the figure-ground*. This is a four step process: (i) in order to maintain and foster the internal connectivity of the sample site as well as that between the sample site and its surroundings, lay down the main street network by continuing the major roads surrounding the site; (ii) start distributing the building envelopes from one side of the site by following the considerations formulated at the previous point; (iii) if necessary, add secondary streets to make each building in the site accessible; (iv) verify whether alignments and distances between buildings correspond to the values of ASB and MDBB.

3. Kochi

Kochi (or Cochin) is a coastal city with a population of 0.67 million [22] in the southern Indian state of Kerala. It is an important port town with tremendous industrial and tourism potentials. It is one of the 100 cities that was selected for the smart city funding from the Government of India [23]. Today's Kochi consists of the historical Fort Kochi and Mattancherry peninsula, Ernakulam mainland, reclaimed Wellington Island, Bolgatti Island, Vipin island, and several other islands in the estuary of the Vembanad lake, adjoining the Arabian sea.

The great flood of the river Pariyar (1341) resulted in the formation of a new natural harbour. The Kochi state, formed in 1102, shifted its capital to Kochi in 1405 following this flood [24]. By 1440, a large settlement around Mattancherry hosted a wide variety of traders from China to the Middle East, making Kochi an important port town on the southwest coast of India [24]. By 1503, skirmishes between the Portuguese army and the local kingdom resulted in the battle of Kochi, with the Portuguese taking control of the city [25]. In 1665, the Dutch and, by 1795, the British, captured this important port town and controlled the spice trade [25]. By 1814, Kochi became part of the British empire who ruled the town until independence in 1947. During this period, Kochi expanded significantly in its population and area (Figure 2) to its current form.

Kochi today is a strategic port city on the western coast of India. It hosts the headquarters of the southern naval command and the new container terminal of Vallarpadam island that opened in 2011, making it the 4th most productive in the country [27]. Kochi's predominant economic sectors include IT, tourism, ship-making, spice export, health services, and banking [28]. Even today, the influence and fusion of Arab, Chinese, Portuguese, Dutch, and British periods can be seen in the architecture and culture of the city, with many historical buildings, religious spaces, as well as intangible cultural elements such as foods, traditions, customs, or the practise of different languages in everyday life [29].

Figure 2. Expansion of Kochi from 1890 to 1980. Source: [26].

4. Dataset, Primary, and Contextual Characters

UMM relies on the input information of two georeferenced datasets: building footprints and street network. However, since reliable information on the latter was missing in Kochi, the methodology was adapted to use only building footprints instead. These were manually drawn in vector format by architecture students at Cardiff University (UK), between October 2020 and January 2021. The area of Kochi considered in this paper (Figure 3) consists of 94,963 buildings. Due to aforementioned data constraints, only 26 of the 74 primary characters of urban form were considered, after exclusion of all those related to streets. For instance, in terms of buildings, footprint areas, elongation, and alignment to neighbouring buildings were measured. In terms of cells, size, coverage ratio, and ratio between number of neighbouring cells and cell perimeter were calculated; 104 contextual characters were then derived from the 26 primary characters by computing their mean, range, Theil index, and Simpson index for local areas up to three topological steps. The 26 primary characters and the 104 contextual characters alongside their median values across the study area are presented in Table A1, in the Appendix A.

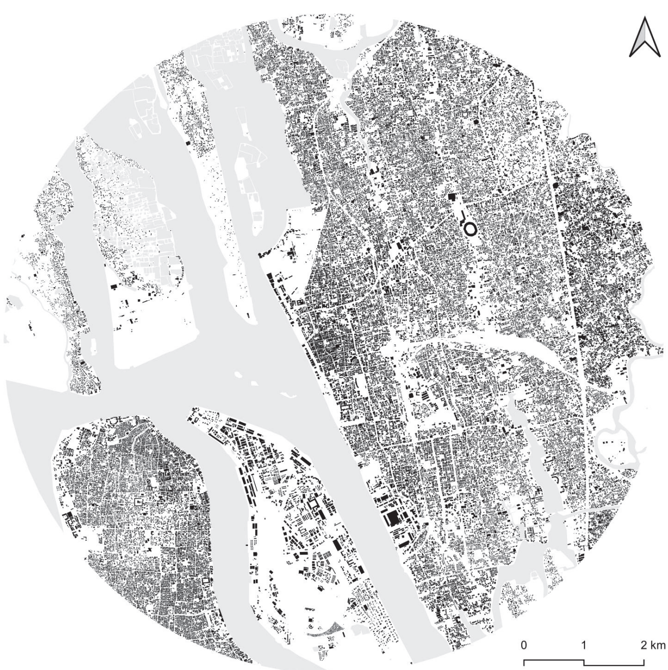

Figure 3. Study area. Black represents building footprints, the only input information used for the UMM application in Kochi.

5. Results

5.1. The Morphometric Taxonomy of Kochi

AHC, with a third order connectivity matrix as spatial constraint, was recursively applied to the 104 contextual characters for solutions up to 25 clusters. The best silhouette score, combining best value with the most detailed classification, was found for 17 clusters (UTs). However, after having mapped this result, two UTs, roughly corresponding to the historical district of Kochi/Mattancherry and Marine Drive were still characterised by considerable morphological heterogeneity. For example, the latter included both the area of the historical Ernakulam Bazaar, characterised by a dense, fine-grained urban fabric, and a newly developed area north-west of the Kerala High Court, which, although being dense, did not have the same granular urban fabric of the former. A second round of agglomerative clustering was thus performed on these two UTs. Through the silhouette score technique, seven clusters (UTs) were found to be the optimal representation of Marine Drive and five in the historical district. By combining this clustering output with the first one, 24 different UTs were identified overall. The unified dendrogram and map of Kochi with buildings colour-coded according to their respective UT and levels of similarity are presented in Figures 4 and 5, respectively; in both figures, a colour-code is attributed to UTs such that each UT is distinctively identified by a different colour, and the more similar the colours, the more similar the urban form.

The 24 UTs seem to align with different phases of urban development of Kochi as well as specific functional areas, providing a first validation of the effectiveness of the process. The most historical part, located in the west peninsula, is largely characterised by UTs in the green shades (e.g., UT6, UT7, UT8). These typically feature a rather uniform, informal urban fabric, with permeable street networks, blocks of regular size, traversed by pedestrian paths, high block, and cell coverage, with small cells and building footprints. Often occupied by makeshift buildings of one storey only, ground floors, especially along main streets, host a range of commercial activities. Streets are often of variable width with several levels feeding into each other. The area of historical warehouses, located around the top of the peninsula, are correctly classified as a separate UT (i.e., UT11): this is mainly characterised by a compact, medium built-up density, one two-storey building on tight cells, aligned to respond to street hierarchy, often hosting public and retail activities on the ground floor. Larger cells and buildings are generally located along main roads and crossings. Blocks are quite regular, with high internal permeability thanks to interconnecting lanes. Willingdon Island (located east of the peninsula hosting the historical core of Kochi) with its mix of military, maritime, and industrial buildings is well represented by UT15: this type is mainly characterised by bulky buildings, a great diversity of cell and building sizes, generally much greater than in any other UTs. Access takes place from main arteries and many cells have direct access to water. It has an unconventional form, ad hoc to function. Kochi mainland has also undergone different phases of urban development and hosts specific functional areas seemingly reflecting the UTs identified through the UMM approach. More precisely, we notice a correspondence between the oldest parts of Kochi mainland, facing the backwaters of the Arabian Sea, dating back to the beginning of the 20th century, and the UTs represented with warm colours. UT21, for example, largely corresponds to the historical area of the Ernakulam Market: it features above-average density, a relatively more chaotic urban fabric, with both compact and elongated buildings mostly not aligned with their respective cells, except in the three main streets of the area (Market street, Broadway, and Jew street). For what concerns more recently developed areas, UT12 seems to capture most of them. It is mainly characterised by a fairly homogeneous, granular, dense urban fabric, often punctuated by large, specialised buildings (e.g., Jawaharlal Nehru Stadium, PVS Memorial Hospital) and infrastructures; here, the former tend to colonise the edges of main urban roads, while ordinary types are independent, compact, medium density buildings, with medium cell coverage and in close proximity to each other, with access from a network of secondary and local streets. Each block has a high permeability due to frequent capillary roads and cul-de-sacs. The orientation of buildings is more regular along main roads, while it breaks down towards the inner parts of blocks.

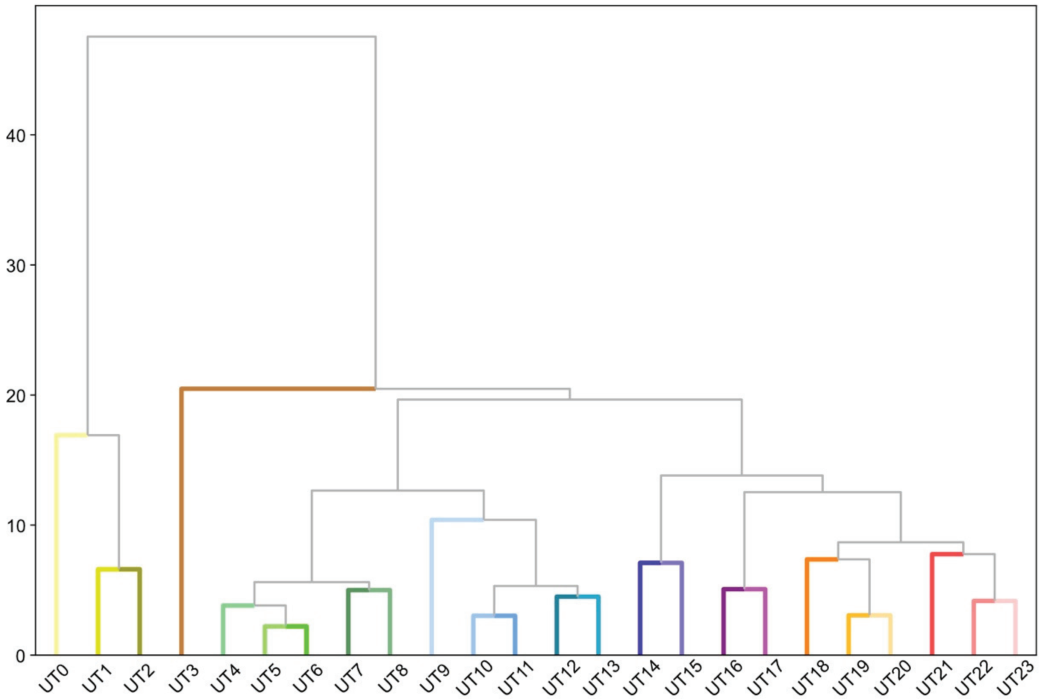

Figure 4. Dendrogram of the 24 UTs of Kochi, colour-coded according to their level of similarity. The *y*-axis represents Euclidean distances between UTs.

5.2. Morphometric Profiles of Urban Types in the Historical District of Kochi

Since the research aims at exploring the degree to which (re)-generative figure-ground design demonstrations capture the intangible character of pre-existing urban fabrics, and this is particularly relevant in historical sites, morphometric profiles are generated for three UTs (i.e., UT7, UT18, and UT1) located in the historical district of Fort Kochi/Mattancherry. Intervals for the six primary characters and percentages of buildings falling in each interval for UT7, UT18, and UT1 are provided in Tables A2–A4, respectively, in the Appendix B. UT7 is characterised by a very fine-grained, relatively dense urban fabric, with most cells (90%) and most buildings (61%) falling in the first interval of their respective distributions, i.e., up to 336.1 m^2 and up to 79 m^2, respectively. Coverage ratios tend to be more evenly distributed, however, the intervals with more observations (those with more than 10% of them) have values around 0.50 (i.e., 50% cell coverage). Mean distances and alignments between neighbouring buildings tend also to be very small: 46% of buildings are located between 0.1 and 3.7 m from their nearest neighbours and tend to align with them, most buildings diverging only between 1.4 and 4.8 degrees. In terms of elongation, buildings of UT7 show values evenly distributed across intervals, corresponding to a mix of building footprints, from squares to elongated rectangles.

The morphometric profile of UT18 suggests a slightly coarser and less dense urban fabric, with roughly half of the cells falling in the first interval (up to 336.1 m^2) and 34% being in the second one (i.e., between 336.1 and 650.9 m^2). Building footprints follow a similar pattern, with most (40%) concentrating in the second interval, i.e., between 79 and

145.1 m^2. Cells of UT18 tend also to be less built-up than in UT7, with most concentrating in intervals with coverage ratios between 0.29 and 0.47, corresponding to a coverage of 29% and 47%, respectively. As in UT7, buildings tend to be close to each other, 62% are less than 8.3 m away from their respective neighbours, and aligned with them, 77% diverge for 4.8 degrees or less. Finally, building footprints of UT18 tend to be more square-shaped than rectangular, with most observations falling into the top seven intervals.

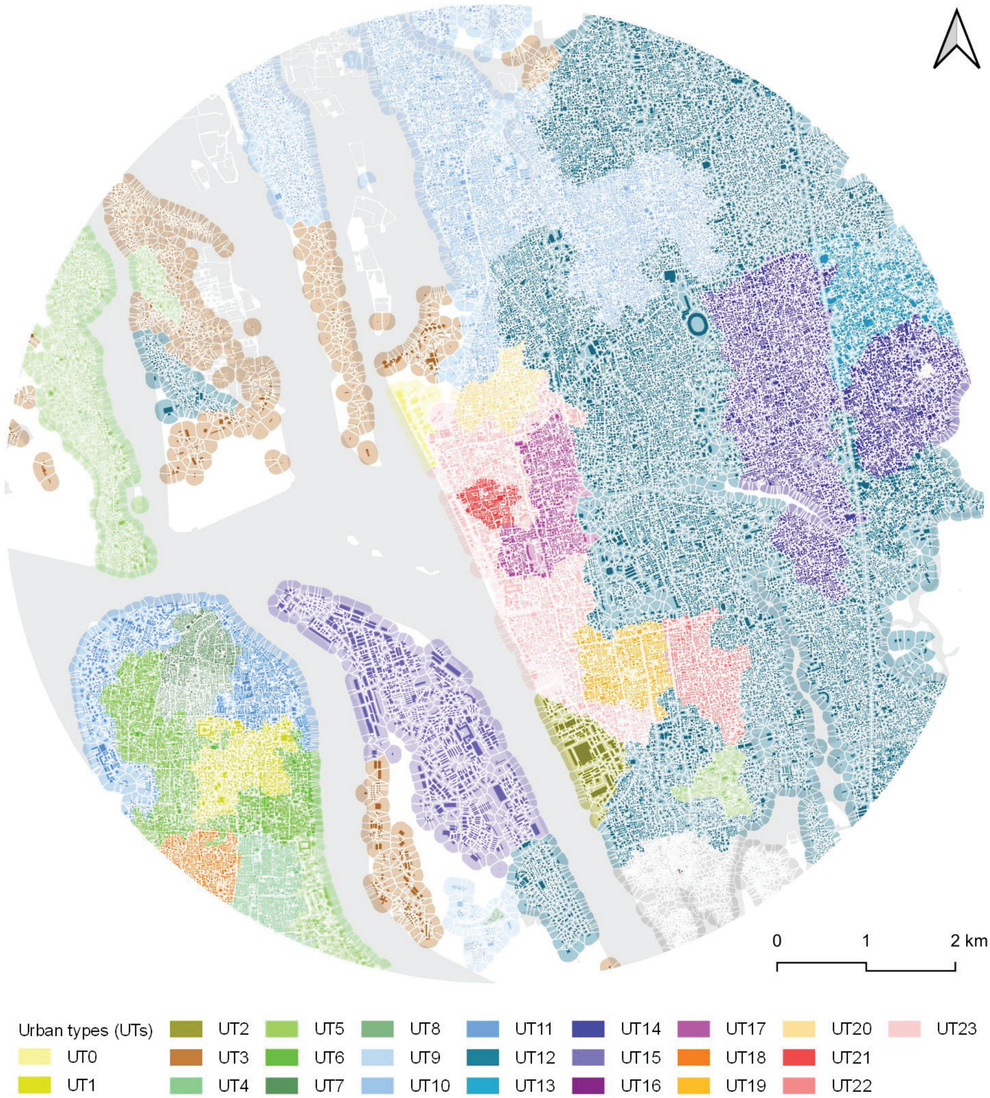

Figure 5. Morphometric taxonomy of Kochi. Buildings are color-coded according to their respective UTs and level of similarity.

UT1 is the least dense and coarsest of the three, with most cells (36%) measuring between 336.1 and 651 m^2, and most building footprints (42%) measuring between 79 to 145 m^2. Coverage ratios tend to be lower than in UT7, with most values (intervals with more than 10% of observations each) concentrating between 0.11 and 0.33, i.e., 11% and 33%

cell coverage, respectively. Mean distances between buildings tend also to be slightly larger than in UT7, with most being distant from 3.7 to 17.3 m with respect to their neighbours. On the other hand, buildings tend to be more aligned with each other than in UT7, with most (41%) diverging between 0 and 1.4 degrees. In terms of elongation, building footprints tend to be more square-shaped, with most values concentrating in the top intervals of the distribution.

5.3. Producing Figure-Grounds in Sample Sites

In this section, we present three figure-ground design demonstrations in sample sites that belong to UT1, UT7, and UT18. The first is illustrated in detail, including the process that generates building envelopes from the morphometric profile. The other two applications are purely demonstrative and showcase one design solution for each UT. Since at the time of writing the article, no development areas were officially identified in the district Fort Kochi/Mattancherry, the demonstrations are purely abstract and the only discriminant for the selection of the sample sites is the size (not less than 100 buildings as explained in the Methodology section).

The sample site in UT1 exhibits 140 buildings and has an area (A) of 114,541.7 m^2. It is delimited by Jawahar road to the north, Santo Gopalan road to the east, Cochin College road to the south, and Pandikudy road to the west (Figure 7, top left). After removing the existing fabric, three of the four UNICITI designers involved in the development of the workflow set out to develop, independently, a design iteration each for the site.

To do so, intervals and distribution percentages of CA (Table A2, Appendix B) were used to compute the sum of TCAs (Table 1) and the total number of buildings (171) for the sample site by multiplying A by 100 (the total of all intervals) and dividing this value by the sum of TCAs (66,958 m^2). Having obtained this datum, the number of buildings for each interval, for each of the six primary characters, were then calculated (see Table 2, as an example for BF). Random values were then generated for each interval and primary character, to obtain the actual dimensions of the building envelopes that will populate the site. Values of BF and BE were then randomly matched to avoid uniformity in the new urban fabric, and longer (LD) and shorter dimensions (SD) for each building were subsequently computed. Figure 6 shows the resulting building envelopes for the selected sample site, with intervals and distribution percentages of BF.

Table 1. Computing total cell areas (TCA) and sum of TCAs for the sample site in UT1, starting from intervals and distribution percentages of cell areas (CA) contained in the morphometric profile (Table A2, Appendix B).

CA Intervals	% Cells	Median (M)	Total Cell Areas (TCA)
(24.60, 336.09)	29.70	180.35	5356.91
(336.09, 650.88)	36.59	493.49	18,057.90
(650.88, 1080.39)	20.22	865.64	17,505.06
(1080.39, 1677.60)	9.33	1379.00	12,870.62
(1677.60, 2515.36)	2.89	2096.48	6056.50
(2515.36, 3689.55)	0.59	3102.46	1838.49
(3689.55, 5266.39)	0.37	4477.97	1658.51
(5266.39, 7385.03)	0.07	6325.71	468.57
(7385.03, 10,282.65)	0.07	8833.84	654.36
(10,282.65, 14,106.60)	0	12,194.63	0.00
(14,106.60, 19,523.60)	0.15	16,815.10	2491.13
(19,523.60, 26,922.44)	0	23,223.02	0.00
(26,922.44, 35,608.03)	0	31,265.24	0.00
(35,608.03, 48,659.49)	0	42,133.76	0.00
(48,659.49, 67,909.16)	0	58,284.33	0.00
			Sum: 66,958.05

By visually inspecting the main spatial characteristics of UT1, the three UNICITI designers then produced the following design observations to guide the positioning of the building envelopes on the site. UT1 is characterised by both relatively small buildings in close proximity, constituting the majority of the ordinary urban fabric of this UT, and isolated specialised ones, often surrounded by open space. Both types of buildings tend to abut on nearby streets from which they are accessed with their shortest sides. The existing street network is relatively regular and well connected, tending more to a grid than a tree-like structure. Along main streets, especially those pointing towards landmarks, cell, and building alignments, are more regular. These observations, together with the last step of the methodology, were then used by the UNICITI designers to independently generate three figure-ground assemblages (Figure 7, top right, bottom left, bottom right) for the sample site (Figure 7, top left). Starting from re-connecting the street network, around and through the site, using the context as guidance of local practice, they followed with arranging buildings along main streets and spaces, and adding secondary streets. The results show how a similar urban character was achieved, but in three distinctive attempts, all considerate of the existing contextual character. This suggests that, as a design aid, the morphometric analysis combined to the workflow were effective in generating urban fabrics structurally similar, but not identical to that typical of UT1.

Table 2. Number of buildings for intervals of BF.

BF Intervals	% Buildings	No. of Buildings
(12.02, 78.95)	20.15	34
(78.95, 145.13)	42.00	72
(145.13, 234.55)	24.07	41
(234.55, 371.63)	8.30	14
(371.63, 585.08)	3.56	6
(585.08, 910.02)	0.59	1
(910.02, 1430.61)	0.81	1
(1430.61, 2212.47)	0.30	1
(2212.47, 3423.68)	0.07	0
(3423.68, 5308.78)	0.07	0
(5308.78, 7792.22)	0.07	0
(7792.22, 10,715.89)	0	0
(10,715.89, 14,611.60)	0	0
(14,611.60, 26,037.39)	0	0
(26,037.39, 34,898.16)	0	0

To demonstrate the capability of the workflow, two further exercises of figure-ground generation for UT7 and UT18 are presented in Figure 8. Note that, this time, for matter of brevity, calculations are omitted. The sample site in UT7 is delimited by Eraveli Road to the north, Mohammad Abdul Rahaman Road to the east, Pullupalam Road to the south, and Chakkara Idukku Road to the west. The sample site in UT18 is delimited by Kocheri road to the north, Mary Auso Vaidhyar Road to the east, Pt Joseph road to the south, and Nazareth road to the west. Just out of a visual assessment, the design outputs (Figure 8, top right and bottom right) seem to confirm the ability of the proposed approach of producing new urban fabrics in line with the character and uniqueness of existing ones (Figure 8, top left and bottom left).

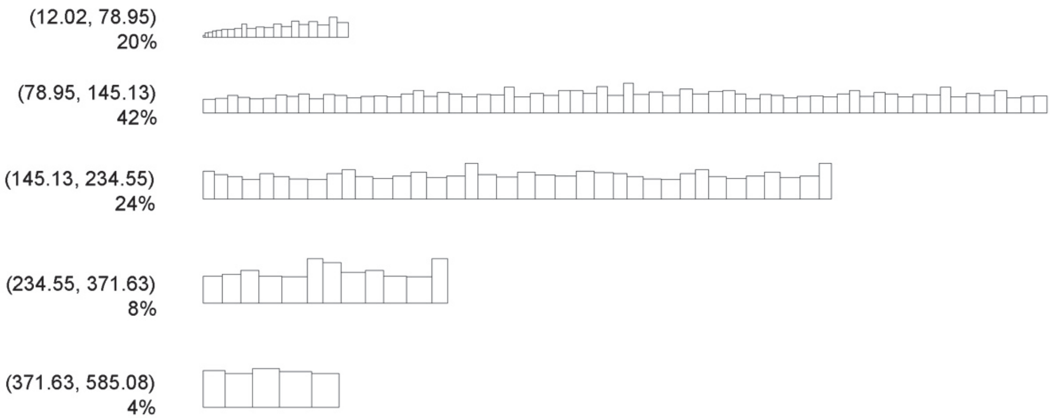

Figure 6. Resulting building envelopes for the sample site, with BF intervals and distribution percentages.

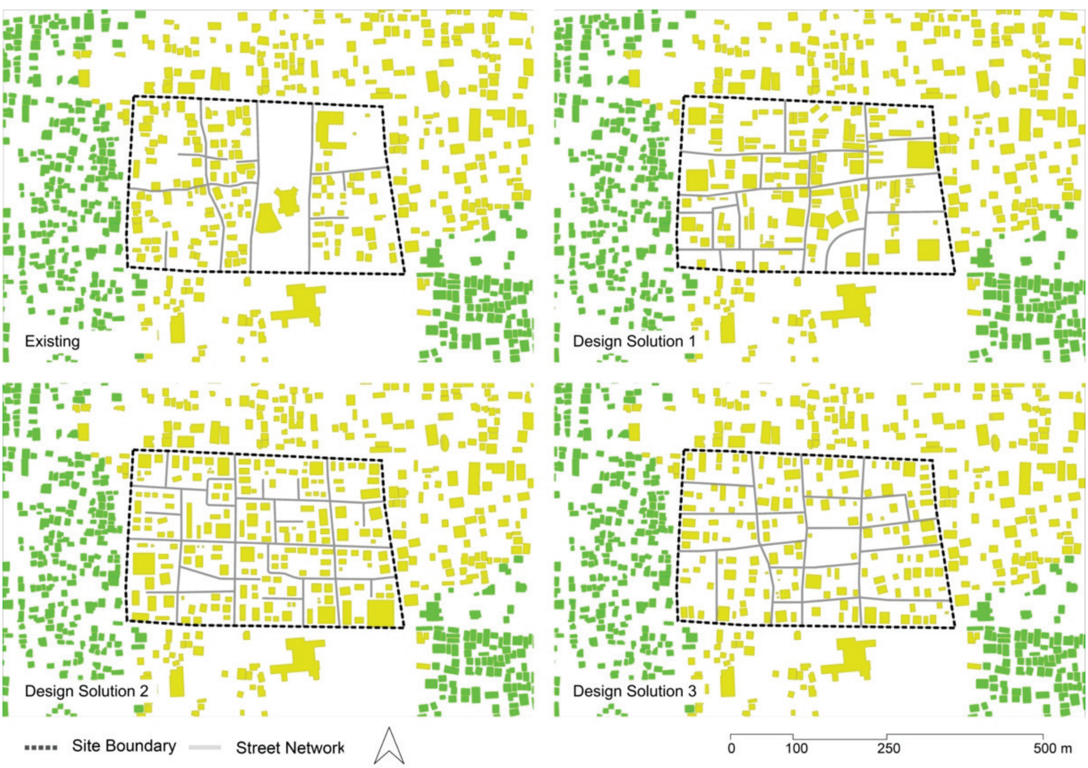

Figure 7. Sample site with existing fabric (**top left**) and three different figure-ground design demonstrations (**top right**, **bottom left**, **bottom right**) proposed by three different designers, in compliance with the morphometric profile of UT1.

Figure 8. Two sample sites with existing fabrics (**top left**, **bottom left**) and two figure-ground design demonstrations (**top right**, **bottom right**) proposed by the same designer, in compliance with their morphometric profiles, UT7 and UT18, respectively.

6. Discussion

In terms of significance of the results, as a design tool, UMM generates typical iterations for selected UTs. Importantly, the workflow leads to the formation of figure-grounds in terms of building envelopes, hence not in terms of real shape nor function. It needs to be reiterated that although UMM can potentially provide useful information to inform a new generation of evidence-based design codes (EBDCs), this potential, as such, is not explored here. At this stage, we are presenting a design demonstration whose subject matter is a fairly reduced proxy of what can be obtained from a full UMM application, in particular, because of data limitations (we are working with 26 out of 74 primary characters of urban form), which do not include any information on streets and building heights. In short, UMM is run on building footprint information alone. As a result, the UTs are identified on the ground of only 104 out of the full set of 296 contextual descriptors normally utilised with optimal input data. Understanding the degree of quality of UMM's output under such largely sub-optimal input conditions was also a reason why we embarked in the study of Kochi in the first place.

In terms of validation, notwithstanding these aforementioned constraints, after a detailed validation (see Section 5.1) conducted with students and staff of Cardiff University, experts with direct experience of the place, against Kochi's urbanisation history and mainland-uses' distribution, we do observe that the resulting taxonomy seems to capture the main characters of the real city to a surprising degree. This gave considerable support to the outputs. However, a systematic process of validation against other layers of social, economic, and environmental information will require further investigation.

In terms of relevance of the proposed methodology and results, UMM-based numerical design guidelines seem to be effective in helping distinct designers towards delivering design outputs that both capture the intangible essential quality that makes for the unique identity of historical UTs of Kochi and yet remain clearly distinguishable from each other. Most importantly, this ability shows up: (i) out of an application based on sub-optimal input data; (ii) over the design of figure-ground building envelopes only, and (iii) across different demonstrations both delivered by different designers over the same UT and by the same designer over different UTs. In all evidence, this potential is particularly interesting when applied in historical/heritage areas, where morphological assets are recognisably associated with deep local socio-cultural contexts and fragile values of place identity, hence continuity with such traits is particularly valuable. However, we would like to stress the importance for Asian cities not only to preserve their current heritage from their valuable past, but also to build today the heritage of their equally valuable future. Stating this means highlighting the importance to learn the essential nature of the past we still treasure to link it up to the present we operate in. A nearly madly ambitious task, to be true, which certainly cannot be reduced to the physical structure of spaces and must involve the forms of city production, its governance and industrial management, its equity and political viability. As per the master planning process alone, it is our ambition, in this paper, to account for an innovation of technical nature that we believe can promote helpful progress in many aspects of urban (heritage) planning. Most importantly, such innovations could potentially impact on the other—and often neglected—side of the medal, which involves the informal settlements of today and tomorrow, along with slums' community protagonism in their production and development in time. Further site analyses and considerations should be carried out to gather more context-based knowledge, which is fundamental to transform figure-ground envelopes through the workflow, helping to define their architectural styles, their relations with private/public spaces, street sections, and surfaces. The workflow for figure-ground generation must also be adapted to reflect possible constraints dictated by local design briefs. The first application of the workflow shows a range of alternatives, none of which is identical to the existing one nor between each other, but all are close to it in terms of figure-ground, character, and circulation showing that we are in the position to generate urban fabric from a limited set of input data which is similar in substance to the original one, but not identical to it. This overcomes a frequent criticism of generative design, perceived as deterministic or acritical. The proposed workflow can be a powerful, evidence-based tool in the hands of designers who want to capture and reproduce the essential character of a place, in fact, any place that makes sense to them as well as the communities involved in the process. This does not mean to reproduce acritically design solutions, but to replicate the structural spatial patterns that have proven an ability to develop, in time, qualities which are considered valuable assets in current society. Such quality should not be reduced to aesthetic ones, but, in fact, involve quality of adaptability in time, hence resilience, flood recovery, support to healthy lifestyle, and walkable access to basic services, etc. This preliminary demonstration suggests that the combination of UMM and a new generation of EBDCs could inform a positive development of the BAU way of building towards a more sensitive and locally responsive urban development framework while, at the same time, keeping it responsive to current requirements, standards and needs. It is also an alternative to niche, context-based, but small-scale developments as the approach is replicable and scalable and can thus be applied to cities and project sites of virtually any size. It can be effective in situations characterised by limited resources, difficult operative conditions, political instability, and widespread informal practices. By providing an established background of knowledge (of UTs and their effectiveness in their context) and flexible spatial proposals, it can also help to retain overall quality control while, at the same time, allowing for the co-production of space. One natural avenue to exploit the potential of UMM towards this Third Way for Asian Cities is testing DCs based on a rigorous, replicable, scalable, and comprehensive science of urban form. Such science is by no means mature but is now rapidly expanding with and beyond the proposed

UMM method. The implications on policy are many and currently under development in forthcoming publications.

In terms of limitations, we acknowledge three main ones. First, while the clustering process to identify UTs is unsupervised, the selection of the optimal number of UTs is based on a heuristic method (i.e., the silhouette score), leaving space to interpretation. Kochi might thus be defined by a different number of UTs. Nonetheless, having tested different clustering solutions and comparing them to phases of urban development and existing functional areas, we believe 24 to be a faithful representation of the different urban fabrics of the city. A second limitation concerns the presence of outliers in the data (e.g., too small BFs). Due to the size of the input dataset, these might go unnoticed, creating a partially biased representation of specific intervals in the morphometric profiles. If that is the case, the morphometric profiles containing outliers can be used to identify them and correct or filter the input dataset. A third limitation is inherent to scalability: a first-hand, accurate, human-based site survey cannot be replaced by any unsupervised morphometric procedure, and, in fact, it should not. UMM should be seen as a large-scale applicable ecosystem whose best use is in conjunction with local, project-specific, and community-based surveys, or, in fact, the development of project-languages along the human-based tradition mastered, for example, in Alexander's pattern language work [30,31].

7. Conclusions

Asian cities are developing exceptionally fast. How we guide and support such development is crucial, for those living in it, for the planet, for both environmental, cultural, and economic reasons. The BAU mode has already compromised the physical and social significance of many urban environments, with forms which are incompatible under many points of view. On the other hand, niche and more sustainable ways of building can embed local cultural contexts, however, they are not capable of coping with the large demand for new housing. This context calls for an alternative which can simultaneously ensure quantity, affordability and, at the same time, respond to the need of building unique cities which embed local cultural values. In this paper, to address this challenge, we proposed a replicable and scalable methodology to: (i) detect morphological uniqueness in cities via the identification of homogeneous patterns of urban form (UTs); (ii) extract morphometric profiles for target UTs; (iii) input this information in a workflow for the generation of new urban fabrics aligned with the character and uniqueness of their respective UTs. The proposed methodology was applied to the city of Kochi, where 24 different UTs were identified, seemingly matching historical-functional patterns. Three morphometric profiles were generated for UTs located in the historical district of Fort Kochi/Mattancherry and used as inputs for figure-ground generation. The outputs showed that, by using the same workflow, it is not only possible to produce urban fabrics aligned with the morphological character of their respective UTs, but also produce different design solutions for the very same sample site. The combination of morphometric analysis and workflow for figure-ground generation can contribute to the production of context-based design in historical/heritage areas and, more broadly, to the above-mentioned Third Way of Building Asian Cities, by providing a scalable and systemic way of identifying the unique character of different city parts and producing design outputs aligned with such uniqueness. While this approach has been presented in relation to the rapid urbanisation in Asia, it is still replicable in virtually any place in the world, provided that, at least, data on buildings are available.

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Appendix A

Table A1. The 26 primary characters and 104 contextual characters with their median values across the study area.

Primary Character	Element	Formula	Contextual Character	Median
Footprint	Building	a_{blg}	mean range Theil index Simpson index	124.1678 93.3752 0.0868 0.4644
Perimeter	Building	p_{blg}	mean range Theil index Simpson index	46.1862 18.5704 0.0251 0.4094
Courtyard area	Building	a_{blgc}	mean range Theil index Simpson index	0.0000 0.0000 0.0000 1.0000
Cardinal orientation	Building	$Ori_{blg} = \mid O_{blgB} - 45 \mid$	mean range Theil index Simpson index	12.2051 6.4277 0.0489 0.2978
Cell alignment	Building	$CAl_{blg} = \left\| Ori_{blg} - Ori_{cell} \right\|$	mean range Theil index Simpson index	6.4250 9.7176 0.2585 0.5192
Circular compactness	Building	$CCo_{blg} = \frac{a_{blg}}{a_{blgC}}$	mean range Theil index Simpson index	0.5561 0.0996 0.0049 0.2056
Corners	Building	$Cor_{blg} = \sum_{i=1}^{n} C_{blg}$	mean range Theil index Simpson index	4.0000 0.5000 0.0171 0.5946
Squareness	Building	$Squ_{blg} = \frac{\sum_{i=1}^{n} D_{c_{blgi}}}{n}$	mean range Theil index Simpson index	3.3104 3.4466 0.1722 0.6333
Equivalent rectangular index	Building	$ERI_{blg} = \sqrt{\frac{a_{blg}}{a_{blgB}}} * \frac{P_{blgB}}{P_{blg}}$	mean range Theil index Simpson index	0.9959 0.0168 0.0003 0.6307
Elongation	Building	$Elo_{blg} = \frac{l_{blgB}}{w_{blgB}}$	mean range Theil index Simpson index	0.7162 0.2668 0.0180 0.1834
Centroid-corner distance deviation	Building	$CCD_{blg} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(ccd_i - \overline{ccd}\right)^2}$	mean range Theil index Simpson index	0.2971 0.6086 0.4551 0.5749

Table A1. *Cont.*

Primary Character	Element	Formula	Contextual Character	Median
Centroid-corner mean distance	Building	$CCM_{blg} = \frac{1}{n}\left(\sum_{i=1}^{n} ccd_i\right)$	mean range Theil index Simpson index	7.9237 2.9362 0.0207 0.3981
Area	Cell	a_{cell}	mean range Theil index Simpson index	457.3075 403.0552 0.1043 0.7593
Cardinal orientation	Cell	$Ori_{cell} = \lvert o_{cellB} - 45 \rvert$	mean range Theil index Simpson index	15.8594 13.9275 0.1125 0.2255
Weighted neighbours	Cell	$WNe_{cell} = \frac{\sum cell_n}{p_{cell}}$	mean range Theil index Simpson index	0.0685 0.0254 0.0179 0.4150
Coverage ratio	Cell	$CAR_{cell} = \frac{a_{blg}}{a_{cell}}$	mean range Theil index Simpson index	0.3127 0.1811 0.0464 0.2180
Circular compactness	Cell	$CCo_{cell} = \frac{a_{cell}}{a_{cellC}}$	mean range Theil index Simpson index	0.5232 0.1452 0.0104 0.1742
Equivalent rectangular index	Cell	$ERI_{cell} = \sqrt{\frac{a_{cell}}{a_{cellB}}} * \frac{p_{cellB}}{p_{cell}}$	mean range Theil index Simpson index	0.9890 0.0660 0.0006 0.4214
Perimeter wall length	Adjacent buildings	$p_{blg_{adj}}$	mean range Theil index Simpson index	47.1169 19.6771 0.0283 0.4360
Shared walls' ratio	Adjacent buildings	$SWR_{blg} = \frac{p_{blg_{shared}}}{p_{blg}}$	mean range Theil index Simpson index	0.0000 0.0000 2.0809 1.0000
Number of courtyards	Adjacent buildings	$NCo_{blg_{adj}}$	mean range Theil index Simpson index	0.0000 0.0000 0.0000 1.0000
Alignment	Neighbouring buildings	$Ali_{blg} = \frac{1}{n}\sum_{i=1}^{n} \lvert Ori_{blg} - Ori_{blg_i} \rvert$	mean range Theil index Simpson index	4.0671 2.6006 0.0541 0.5052
Mean distance	Neighbouring buildings	$NDi_{blg} = \frac{1}{n}\sum_{i=1}^{n} d_{blg,blg_i}$	mean range Theil index Simpson index	9.3790 7.0551 0.0729 0.6777

Table A1. *Cont.*

Primary Character	Element	Formula	Contextual Character	Median
Mean inter-building distance	Neighbouring buildings	$IBD_{blg} = \frac{1}{n}\sum_{i=1}^{n} d_{blg,blg_i}$	mean range Theil index Simpson index	11.1417 2.5860 0.0074 1.0000
Building adjacency	Neighbouring buildings	$BuA_{blg} = \frac{\sum blg_{adj}}{\sum blg}$	mean range Theil index Simpson index	1.0000 0.0000 0.0000 0.6859
Area covered	Neighbouring cells	$a_{cell_n} = \sum_{i=1}^{n} a_{cell_i}$	mean range Theil index Simpson index	3917.0594 2540.8757 0.0556 0.7752

Appendix B

Table A2. Morphometric profile of UT1.

CA Intervals	% Cells	CR Intervals	% Cells	BF Intervals	% Buildings	BE Intervals	% Buildings	ASB Intervals	% Buildings	MDBB Intervals	% Buildings
(24.60, 336.09)	29.70	(0.01, 0.06)	1.26	(12.02, 78.95)	20.15	(0.07, 0.20)	0.59	(0.00, 1.43)	40.59	(0.82, 3.67)	4.30
(336.09, 650.88)	36.59	(0.06, 0.11)	5.63	(78.95, 145.13)	42.00	(0.20, 0.31)	1.93	(1.43, 2.31)	20.59	(3.67, 5.95)	12.81
(650.88, 1080.39)	20.22	(0.11, 0.16)	11.63	(145.13, 234.55)	24.07	(0.31, 0.39)	3.78	(2.31, 3.12)	12.07	(5.95, 8.33)	17.04
(1080.39, 1677.60)	9.33	(0.16, 0.20)	12.30	(234.55, 371.63)	8.30	(0.39, 0.46)	5.33	(3.12, 3.95)	8.15	(8.33, 10.96)	17.85
(1677.60, 2515.36)	2.89	(0.20, 0.25)	10.89	(371.63, 585.08)	3.56	(0.46, 0.52)	5.33	(3.95, 4.83)	5.70	(10.96, 13.91)	17.11
(2515.36, 3689.55)	0.59	(0.25, 0.29)	12.37	(585.08, 910.02)	0.59	(0.52, 0.57)	8.52	(4.83, 5.78)	4.74	(13.91, 17.34)	10.96
(3689.55, 5266.39)	0.37	(0.29, 0.33)	11.70	(910.02, 1430.61)	0.81	(0.57, 0.62)	6.59	(5.78, 6.84)	2.44	(17.34, 21.52)	9.56
(5266.39, 7385.03)	0.07	(0.33, 0.38)	9.56	(1430.61, 2212.47)	0.30	(0.62, 0.66)	6.81	(6.84, 8.06)	1.93	(21.52, 26.72)	6.59
(7385.03, 10,282.65)	0.07	(0.38, 0.42)	8.74	(2212.47, 3423.68)	0.07	(0.66, 0.71)	7.11	(8.06, 9.53)	1.41	(26.72, 33.26)	2.30
(10,282.65, 14,106.60)	0.00	(0.42, 0.47)	5.85	(3423.68, 5308.78)	0.07	(0.71, 0.75)	8.37	(9.53, 11.39)	0.89	(33.26, 41.53)	1.04
(14,106.60, 19,523.60)	0.15	(0.47, 0.51)	4.00	(5308.78, 7792.22)	0.07	(0.75, 0.80)	7.63	(11.39, 13.81)	0.59	(41.53, 52.31)	0.30
(19,523.60, 26,922.44)	0.00	(0.51, 0.56)	3.48	(7792.22, 10,715.89)	0.00	(0.80, 0.85)	7.56	(13.81, 17.03)	0.37	(52.31, 67.13)	0.07
(26,922.4, 35,608.03)	0.00	(0.56, 0.63)	1.56	(10,715.8, 14,611.60)	0.00	(0.85, 0.90)	9.85	(17.03, 21.37)	0.22	(67.13, 87.98)	0.07
(35,608.0, 48,659.49)	0.00	(0.63, 0.71)	0.89	(14,611.6, 26,037.39)	0.00	(0.90, 0.95)	10.07	(21.37, 27.66)	0.15	(87.98, 118.10)	0.00
(48,659.4, 67,909.16)	0.00	(0.71, 1.34)	0.15	(26,037.3, 34,898.16)	0.00	(0.95, 1.00)	10.52	(27.66, 40.37)	0.15	(118.10, 199.79)	0.00

Table A3. Morphometric profile of UT7.

CA Intervals	% Cells	CR Intervals	% Cells	BF Intervals	% Buildings	BE Intervals	% Buildings	ASB Intervals	% Buildings	MDBB Intervals	% Buildings
(24.60, 336.09)	89.54	(0.02, 0.06)	0.45	(12.02, 78.95)	61.39	(0.09, 0.20)	0.76	(0.27, 1.43)	8.46	(0.11, 3.67)	45.90
(336.09, 650.88)	9.14	(0.06, 0.11)	1.36	(78.95, 145.13)	29.35	(0.20, 0.31)	2.64	(1.43, 2.31)	19.38	(3.67, 5.95)	27.01
(650.88, 1080.39)	0.91	(0.11, 0.16)	2.38	(145.13, 234.55)	7.03	(0.31, 0.39)	5.89	(2.31, 3.12)	18.47	(5.95, 8.33)	15.49
(1080.39, 1677.60)	0.26	(0.16, 0.20)	3.48	(234.55, 371.63)	1.51	(0.39, 0.46)	7.67	(3.12, 3.95)	15.64	(8.33, 10.96)	6.35
(1677.60, 2515.36)	0.11	(0.20, 0.25)	4.38	(371.63, 585.08)	0.45	(0.46, 0.52)	7.40	(3.95, 4.83)	10.43	(10.96, 13.91)	3.02
(2515.36, 3689.55)	0.04	(0.25, 0.29)	6.16	(585.08, 910.02)	0.19	(0.52, 0.57)	7.67	(4.83, 5.78)	8.08	(13.91, 17.34)	1.32
(3689.55, 5266.39)	0.00	(0.29, 0.33)	7.22	(910.02, 1430.61)	0.08	(0.57, 0.62)	7.74	(5.78, 6.84)	6.23	(17.34, 21.52)	0.76
(5266.39, 7385.03)	0.00	(0.33, 0.38)	7.44	(1430.61, 2212.47)	0.00	(0.62, 0.66)	8.88	(6.84, 8.06)	4.57	(21.52, 26.72)	0.11
(7385.03, 10,282.65)	0.00	(0.38, 0.42)	10.09	(2212.47, 3423.68)	0.00	(0.66, 0.71)	7.78	(8.06, 9.53)	3.97	(26.72, 33.26)	0.04
(10,282.6, 14,106.60)	0.00	(0.42, 0.47)	10.05	(3423.68, 5308.78)	0.00	(0.71, 0.75)	7.56	(9.53, 11.39)	2.61	(33.26, 41.53)	0.00
(14,106.6, 19,523.60)	0.00	(0.47, 0.51)	10.80	(5308.78, 7792.22)	0.00	(0.75, 0.80)	6.91	(11.39, 13.81)	0.94	(41.53, 52.31)	0.00
(19,523.6, 26,922.44)	0.00	(0.51, 0.56)	11.41	(7792.22, 10,715.89)	0.00	(0.80, 0.85)	6.72	(13.81, 17.03)	0.72	(52.31, 67.13)	0.00
(26,922.4, 35,608.03)	0.00	(0.56, 0.63)	12.05	(10,715.8, 14,611.60)	0.00	(0.85, 0.90)	8.20	(17.03, 21.37)	0.23	(67.13, 87.98)	0.00
(35,608.0, 48,659.49)	0.00	(0.63, 0.71)	9.52	(14,611.6, 26,037.39)	0.00	(0.90, 0.95)	7.40	(21.37, 27.66)	0.19	(87.98, 118.10)	0.00
(48,659.4, 67,909.16)	0.00	(0.71, 1.34)	3.21	(26,037.3, 34,898.16)	0.00	(0.95, 1.00)	6.76	(27.66, 40.37)	0.08	(118.10, 199.79)	0.00

Table A4. Morphometric profile of UT18.

CA Intervals	% Cells	CR Intervals	% Cells	BF Intervals	% Buildings	BE Intervals	% Buildings	ASB Intervals	% Buildings	MDBB Intervals	% Buildings
(41.18, 336.09)	51.15	(0.05, 0.06)	0.27	(12.02, 78.95)	27.21	(0.05, 0.20)	0.35	(0.49, 1.43)	8.57	(0.80, 3.67)	12.28
(336.09, 650.88)	33.66	(0.06, 0.11)	1.15	(78.95, 145.13)	39.75	(0.20, 0.31)	1.06	(1.43, 2.31)	20.49	(3.67, 5.95)	22.70
(650.88, 1080.39)	11.66	(0.11, 0.16)	2.92	(145.13, 234.55)	20.14	(0.31, 0.39)	3.89	(2.31, 3.12)	20.76	(5.95, 8.33)	27.03
(1080.39, 1677.60)	2.65	(0.16, 0.20)	6.45	(234.55, 371.63)	9.63	(0.39, 0.46)	6.01	(3.12, 3.95)	15.72	(8.33, 10.96)	18.64
(1677.60, 2515.36)	0.71	(0.20, 0.25)	7.51	(371.63, 585.08)	2.56	(0.46, 0.52)	7.07	(3.95, 4.83)	11.57	(10.96, 13.91)	11.57
(2515.36, 3689.55)	0.09	(0.25, 0.29)	9.36	(585.08, 910.02)	0.62	(0.52, 0.57)	6.80	(4.83, 5.78)	6.27	(13.91, 17.34)	4.33
(3689.55, 5266.39)	0.09	(0.29, 0.33)	14.84	(910.02, 1430.61)	0.09	(0.57, 0.62)	6.71	(5.78, 6.84)	5.48	(17.34, 21.52)	2.03
(5266.39, 7385.03)	0.00	(0.33, 0.38)	14.22	(1430.61, 2212.47)	0.00	(0.62, 0.66)	8.83	(6.84, 8.06)	3.89	(21.52, 26.72)	0.97

Table A4. *Cont.*

CA Intervals	% Cells	CR Intervals	% Cells	BF Intervals	% Buildings	BE Intervals	% Buildings	ASB Intervals	% Buildings	MDBB Intervals	% Buildings
(7385.03, 10,282.65)	0.00	(0.38, 0.42)	12.54	(2212.47, 3423.68)	0.00	(0.66, 0.71)	9.10	(8.06, 9.53)	3.36	(26.72, 33.26)	0.18
(10,282.65, 14,106.60)	0.00	(0.42, 0.47)	11.57	(3423.68, 5308.78)	0.00	(0.71, 0.75)	9.01	(9.53, 11.39)	1.41	(33.26, 41.53)	0.09
(14,106.60, 19,523.60)	0.00	(0.47, 0.51)	8.92	(5308.78, 7792.22)	0.00	(0.75, 0.80)	9.63	(11.39, 13.81)	0.71	(41.53, 52.31)	0.09
(19,523.60, 26,922.44)	0.00	(0.51, 0.56)	4.59	(7792.22, 10,715.89)	0.00	(0.80, 0.85)	7.42	(13.81, 17.03)	0.62	(52.31, 67.13)	0.09
(26,922.44, 35,608.03)	0.00	(0.56, 0.63)	3.18	(10,715.89, 14,611.60)	0.00	(0.85, 0.90)	8.48	(17.03, 21.37)	0.27	(67.13, 87.98)	0.00
(35,608.03, 48,659.49)	0.00	(0.63, 0.71)	1.77	(14,611.60, 26,037.39)	0.00	(0.90, 0.95)	7.69	(21.37, 27.66)	0.44	(87.98, 118.10)	0.00
(48,659.49, 67,909.16)	0.00	(0.71, 1.34)	0.71	(26,037.39, 34,898.16)	0.00	(0.95, 1.00)	7.95	(27.66, 40.37)	0.44	(118.10, 199.79)	0.00

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Article

Safe Haven—Bath House and Library by the Burmese Border

Anett Mizsei [1,*] and Péter György Horváth [2]

[1] Ybl Miklós Faculty of Architecture and Civil Engineering, Óbuda University, Budapest, 1034 Gyor, Hungary
[2] Simonyi Károly Faculty of Engineering, University of Sopron, Sopron, 9400 Gyor, Hungary; horvath.peter.gyorgy@uni-sopron.hu
* Correspondence: mizsei.anett@ybl.uni-obuda.hu; Tel.: +36-70-340-16-50

Abstract: This study gives an overview of contemporary vernacular tendencies in Thai architecture. The research includes ecological, economical, ergonomic and cultural aspects, and the aim is to find a possible future direction for architectural design that is able to incorporate local features and follow traditions yet apply them in a contemporary way. As an example, a case study was carried out about a project realized in Safe Haven Orphanage in Thailand. It consists of two small-scale buildings designed and constructed by TYIN Tegnestue Architects, Sami Rintala and Hans Skotte, together with volunteers and the local community, and they are great examples of a community building "healing architecture". Due to their aesthetics, their ecological and sustainable approach and their structures, they can provide cultural continuity, which is key for the organic evaluation of regional architecture.

Keywords: architecture; healing architecture; ergonomics; community building; ecology; architecture for children; low-tech; universal design; vernacular architecture; regionalism

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1. Introduction

The core question of this research is what design and construction methodologies can be applied to create projects on a small scale, yet with great added value, with no standards and regulations and almost no sources for construction and maintenance present. The answer may lie in a rather underrepresented branch of architecture, which puts the real needs of users first, opting for low-tech solutions and considering local cultural, climatic and social characteristics and creating a balance between ecology and human comfort.

The location chosen for this study is Central-Western Thailand. The traditional architecture and technologies specific for this region were well alive back in the 1970s. However, "rapid urbanization and economic development of the countries in the region led to a massive destruction of these buildings and replacement by modern types at the beginning of the 1990s" [1]. This international style of contemporary architecture lacks the values and cultural content that traditional architecture owns in regards of comfort, ecology, economy and aesthetics [2]. In contradiction, in Western countries, this 20-year period was exactly the era of professionals and thinkers of the field rediscovering the ecological and aesthetical values in vernacular architecture [1]. It was not until the early 2010s that "the vulnerability of vernacular traditions under the threat of modern developments is the issue most commonly addressed, used as object of research and applied to policy" [3]. According to publications, the damage in architectural heritage was the greatest in rural areas—particularly smaller, traditional residential buildings—compared to important national monuments, acknowledged and protected more efficiently and effectively [unige]. As a conclusion of studies and articles [1–3] on this era, it is clear that copying Western patterns without adapting them to local needs led to a significant tangible (actual buildings) and intangible (technology, traditional building methods and knowledge) loss, in addition to decreasing comfort for users.

Ergonomics, as a discipline, is present in all phases of product design and manufacturing and has an extensive literature in academia. The aim of the ergonomic approach is to optimize human–product interactions, i.e., to make human activity more efficient, safer, more comfortable and more satisfactory in all respects [4] when producing or using the product, service or process.

Focusing on the concept of ergonomics in the field of architecture, it can be said that a number of ergonomic aspects are fixed through various regulations: in order for a building to be realized, it is necessary to comply with current legislation, which is often based on ergonomic and anthropometric data. Design decisions are therefore possible only within this legal framework, considering the given task, the needs of future users and the available resources. Creative freedom primarily covers aspects not included in law [5]. The interesting thing about the two projects chosen as the subjects of this case study is that they were built in a location with significantly less regulations than in Europe or North America. Such a situation—in addition to the freedom of design—means a great responsibility for all participating creators. At the same time, it provides an opportunity to work more closely with the user group, to recognize real needs and to serve them in as many ways as possible (Figure 1).

(**a**) (**b**)

Figure 1. (**a**) Picture of the Bathhouse. Photo of Safe Haven Bath house, photo: Pasi Aalto, architecture: TYIN Tegnestue (Andreas G. Gjertsen, Yashar Hanstad), Available online: http://www.tyinarchitects.com/download/works/2009_safehavenbathhouse/01_safehavenbathhouse_photos_hires.Zip (accessed on 13 July 2021). (**b**) Picture of the Library. Photo of Safe Haven Library, photo: Pasi Aalto, architecture: TYIN Tegnestue (Andreas G. Gjertsen, Yashar Hanstad), Available online: http://www.tyinarchitects.com/download/works/2009_safehavenlibrary/01_safehavenlibrary_photos_hires.zip (accessed on 13 July 2021).

The aim of this paper is to study two contemporary buildings of the Safe Haven orphanage in Burma (designers: TYIN Tegnestue Architects, Sami Rintala, Hans Skotte) based on the methodologies and analytical aspects presented in the above sources. In this case, it is not simply a kindergarten or school environment, but provides home for a traumatized, injured and vulnerable group, where the cooperation and community building mentioned above are of increased importance. At the same time, the financial resources were limited, so the project is also a good example of low-tech and low-cost architecture based on local traditions and heritage, realized through cooperative construction. Such projects, although small in size, become more and more valuable in our time and provide new ways for architecture that allow for a more harmonious coexistence of people, design and environment while fulfilling important social missions. The two projects are chosen to represent the significance of ergonomics in architecture, both in the physical and psychological points of view. In addition, they might be a possible future direction for vernacular design, adopting and keeping local traditions alive in a contemporary way.

2. Materials and Methods—Theoretical Background

The aim of this study is to analyze two buildings created for a special group of children (orphaned Burmese refugee children) and their mentors, caregivers and teachers. Three main aspects are to be considered: ergonomics, ecology (including economy and sustainability) and connection to regional architecture. This chapter includes theoretical background and an overview of publications on these topics.

The most important question is how traditional knowledge and technologies—regional architectural features—can be preserved in a contemporary way. Is there any method that leads back to the sustainable and environmentally conscious way of building and living, without impacting the comfort and well-being of users? These issues are essential to solve in order to prevent further damage and loss of valuable architectural heritage. Meanwhile it opens up the possibility to develop contemporary vernacular buildings, which evolve from that heritage, fits in local cultural patterns, and still meet the challenges of the 21st century.

2.1. Ecological Aspects

In the second half of the 20th century, mass production and consumption, mobility, energy demand and, with it, emissions of pollutants and waste have reached alarming proportions. The 1970s brought a widespread recognition that a change of approach was needed in industry, design and even everyday life to offset the environmental damage caused by the above. Reducing size and quantity, while raising awareness for quality and design for the whole lifecycle of products have slowly come to the forefront of interest of product designers and architects: a new design paradigm has begun to take shape. Parallel to this, a number of other sectors have also begun to discover a more ecological approach, considering sustainability and the human–nature relationship. This ecological approach came hand-in-hand with the rising appreciation of vernacular architecture and traditional knowledge, as pointed out in the introduction.

In 1973, Ernst Schumacher published his book Small is Beautiful—Economics as if People Mattered, in which he defined the principles of a new, humane economics. He asks himself what is really required from scientists and technologists in these times and answers in three points that became the core of his work. These characteristics of methods, technology and equipment are that they are affordable and accessible to everyone, suitable for small-scale application and also relate to people's creativity [6]. These postmodern ideas are the basics of post-industrial society, and they soon swept through architectural theory and practices, too. In addition to high-tech solutions, architects rediscovered local, traditional solutions, and a wider discussion started about people's real needs. In Northern Europe, the theoretician, professor and architect Juhani Pallasmaa was one of the most important representatives of this field.

It is no wonder that Sami Rintala and his collegues, who studied in Pallasmaa's workshop, have been leading their practices according to those principles. Rintala approaches all of his projects as eco-design experiments, especially focusing on the relationship between man and nature. In most cases, the key is to break down the sharp line between the built and the natural environment in order to guide people back to their origins and make them aware that they are still a part of it. However, his ecological thinking does not end in this poetic attitude. He strives to create reasonable buildings: the first and most important step in sustainability is to reduce size in all cases. Instead of the needs created by the media and the consumer world, it researches one's real needs and desires—understanding this is key to creating a reasonable scale and comfort [7]. It is a very important point to consider when helping people of different cultures. Bare import of technology has its risks and setbacks. Despite good intentions, they may cause more harm than benefit when the result is foreign to local culture. The outcome might cause psychological and sustainability issues which cannot easily be solved later and which Thailand (alongside many other developing regions of the world) is already suffering from.

2.2. Ergonomics

In recent decades, the architectural profession has begun to acknowledge the importance of ergonomics and its own shortcomings in this field. Emerging social sensitivity, a demand for a more inclusive environment for groups or individuals with altered abilities, have put aspects of ergonomics at the focus of research. For example, comprehensive anthropometric databases have been developed, such as Childata, Adultdata and Olddata (Department of Trade and Industry), published between 1995 and 1998. Recent possible publications on the subject analyze these issues in a complex way, especially in areas of social importance such as hospitals and educational institutions. In many cases, their authors formulate specific methodologies to aid design [4,5,8]. It is increasingly common for the field of ergonomics to be extended beyond physically measurable anthropometric scaling to include psychological, spiritual or cultural factors [9–11].

In addition to the importance of individual design decisions and attitudes, the implementation of ergonomic design also depends on factors such as available basic data, that designers rely on, or local regulations in place. In addition, sustainability issues need to be mentioned here. By the 21st century, ecology has become an unavoidable ethical and design aspect, while the comfort, health and well-being of users are not to be compromised for the sake of environmentally friendly construction. One of the most important tasks of architecture is to reconcile these two aspects along a new paradigm that allows for the well-being and harmonious coexistence of man and nature [12]. As another study points out, "an environment-friendly building design cannot neglect the fact that building users are themselves part of the environment" [4]. From another point of view, the leading rating systems for the building's sustainable performance, such as LEED, as an example, mentions ergonomics as part of their strategy, these indicators are rather focusing on human interactions with specific elements or equipment, not buildings as a whole [4].

Similar ideas are expressed by Finnish architect-theorist Juhani Pallasmaa: "The essential mental task of architecture is accommodation and integration" [11]. Dwelling—in other terms "existence" itself—is closely related to the primary function of the building, but it is also more than that: "Architecture articulates the experiences of being-in-the world and strengthens our sense of reality and self" [11]. In order to establish this integration, the building should not draw a sharp boundary between external (natural) and internal (artificial) spaces [9]. In the design practice of Pallasmaa's student Sami Rintala, these transitional spaces are the key: the surrounding natural landscape can be experienced from there, in contrast of the seclusion and loneliness of the interior. Otherwise, this transition space induces a dialogue between the building, its user and its environment [7].

Although there is no comprehensive design methodology that is universally applicable, available publications from recent years have set out certain principles and factors that are key to the design of a product in terms of ergonomics. In addition, these were the basis of the design methodology of the architects, who created the two projects.

1. Involving users in the design process not only makes the designer's job easier, but also increases user satisfaction during the whole lifespan of the building.
2. Empathy: the diversity of people and their abilities must be taken into account. In addition to physical requirements, mental, psychological and cultural factors also play an important role, although there is usually less focus on them.
3. The mechanical application of stereotypes and standards is a bad practice. Usually, regulations are based on categories and standardization, unable to serve the real needs and abilities of people. Instead of relying only on standards and stereotypes, a system-oriented approach is needed, with consideration of the effect that the environment as a whole has on the actual people using it.
4. A holistic design approach is required instead. In the case of the built environment, this should take into consideration not only the main function of the building or its structures, but all the expected activities that future users might perform [4].

The political crisis in Burma, as in most wars, has serious consequences for the population to this day. Many children lose their families or find themselves in a hopeless situation from which only outside help can provide a way out. The Safe Haven orphanage was established to heal physical and mental injuries and to build a better future for those it cares for [13]. The events these children experience—the loss of their families, leaving their homes—are traumas that affect their sense of security, their socialization, their image of themselves and their place in the world in the long run. All this makes the ergonomics of their environment a high priority, especially regarding psychological and cultural factors. During the planning, all user groups must be taken into account with all their physical and mental needs, social background and past [4]. Therefore, caregivers and teachers are also to be considered the primary users of the building, alongside children. For children to feel safe and develop in a healthy way, they must have a loving relationship with at least one adult, and that adult must be present in their lives regularly [10]. The formation of these bonds should and can be supported by good design. In the case of children, the improper or inaccurate use of buildings and equipment must also be taken into account as their foresight of the possible consequences is limited. Beyond safety, a comfortable environment adapted to a child's scale promotes physical development and should always be shaped by ergonomics [9]. Of course, the users who maintain and operate the building also need to have an effective and safe work environment.

An environment that meets the needs of children (especially in the preschool age group) is challenging and stimulating for children with different perceptible textures, sounds, lights and colors. A diverse and multisensorial spatial system can serve them well. Quiet places serve for individual studying, more open community spaces for group activities and a completely open outdoor area for freedom of movement and physical development. There are four basic aspects to nursery architecture: space, scale and proportions, colors and lighting [10].

The psychological aspect of spaces created for children is also a major issue. More and more articles are considering it as equally important as the physical aspects of ergonomics: "involving the compliance of the product with the needs of physical compatibility (anthropometric, biomechanical and perceptive) of safety, well-being, and finally of value—emotional and subjective—that the individual-user attributes to his relationship with the product" [14]. In carefully shaped spaces, children's spatial intelligence develops, as the space stimulates and directly influences their behavior, thinking, feelings and imagination [4]. Architecture creates certain frameworks for our lives, our existence. A carefully designed environment for children provides space for physical, social, emotional, linguistic and cognitive development. Four main aspects can be distinguished for this purpose: movement, comfort, competence and control. A variety of possible movements and activities are the core of both muscular and intellectual development. In addition, spatial orientation and the development of healthy boundaries are related to the spaces provided for them. The comfort of the place involves the proper amount of stimulation for all senses. A supportive environment helps children to develop the feeling of competence: they can explore, use and live the space freely and independently if the space in question is designed with the correct features for each activity or function. Control is both about safety and the children's own experience of being in charge for their own actions. Design should consider the safety and access of the caretakers as well as the privacy of children [10]. To sum up, a safe and ergonomically designed space not only motivates children but also sets limits. These constraints can be realized on two levels: on the one hand, through the building's own design, and on the other hand, by providing the supervisor control over the situation with the appropriate vision, acoustics and accessibility.

Isenberg and Jalongo state similarly in their five criteria that architectural design:

1. conveys a message to children about desirable behaviors;
2. provides and facilitates freedom of movement;
3. encourages creative learning processes;
4. provides educators with supervision and guidance for children;
5. with the accessibility of different materials, tools and toys and with their openness from the child's point of view, it creates not only free play, but also a sense of possession and ownership of one's own little world in children [9].

When it comes to architecture, according to publications from the past decades, there seems to be a tendency for professionals of the field to become more and more aware of the significance of ergonomics and adapting and researching it with a holistic approach.

In addition to the physical and psychological aspects, sustainability also became part of the discussion. Very few of them mention, however, the importance of local cultural and architectural heritage and mainly focus on historical aspects [15]. This article is therefore aimed to emphasize how cultural and architectural heritage of a specific area can induce a balance between ergonomics and sustainability, meanwhile exploring the design methodology which made it possible to connect them.

2.3. Traditional Architecture in the Region and Contemporary Vernacularity

The archetype of traditional house in this region evolved from early examples, that date back in the 13th century. There are basically two types:

1. houses floating on the water surface;
2. standing on stilts, located on riverbanks or lands.

The latter can be temporary/semi-permament, usually built from bamboo, or permanent and made of wood [3]: "The traditional Thai house is ideally adapted to its environment. Open high-pitched roof that facilitates air circulation. Open windows and walls in combination with a large central terrace provide ideal ventilation and offer relief from the hot and humid climate. Wide overhanging eaves protect the house from sun and rain. Rainwater runs off the steep roof quickly and falls through the permeable terrace and house floors" [2]. From another point of view, vertically, these buildings consist of three main parts: the roof, the floor structure built on stilts and the living area enclosed by the two [16].

Raised floors serve more than one function. It provides optimal ventilation, protects the interior from flooding waters [17] and marks the different functional zones of the house [16]. Ventilation has a significant role in the evaluation of Thai houses. Due to the humid and hot climate, it is the only way to prevent mold and structural damages without chemicals. It is also essential for a healthy and comfortable environment for users. Another important characteristic element serving this purpose is the gap between the top of the walls and the roof [17]. In the floor plans of traditional Thai houses, the terraces are the key organizers of the life of the users. Larger open spaces in the center or narrower verandas around the house under the overhanging eaves serve as transitional spaces [16].

The contemporary vernacular architecture of the region is still underestimated and weakly documented. According to the study of Punpairoj, it is an organic process which is a result of a community working together rather than the design of an individual architect. There are two opposite approaches of vernacular architecture: the "decline" or "revival" of them, using modern structures and materials to meet the requirements of today [3].

Projects such as the two small-scale houses of this case study are opportunities to find new possible approaches for contemporary architecture, inspired and influenced by local technologies and culture. The significance of them lays both in their design and community-building effect, which can make a huge difference for both builders and users. This cooperation is, however, crucial, as it guarantees to avoid alienating and forced designs, which are not sustainable, mainly because the community has no connection to it.

3. Results—Case Study

"The body image [...] is informed fundamentally from haptic and orienting experiences early in life. Our visual images are developed later on, and depend for their meaning on primal experiences that were acquired haptically" [18]. The analysis of the next two case studies is based on the above aspects, focusing on their functionality, actual usage and connections to their physical, social and built environment. Their geometry, technical design and ecological features were taken into consideration, in addition to decoding their dimensions according to anthropometric data for each age group, through their published plans, on-site construction photos and structural details from the architects.

3.1. Safe Haven—How It Started

Tasanee Keereepraneed is a local woman living in the heart of Thailand, in Ban Tha Song Yang, which is about a two-hour bus ride away from the Burmese border. Since 1987, she has been caring for orphans. Together with her brother, they now care for about 60 children who came from the surrounding areas of Thailand and Burma. They provide housing, full care, medical assistance and education to these children, supporting themselves with the help of volunteers and donors, as well as NGOs. Most of the children were orphaned by the Burmese political crisis and military dictatorship [13]. The age of the residents ranges from 0 to 20 years. Different age groups eat, study and play together, much like in a family environment. From an early age, they are also taught responsibility and housework appropriate to their abilities, in addition to elementary education. The primary goal is for children of typically Burmese descent to acquire Thai citizenship as adults. In addition, an important element of education is a loving, inclusive atmosphere [19], which is the key to a more peaceful future in the region. The orphanage has been built in several phases, depending on the actual needs and incoming offers. The founding siblings, who themselves had lost their parents early on, converted the inherited parental home for their protégés. Their future plans include the development of a drinking water supply system, dormitories with additional beds and the construction of a health center [13]. In recent years, however, two remarkable buildings have been built on the site. The Library and the Bathhouse were created through volunteer work, and they are important steps for the future of the home, despite their small size.

3.2. Background of the Design

In 2009, TYIN Tegnestue, a non-profit humanitarian organization, invited architects Sami Rintala and Hans Skotte, as well as 15 architecture students studying in Norway, to realize two buildings together, both made of traditional, local materials [20]. The small buildings create value beyond their functionality: they serve the physical and mental health of those living here. These projects represent an architectural approach that relies on local materials and building traditions and does not function as a kind of top-down 'design aid package', but rather lifts up a highly vulnerable group in the long run with real results.

In a tropical climate such as that of Thailand, the key to preventing epidemics is collective and personal hygiene, which is served by the bath. It was built next to a young teak plantation. The toilets are enclosed in two rooms covered with red and yellow plaster. In addition to the traditional one, there is also a flush toilet inside. Between the two is located the bathroom, opening up to the forest area, which is a culturally accepted solution in the area. Openness, however, is often used as a tool to promote children's safety and well-being in Western civilizations, too [21]. This "porch", covered with bamboo shading, combines different functions. On the site, there is no sewerage, but at the same time, it is often flooded by torrential rains Therefore wastewater treatment and keeping the surfaces clean was a great challenge. An important element of the project is the easy-to-wash and quickly drying, ventilated floor and the closed drainage of wastewater led into underground desiccators (Figure 2).

While the bath serves primary physical and infrastructural needs, the library is a place for children to develop mentally in order to break out of the spiral of poverty. It opens up opportunities for culture, education and self-education, while encouraging socialization and individual development as well. It serves as a library, playground, classroom and meeting point at the same time. Since internet access is only possible from here, it literally opens the door to the world. Under the roof are computers on one side and the actual library on the other. Among them is a gateway—a transition area—where the rocks of the terrain were included into the concept by the creators, serving as stairs. This is the point where students leave their slippers or shoes behind before entering the building, which is a local tradition. The concrete walls made on site embrace rows of bookshelves. Inspired by traditional construction methods, the natural appearances of the materials are preserved, if possible. At the corner, shelves take a turn and form a stairway to the airy, quiet attic. The wooden floor, with its level raised from the ground serves as a platform for the 'classroom', but also works as a seat during outdoor activities. It was made with a slightly tilted carpentry structure, shaded by bamboo slats, letting in soft light and fresh air.

Figure 2. Interior of Library. Photo of Safe Haven Library, photo: Pasi Aalto, architecture: TYIN Tegnestue (Andreas G. Gjertsen, Yashar Hanstad), Available online: http://www.tyinarchitects.com/download/works/2009_safehavenlibrary/01_safehavenlibrary_photos_hires.zip (accessed on 13 July 2021).

3.3. Analysis of Ergonomic Aspects

From Pallasmaa's point of view, the fundamental task of architecture is to restore the human–nature relationship, in this way improving the mental well-being of the users [6]. To achieve this, the building does not draw a sharp line between its user and the environment, thus connecting the two instead of separating them. Still, it provides adequate protection for people. Due to permissive local regulations, the designers had excessive freedom during the design process, therefore, they could focus on the local traditions and climate

These design decisions influence the whole lives of the children growing up here now or in the future. For the right architectural solutions, the creators and builders had to get to know the community, its unique needs and difficulties. Knowledge of the local culture facilitates a mentoring system among children and helps them integrate into society. A lack of regulations made it possible to involve users—children and adults alike—in the design and construction. With this, the two buildings not only serve their needs better, but the building process has become part of the history of the community. This fundamentally determines their relationship to the buildings. Since the projects are located within the enclosed area of the orphanage, they could open up to their surroundings. Children use the area freely (according to a defined agenda, of course), so openness serves the function well and does not raise security issues.

3.3.1. Anthropometry and Functionality

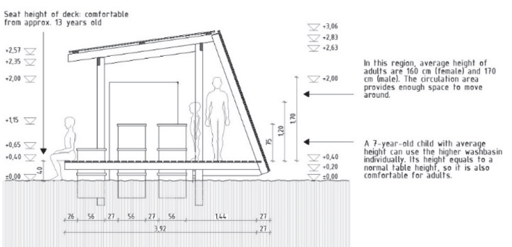
One of the primary aspects of ergonomics is anthropometric sizing, which serves as the basic usability and functional issues. Available anthropometric databases were examined for this analysis (Table 1) [22,23]. The database is a result of a survey from several countries around the world, with data from Japan, China and Sri Lanka from the Far East region. However, due to the nature of the examined projects (manual construction and usage of materials found on site), the dimensional accuracy of the implementation shows greater differences than the differences that can be discovered in the database between the individual ethnic groups. Furthermore, given that all ages are present in the children's group, there was no specific age range to size objects for. Thus, local characteristics are more relevant in adult sizing, for which data from the region were used.

Table 1. Example of anthropometrical data.

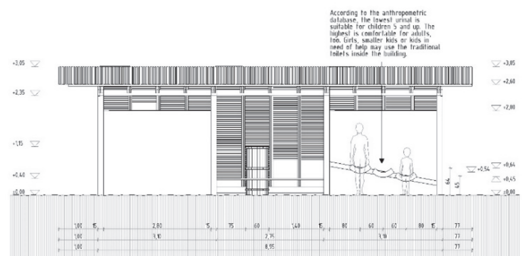
Age	Gender [1]	Height [2]	Reach Range above Head [2]	Seat Depth [2]	Lumbar Height [2]	Step Height [2]	Seat Height [2]
2	M	87.9	104.5	23.5	37.5	33.7	20.5
	F	87.6	104.5	24.5		34.3	
3	M	95.1	113	25.0	41.7	39.7	23.0
	F	94.2	112.5	26.0		38.6	
4	M	102.1	121.5	26.5	46.1	41.7	25.5
	F	101.2	120.5	27.5		41.5	
5	M	108.6	130.5	28.0	50.7	47.0	27.0
	F	107.6	129.0	29.5		45.1	
6	M	116.2	139.0	30.5	54.7	50.4	29.5
	F	115.1	138.0	31.0		52.1	29.0
7	M	120.8	147.5	32.5	58.2	52.6	31.5
	F	120.12	145.5	33.5		54.1	31.0
8	M	125.4	155.0	34.0	61.5	54.8	32.5
	F	124.4	153.5	35.5		57.3	33.0
9	M	129.8	161.0	36.5	64.9	59.7	34.0
	F	130.2	161.5	38.0		59.4	
10	M	135.0	168.0	38.0	67.6	61.0	36.0
	F	135.6	17.5	40.0		61.9	36.5
11	M	139.13	174.0	39.5	71.3	62.8	37.5
	F	142.45	176.0	41.0		63.6	
12	M	145.22	183.5	41.5	73.6	65.2	39.0
	F	148.1	183.5	43.5		66.8	38.5
13	M	150.7	190.5	43.5	75.5	65.8	40.5
	F	151.7	189.0	44.5			39.0
14	M	158.5	199.0	46.0	76.5	66	42.5
	F	154.3	193.0	45.5			39.5
15	M	162.8	206.0	48.0	77.2	66.7	43.0
	F	156.0	196.0	47.0			40.0
16	M	166.1	210.0	49.0	78.0	68.8	44.0
	F	158.1	196.5	48.0			40.5
17	M	168.7	212.5	49.5	78.0	68.1	44.5
	F	158.8	197.0	48.0			40.5
18	M	169.0	215.0	50.0	78.7	68.1	44.5
	F	155.0	197.0	48.0			40.5

[1] M—male, F—female. [2] Data given in cm.

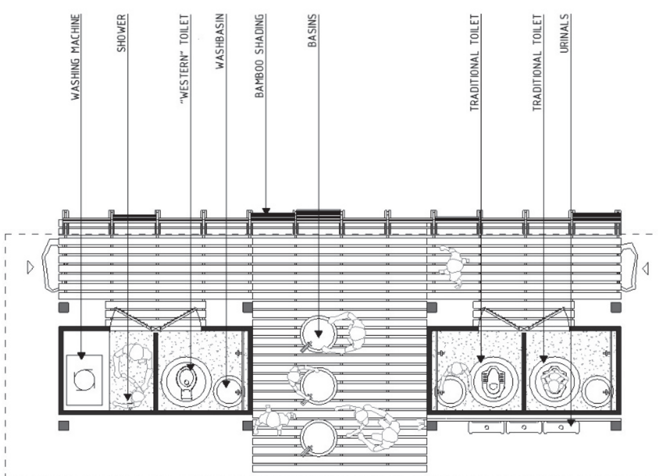
For the above reasons, in the bathhouse (Figure 3a–c), only the toilets are indoors. The building provides enough cover for the urinals on the north side. Placed at three different heights (45, 55 and 65 cm), they are suitable for growing kids from the age of about 5. Smaller children or children in need of help can use the traditional toilets located indoors. The advantage of these is the floor-mounted design, as smaller children are able to use them alone or with minimal help, unlike the higher wall-mounted flush toilets. However, such an item was also established for children to get used to that design, too. The cabins have a size of 125 * 140 cm, so there is enough space (approx. 60 * 60 cm) for the caretaker during use. The shower and washing machine are also in a lockable unit—the latter had to be protected from tropical showers and connected to electricity. The shower cubicle is 70 * 125 cm in size with a built-in design. This makes it easier for helpers to access, as there is no edge, no obstacle and no risk of accidents. The lamella cover provides safe limits for the space but does not close it. By learning to use Western-type toilets and showers, they can later easily adapt to the culture of either the city or other parts of the world. In addition, given the spacious area, it is possible to bathe more than one child at the same time, which is culturally accepted at the area.



(a)



(b)



(c)

Figure 3. (**a**) Cross-section of Bathhouse; (**b**) elevation of Bathhouse; (**c**) floor plan of Bathhouse. Figures: Own drawings of the author (Mizsei, A.) based on TYIN Tegnestue Architects (Andreas G. Gjertsen, Yashar Hanstad), Available online: http://www.tyinarchitects.com/ (accessed on 13 July 2021).

Daily bathing routine and washing hands takes place on a light-structured wooden deck between the two closed parts of the building, with three washbasins of different heights. These are actually garden taps for which the "well" was built of large diameter reinforced concrete channels, protected by a grid on top to prevent children falling in. These elements have different heights: a 25-cm-high lower bowl and two others with height of about 75 cm. Washbasins in the middle can be used for hand washing without any help needed, and with the different sizes, even smaller kids can start using them independently, without help. The space around them (275 * 380 cm) is enough for the caregivers to organize the bathing either individually or in small groups of children. The washbasins are standing free, in the middle of the space, so there is still a 60-cm-wide lane for the access of cabins. A minimum of the same width is available in the covered, side-open traffic in front of the cabs. This way, the functions can be used simultaneously.

In the case of the library building (Figure 4.), the application of a 35-cm module size was used. It is ideal for storage, but has further features, as well. The shelves surround the space and at the end of the building form a stairway which children can climb on. They can access the attic from here or use the stairs as seats for the preschool and primary school age group. At the same time, the floor, raised 45 cm above the ground, adapts to the seat height of adults, making it suitable to sit on while observing and supervising outdoor play. Thus, the adult may be present, but stay in the background only for safety reasons or necessary intervention. The interior is comfy with a large carpet. A free area of about 2 * 5 m is enough for up to 30 children. In the other side, however, computer workstations were established with traditional desks and chairs. There is enough space behind the two workplaces for the instructor to supervise and help.

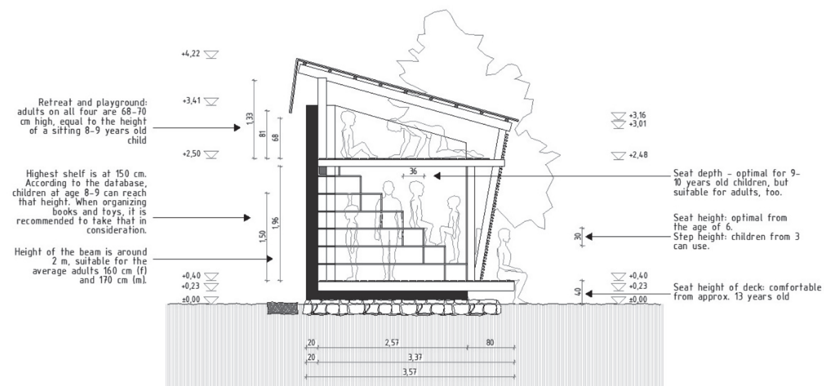
An important and special part of the construction is the attic, which is a great option for children to retreat to, whether being alone or in small groups—with a sibling or a good friend. Of course, it is also accessible and safe for adults: the height of 60–135 cm allows for younger children to play and read comfortably while sitting, but it also remains accessible for older kids or adults, which is essential from a safety point of view and also necessary for maintenance and cleaning.

3.3.2. Physiological Characteristics

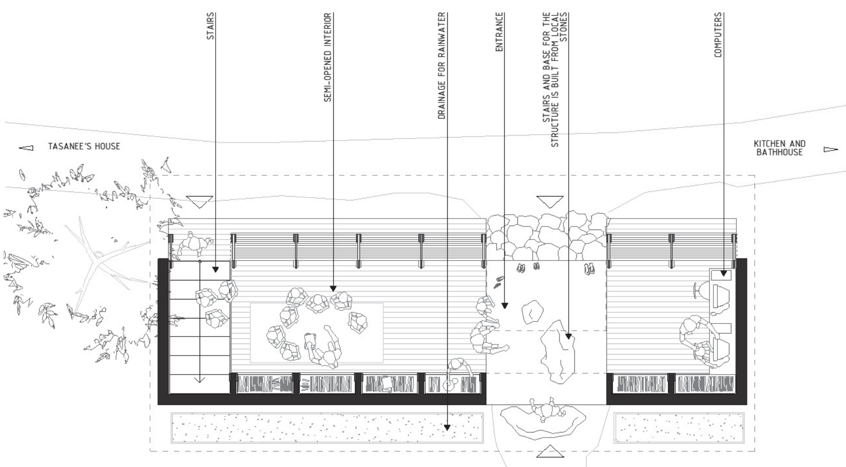
During the designing and building process, a number of aspects had to be taken into account, such as ecological considerations, financial possibilities and constraints, and the life expectancy, maintenance and repair of the two buildings. Important decisions had to be made for their whole lifespan in terms of safety and long-term accessibility and functioning. This includes not only the main functions, but also all future activities performed in, on or around them.

The floor of both buildings is made of local wood planks that are resistant to water if ventilated and dried out occasionally. Therefore, structures are lifted from the ground and the planks are built in with small gaps between them. It is a non-slipping, natural material, pleasant to touch and—similarly important—to smell, which was easy to assemble during a workshop organized with local volunteers and architecture students from all over the world. Later on, the planks can easily be replaced with simple tools by local workers. This is especially important for the bathing functions of the bathroom, where breakdown might happen faster. To avoid this and lengthen the lifespan of the structure, it opens up from the sides to ensure the flow of air. Meanwhile, partial shading creates a sense of protection and protects from the hot southern sunshine. Still, it allows enough sunlight to have a drying and disinfecting effect.

The buildings are located close to each other, near a traditional building, which functions as the kitchen and dining area. The examined buildings were also made using local materials, so the natural colors and textures of wood, bamboo and stone appear, thus ensuring cultural continuity and connection with the previous, traditional structures. These natural materials are environmentally friendly but also "human friendly": they are safe, they do not need toxic surface treatment or preservatives, they are easy to replace and provide durable surfaces. Their touch and sight blend the houses in the surrounding natural landscape and built environment. Bamboo has been used on surfaces that are particularly exposed to weather because it is more durable and even more easy to replace. In addition, it is lightweight, which minimizes the risk of accidents and simplifies construction and maintenance processes. Locally available natural earth pigments were used to color the surfaces.



(**a**)



(**b**)

Figure 4. (**a**) Cross-section and (**b**) floor plan of the Library. Figures: Own drawings of the author (Mizsei, A.) based on TYIN Tegnestue Architects (Andreas G. Gjertsen, Yashar Hanstad), Available online: http://www.tyinarchitects.com/ (accessed on 13 July 2021).

3.3.3. Psychological and Cultural Aspects

The loss of their home and family is a serious trauma for every child who has to survive such things. Far away from their homes, one of the most important tasks of Safe Haven is to help them heal from those experiences. The spatial system, materials and colors of the examined buildings are suitable for creating objects and places to connect to [24], slowly taking over the role of the home in the lives of the children. Aspects of this are examined in this chapter (Figure 5).

Figure 5. Group of children playing in the Library building. Photo of Safe Haven Library, photo: Pasi Aalto, architecture: TYIN Tegnestue (Andreas G. Gjertsen, Yashar Hanstad), Avail-able online: http://www.tyinarchitects.com/download/works/2009_safehavenlibrary/01_safehavenlibrary_photos_hires.zip (accessed on 13 July 2021).

The community of different age groups creates a special situation in the orphanage. In addition to being educated for their independent lives in the future, children learn to cooperate and help each other. This is why the projects analyzed here are in a special position. In addition to being inclusive for all ages and abilities, it is neither necessary, nor even desired to completely rule out the presence of a helping hand or caretaker in all cases. Older or more experienced children can share their knowledge with their younger peers, helping them until they can cope on their own. Its community-building and educational benefits are invaluable, not only for the recovery and development of traumatized children, but also for their later lives, when it comes to further education, workplaces or private life. Empathy is thus manifested in buildings on two levels: on one hand, their design responds sensitively to the users' problems, and on the other hand, they encourage desirable, empathic behaviors. Both the bathhouse and the library contribute greatly to these values.

Independence and the relationships between children and young people are of priority. However, adult management, supervision and attachment to caregivers are also important for the users. In the bathhouse, the little ones are helped to bathe by adults or their older "siblings". These are intimate moments when they receive the full, undivided attention of the caregiver. In addition, there are no tables or chairs in the library except for the two computer desks. The teacher and students sit in a circle on the floor or carpet, horizontally on the same level, forming a group. This horizontal system encourages personal connections and is being rediscovered nowadays in the Western world by democratic and alternative educational methodologies. In addition, the more flexible the space is, regarding its arrangement and usage, the less harm the constant sitting position makes on the posture of students [25]. Its significance is enormous when it comes to children who are cut off from the family environment. It gives children a family-like experience, strengthens the sense of belonging, encourage cooperation and acceptance of each other.

The use of local workers and building materials available in the area has resulted in architectural forms that are related to local archetypes. This makes them look "familiar" to the children, which will help to strengthen the children's identity and their sense of security. In addition to their physical and mental development, it provides cultural continuity. Given their past injuries, this is particularly important for this group.

Due to the open design of the small library, it connects to a much larger area than its actual size. It is a central point in a free area, where community life and games flow around it freely. Similarly, in local building traditions, outdoor and transitional spaces also have a great significance: most activities throughout the day take place outside the house. Moreover, the interior usually has a direct visual connection to the exterior, as traditional Thai buildings are not enclosed by walls, but only roofs and floors [16]. Arriving from the outdoor activities, the building welcomes children between the two wings of the building, where they can prepare for joining the quieter, organized, guided classes covered and protected by bamboo blinds. The function of the attic is to provide shading and ventilation, in addition to offering children a private playground and their own space. The significance of these nooks for them is huge in the long run: they are imprinted into their memories, and they improve their perception of space and their own place in it. For those who have lost a home, such spaces can restore their attachment to places.

When it comes to colors, the two buildings work together. Wood, bamboo and locally found stones remained untreated, with a natural, rustic appearance—another important feature of building traditions of the region [17]. The walls built from concrete blocks are plastered and given a slight coloring: yellow and red appear on the bathhouse, and a natural, cooler, blue-gray shade on the library. In addition to its playful sight, the reason behind the difference lays in function. The bright colors of the bathhouse not only refresh the body but also enliven the spirit and slightly increase the feeling of warmth. Blue appears as a calming contrast. In the library, the cool, soothing shades help kids to focus. Books, toys and fabrics are enough of bright colored spots in the library. The softness of wood, bamboo, textiles and paper also provides the small study room better acoustics, which helps to focus attention and transforms learning into a pleasant daily activity.

4. Discussion

In the two projects of the case study (Figure 6), the creators also step back to simple solutions: orientation, lighting and creating a good microclimate. Meanwhile, they create "pleasant" places for the community, as one of the essential elements of sustainability is that users love the building so they can and want to use it for as long as possible. Recognizing that the main problem is not energy supply—energy is available almost indefinitely from different sources—the real problem is waste generation. It responds to minimize this with a timeless design and proper material selection. With these fundamentals, he follows the ideas of Pallasmaa, who preferred the "living" materials of traditional cultures and the humanistic scale to the abstract and universalizing effects of modern technology [11].

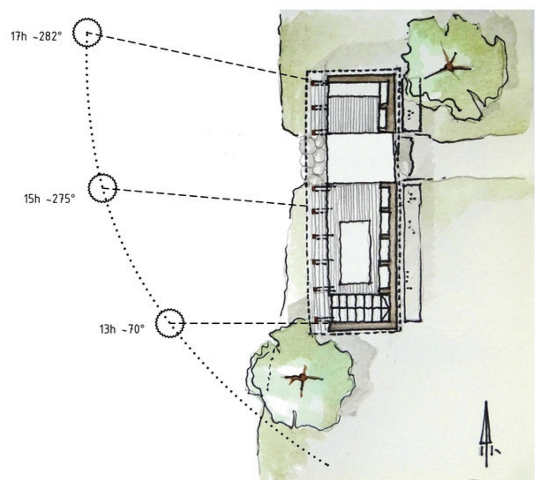
(**a**) (**b**)

Figure 6. (**a**) Design on site—sketches. (**b**) Community building.Sketches of the designers and photo of the building process TYIN Tegnestue Architects (Andreas G. Gjertsen, Yashar Han-stad), Available online: http://www.tyinarchitects.com/downloads/ (accessed on 14 July 2021).

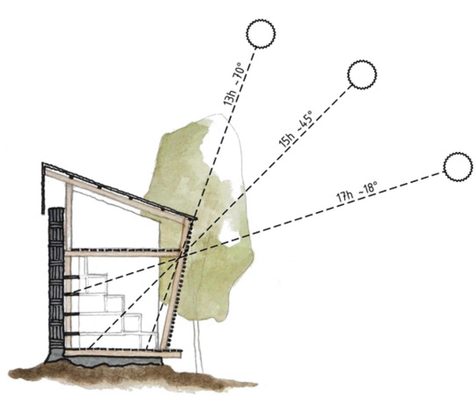
In addition to their theoretically grounded approach, the construction and realization played an important role in the design. Being from all over the world, the architects did not design the buildings in advance, but did so "in situ" after getting to know the culture and building traditions, as well as considering the available sources, local conditions and climate. The final design was chosen after a few days of workshops. This way, they could ensure cultural continuity through their "gentle" intervention. This chapter is to detail connections and similarities to local building practices and point out any differences.

4.1. Orientation and Place

Traditionally, Thai inhabitants settled in smaller farming communities, with buildings organized around a common space [16]. The orphanage follows this pattern with different buildings for different functions loosely inhabiting the field. The two buildings fit into this concept, with their individual pavilion-like appearance (Figure 7).



(**a**)



(**b**)

Figure 7. (**a**)Library floor plan sun path. (**b**) Library section, sun path. Sketches of san path, based on TYIN Tegnestue Architects (Andreas G. Gjertsen, Yashar Hanstad), Available online: http://www.tyinarchitects.com/ (accessed on 23 August 2021).

Mostly, regional Thai houses were oriented lengthwise in an east–west direction. This way, they could avoid excessive heating from the sun [16]. The library is oriented exactly this way. Large openings to the west provide enough light throughout the day and lets in the most direct sunlight in the evening, so they can use the building for as long as possible.

However, there are examples of traditional houses, especially in the north [16] where the climate is less hot and temperature fluctuates more daily, that are oriented south–north. However, the area of the orphanage lays in Central Thailand, with relatively hot and humid weather, and the main usage of the bathhouse takes place in the mornings and evenings. In addition, due to its function, structures are more prone to dampness and mold. Facing to the south, structures can easily be dried up by the strong solar radiation, working as a natural disinfectant (Figure 8).

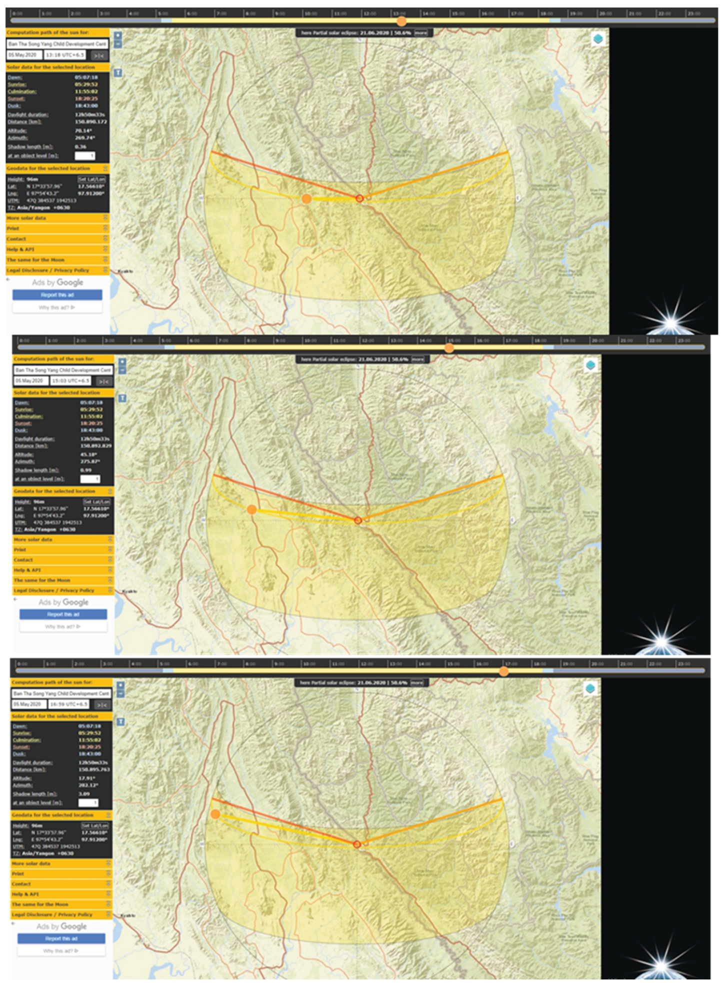


Figure 8. Sun path diagrams at 13:00, 15:00 and 17:00 at the location. Sun path diagrams. SunCalc.org, Available online: https://www.suncalc.org/#/17.5661,97.912,18/2021.08.23/15:15/1/3 (accessed on 23 August 2021).

4.2. Spatial Organization

Both buildings follow some basic principles of traditional Thai architecture. Maybe the most important is that both have an open terrace in the centre and verandas under the roof. Such transitional spaces play an important role of daily life in Thai culture and therefore important in the socialization of these children.

The buildings also have large openings and visual connection to the exterior, which is also an important principle of regional architecture. Floor levels are lifted, standing on stilts, providing a seat: "In this pattern of local Thai culture, the act of sitting or lying down on wooden floorboards became a feature of the normal lifestyle. As explained, the steps between the platforms in the houses were used for eating, resting or sleeping in order to obtain the benefit of the natural cool breezes passing through the space underneath" [16]. Bamboo shadings protect the interior without enclosing it hermetically. Life can flow in and around the houses uninterrupted.

Usually, the ground floor is used for the main functions of regional buildings, with the attic serving only as a buffer zone or storage. In the case of these projects, only the library has an attic, which is for storage and serves as a zone for children to climb and play. The main library and educational functions remain downstairs.

Traditional Thai houses have around 40% of their floor area as terraces (open or semi-open transitional spaces) and up to 60% with the veranda areas added [3]. Those proportions, of course, are a bit different due to the functions and usage of the buildings: more for the bathhouse and a bit less for the library.

4.3. Structures, Materials and Building Process

Permanent structures in Thailand are usually made of wood. For semi-permanent or temporary ones, on the other hand, bamboo is used more commonly [3]. A basic feature is that all regional buildings have a lightweight structure and wooden plank walls where necessary. However, in the last 20 years, masonry blocks and concrete also have been used in an attempt to follow Western patterns, in spite of the fact that they cannot provide the advantages that traditional, ventilated structures do. However, according to [2], these houses "benefit from the massive construction in a region where night temperatures often drop below the comfort zone, and there is a larger diurnal temperature swing" [2].

Both buildings analysed here are kind of a hybrid structure, with solid walls enclosing parts of them or specific functions, such as toilets or bookshelves. This way, the designers and builders could balance between modern masonry structures and traditional appearance and technology. In fact, they managed to benefit from both by appropriately deciding the proportions and disposition of each. The massive blocks create the core of the structure with the wooden roof "floating" above it, using the traditional method of creating a gap between walls and roofs to let air and light in. Stilts are kept quite low, as children need easy access to the buildings; still, they benefit from the cooling effect of air under them.

One reason, that solid walls and structures slowly started to displace traditional structures are the costs. Both timber and the labor cost of professional vernacular carpenters are not affordable for low-income village people or—as in our example—for an orphanage financed from donations. These two buildings are good examples that needed no advanced craftsmanship and could be realized by volunteers from materials available around. Still, they do connect to traditional architecture of the region.

5. Conclusions

To sum up, this study gives an overview of the traditional and contemporary vernacular architecture of Thailand and the problems that the loss of traditional knowledge causes. It is also an attempt to reveal the ergonomic aspects of traditional architecture, pointing out the specific ergonomic requirements for the environment designed for children and their caregivers. The buildings chosen for the case study are good examples of today's socially sensitive architectural approach, based on local materials, community building, and an ergonomic and ecological approach that works harmoniously both with the natural and the built environment. These two small-scale projects also demonstrate that a highly functional and ergonomic solution can emerge without strict regulations if created with the empathetic attitude of the creators and the involvement of end users.

In addition to their functionality, the aim of the buildings is to strengthen the users' identities and not estrange them from their own cultural heritage. This kind of approach is also beneficial for the participating architects and students, too, as they might also find a way to return to their own roots and seek local solutions in their practices later on. Projects and processes such as these therefore represent a great educational value in our overly technocratic world.

The most important outcome of this study is, therefore, that neither ergonomics nor sustainability should be examined without consideration of the local features of architecture and society. Contemporary design needs to acknowledge its characteristics: the only way to sustainability is following and organically evaluating traditional regional building technologies. This connection and the how incorporating more elements from traditional architecture and cultural attributes affect design methods, construction and community building might be a direction for future studies.

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heritage

Article

Spatial Distribution Characteristics and Influencing Factors of the World Architectural Heritage

Xuefei Wang [1], Jiazhen Zhang [2,*], Jeremy Cenci [2] and Vincent Becue [2]

1 School of Architecture, Southeast University, Nanjing 210096, China; 220210202@seu.edu.cn
2 Faculty of Architecture and Urban Planning, University of Mons, 7000 Mons, Belgium; Jeremy.cenci@umons.ac.be (J.C.); Vincent.becue@umons.ac.be (V.B.)
* Correspondence: Jiazhen.zhang@umons.ac.be

Abstract: This research focusing on the world architectural heritage sites registered in the World Heritage List established by UNESCO aimed to analyze its spatial distribution characteristics and influencing factors at the world and regional level to provide a scientific basis for further architectural heritage conservation. Firstly, this study explored the spatial distribution characteristics of the world architectural heritage sites using the ArcGIS spatial analysis method. Then, we used the space–time statistical method to analyze their spatial and temporal distribution characteristics. The main findings are as follows: (1) world architectural heritage sites are distributed in clusters with imbalanced patterns and a strong degree of concentration: in Western Europe, Eastern Asia, and Northwestern Latin America, with clear country distribution, especially in Italy, China, and Mexico; (2) the time of construction can be divided into four stages: the ancient historic sites stage, the uniform and stable stage, the stage of growth in Asia and Europe, and the stage of growth in Europe, America, and Africa; (3) different types of heritage sites are unevenly distributed, and the type distribution differs significantly between regions, with regional uniqueness. The authors also analyzed the influencing factors of the spatial distribution characteristics and highlighted the important influence of the geographical environment, historical evolution, economic strength and discourse power, international heritage protection situation, and registration policy. This study may provide basis for specific guidance and directions for heritage protection for various countries and regions.

Keywords: architectural heritage; spatial distribution characteristics; spatial layout; spatial structure; influencing factors; UNESCO heritage; heritage protection

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1. Introduction

The protection of cultural and natural heritage is now a cultural trend affecting the world and a cultural hotspot concerning governments, people, and various international and regional organizations [1,2]. Architectural heritage, which is subordinate to cultural heritage, is an important part of cultural heritage protection. In addition to the universal value and significance of cultural heritage, architectural heritage is more important because it is directly and closely related to the human living environment.

Architectural heritage is the carrier of human historical activities, the memory of the city, an indispensable and important part of human civilization. The term "architectural heritage" comes from the Venice Charter, which means historic monuments and sites [3]. The systemic protection of architectural heritage began in the Renaissance. The changes in the concept of heritage protection are mainly reflected in the international conservation documents and charters published in different periods [4]. With the passage of time and the deepening of academic understanding of heritage management, more and more protection regulations have been promulgated [5–7]. The Athens Charter, the Venice Charter, the World Heritage Convention, the Florence Charter, etc. represent the stage achievements of the formation of the concept of protecting cultural and natural heritage, which reflect the new thoughts of heritage protection in various periods. In recent years, under the circumstances of globalization, informatization, and climate change, protection of the architectural heritage has become more comprehensive, complex, and urgent.

Architectural heritage includes not only single buildings of superior quality and their surroundings, but also all towns or villages with historical and cultural significance [8]. It is an important carrier of local cultural identity [9], and its spatial distribution to some extent reflect the historical context and evolution process of civilization development and its internal relations in different geographical locations. At present, academic research on architectural heritage from the perspective of space mainly involves micro and medium aspects, as well as macro-level research on specific types of architectural heritage, such as industrial heritage, religious architectural heritage, etc. [10–12]. Studies on the spatial distribution characteristics of architectural heritage sites on the global level are scarce.

Regarding understanding of architectural heritage value, the academic community has experienced a corresponding development process [13]. Older research on the spatial distribution of architectural heritage was mainly concentrated on the field of architecture and geography. Due to the interdisciplinary nature of the concept of architectural heritage, it often intersects with archaeology, art humanities, tourism, and other fields [14–17]. In terms of research objects, studies on the spatial distribution of architectural heritage often overlap with related studies on specific heritage types, such as world heritage [18], endangered world heritage [19], industrial heritage [20], agricultural cultural heritage [21], mining heritage [22], cultural landscape heritage [23], religious architectural heritage [24], and settlement heritage [25]. On the spatial scale, studies have been conducted on the hemispheric, zonal, intercontinental, national scales, etc. However, the statistics of all the sites have not been sorted out and the research has not been carried out at the global level.

Therefore, from the perspective of spatial distribution, this study used the ArcGIS software (Geographic Information System Company, Environmental Systems Research Institute, West Redlands, CA, USA) spatial analysis and the geographical model method to study the general spatial distribution characteristics of the world architectural heritage sites registered in the World Heritage List. The influencing factors were further studied to reveal the spatial distribution patterns and provide a scientific basis for the research on the system and the method of architectural heritage protection.

2. Research Materials and Methods

2.1. The Source of the World Architecutral Heritage

The architectural heritage in this article refers to the architectural heritage sites that were examined and approved according to the standards and procedures stipulated in the World Heritage Convention issued by UNESCO (the United Nations Educational, Scientific and Cultural Organization) and then registered in the World Heritage List after being confirmed by the UNESCO World Heritage Committee.

At present, in this list, there are 1154 world heritage sites in the world, including 897 world cultural heritage sites, 218 world natural heritage sites, and 39 world cultural and natural heritage sites. The UNESCO 1972 World Heritage Convention defines architectural heritage as cultural heritage monuments, groups of buildings and sites with the outstanding universal value from the point of view of history, art, or science [26]. Based on this convention, an architectural heritage site can be interpreted as an "artifact", where its elements are witnesses of the cultures, actors, and events that occurred during the life of the building [27].

The world architectural heritage sites listed in this article are based on the 2021 statistics. Referring to the standard description of the World Heritage Convention and the Operational Guidelines for the Implementation of the World Heritage Convention, the authors selected 877 architectural heritage sites as research objects distributed between five global politico-economic and cultural zones, 148 countries and regions, involving seven heritage types, including sites, monuments, group of buildings, cultural landscape, heritage towns and town centers, heritage canals, and heritage routes (Table 1) [28,29]. All the tables and figures in this article were elaborated by the authors.

Table 1. Architectural heritage types and definitions.

Types	Definition
Sites	Works of man or the combined works of nature and man, and areas including archaeological sites which are of outstanding universal value from the historical, esthetic, ethnological, or anthropological point of view.
Monuments	Architectural works, works of monumental sculpture and painting, elements or structures of an archaeological nature, inscriptions, cave dwellings, and combinations of features, which are of outstanding universal value from the point of view of history, art, or science.
Groups of buildings	Groups of separate or connected buildings which, because of their architecture, their homogeneity, or their place in the landscape, are of outstanding universal value from the point of view of history, art, or science.
Cultural landscapes	They are illustrative of the evolution of human society and settlement over time, under the influence of the physical constraints and/or opportunities presented by their natural environment and of successive social, economic, and cultural forces, both external and internal.
Heritage towns and town centers	(i) Towns which are no longer inhabited but which provide immutable archaeological evidence of a past; these generally satisfy the general criterion of authenticity and can be easily managed; (ii) historic towns which are still inhabited and which, by their very nature, have developed and will continue to develop under the influence of socioeconomic and cultural change, a situation that renders the assessment of their authenticity more difficult and any conservation policy more problematical; (iii) new towns of the twentieth century which paradoxically have something in common with both the aforementioned categories: while their urban organization is clearly recognizable and their authenticity is undeniable, their future is unclear because their development cannot be controlled.
Heritage canals	A canal is a human-engineered waterway. It may be of outstanding universal value from the point of view of history or technology, either intrinsically or as an exceptional example representative of this category of cultural property. The canal may be a monumental work, the defining feature of a linear cultural landscape, or an integral component of a complex cultural landscape.
Heritage routes	The concept of heritage routes is shown to be a rich and fertile one, offering a privileged framework in which mutual understanding, a plural approach to history, and a culture of peace can all operate.

2.2. World Architecture Heritage Coordinate Data

With the help of the Google Earth Map Coordinate picker, the spatial coordinates of the sites in the list that conform to the architectural heritage criteria were calibrated [30]. The spatial distribution map of the world architectural heritage was generated (Figure 1).

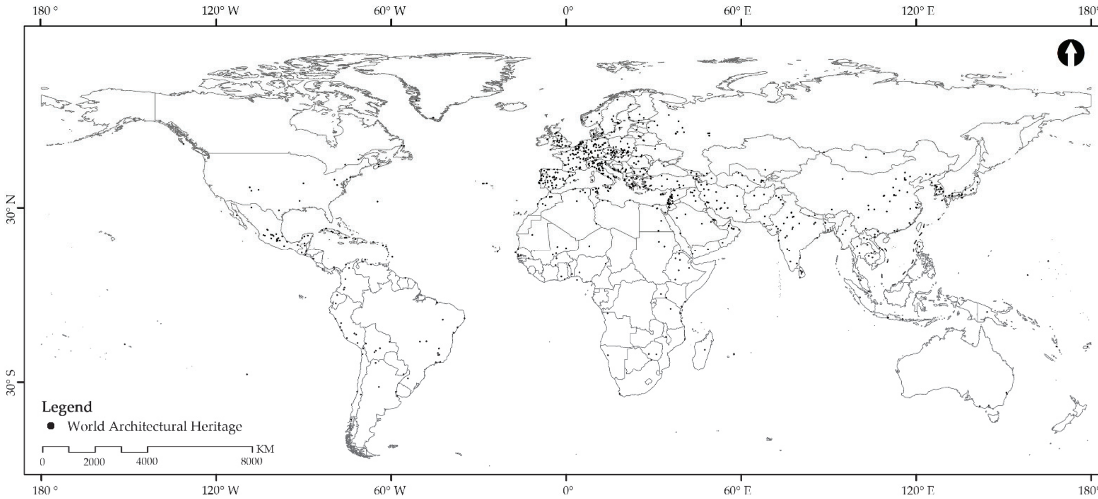

Figure 1. Spatial distribution map of the world architectural heritage. Note: The Antarctic plate is not shown in the picture because it does not feature any sites from the World Heritage List.

2.3. Analytical Methods

With the help of the correlation operation model in the ArcGIS software, using the spatial analysis method of the nearest neighbor analysis and kernel density, as well as the traditional geographical model method of the spatial Gini coefficient and the imbalance index, this study analyzed the distribution characteristics of architectural heritage in the worldwide geographic space [31].

2.3.1. Nearest Neighbor Analysis

On the macroscale, architectural heritage is distributed as points on the world map. The spatial distribution patterns of point elements can be summarized into three types: clustered type, random type, and dispersed type. The nearest neighbor index can be used for the analysis of the proximity degree of point elements in the geographic space. We calculated the nearest neighbor index as follows [32]:

$$R = \frac{\overline{d}}{d_E} = 2\sqrt{Dd} \quad (1)$$

where $\overline{d}$ represents the average of the distances between the nearest points, d_E refers to the theoretical nearest neighbor distance, and D is the point density; d_E in this formula can be calculated as follows [33]:

$$d_E = \frac{1}{2}\sqrt{\frac{A}{n}} = \frac{1}{2\sqrt{D}} \quad (2)$$

where A refers to the total area of the administrative district with architectural heritage sites and n is the amount of world architectural heritage sites.

2.3.2. Kernel Density Analysis

To further explore the aggregation areas of the world architectural heritage, the kernel density estimation model was used to evaluate the spatial aggregation degree of the architectural heritage. The kernel density estimate value was calculated as follows [34]:

$$f_n(x) = \frac{1}{nh}\sum_{i=1}^{n} k\left(\frac{x - X_i}{h}\right) \quad (3)$$

where n represents the world architecture heritage amount, k is the kernel function, $x - X_i$ refers to the distance from the estimate point x to the sample X_i, and h is the search radius.

2.3.3. Imbalance Index

The spatial structure difference of the world architectural heritage is reflected in the difference in the number of architectural heritage sites in different regions. The imbalance index was used to reflect the equilibrium index of the distribution of the architectural heritage in different regions. The calculation formula was as follows:

$$S = \frac{\sum_{i=1}^{n} Y_i - 50\ (n+1)}{100n\ -\ 50\ (n+1)} \quad (4)$$

where n refers to the number of regions, Y_i is the cumulative percentage of the number of architectural heritage sites to the total in the region i. If S = 0, the world architectural heritage sites are evenly distributed in each region. If S = 1, they are concentrated in a certain region. The closer the S value is to 1, the more unevenly the world architectural heritage sites are distributed.

2.3.4. Gini Coefficient

The Gini coefficient was used to describe the distribution of spatial elements in discrete regions, and can be calculated as follows [35]:

$$G = \frac{-\sum_{i=1}^{n} P_i l_n P_i}{l_n N} \quad (5)$$

$$C\ =\ 1\ -\ G \quad (6)$$

where N is the number of regions, P_i refers to the percentage of the number of architectural heritage sites to the total in the region i, and C represents the uniformity of distribution. In theory, the Gini coefficient is between 0 and 1, and a higher Gini coefficient indicates a higher concentration.

3. Analysis of the Spatial Structure Characteristics of the World Architectural Heritage

3.1. The Characteristics of Spatial Distribution

3.1.1. Type of Distribution Structure

We used ArcGIS10.5 to conduct the nearest neighbor analysis of 877 world architectural heritage sites. The results show that the average observation distance $\overline{d}$ is 180,428.4902 m, the expected average distance d_E is 304,183.9475 m, and the nearest neighbor ratio is 0.59, less than 1, which shows that the world architectural heritage sites are clustered in space.

3.1.2. Overall Distribution Pattern

The kernel density analysis in the ArcGIS10.5 spatial analysis tool was used to divide the spatial pattern of the world architectural heritage sites into four levels according to the density value, namely, core-density, high-density, medium-density, and low-density. Then, we generated the kernel density distribution map of the world architectural heritage (Figure 2).

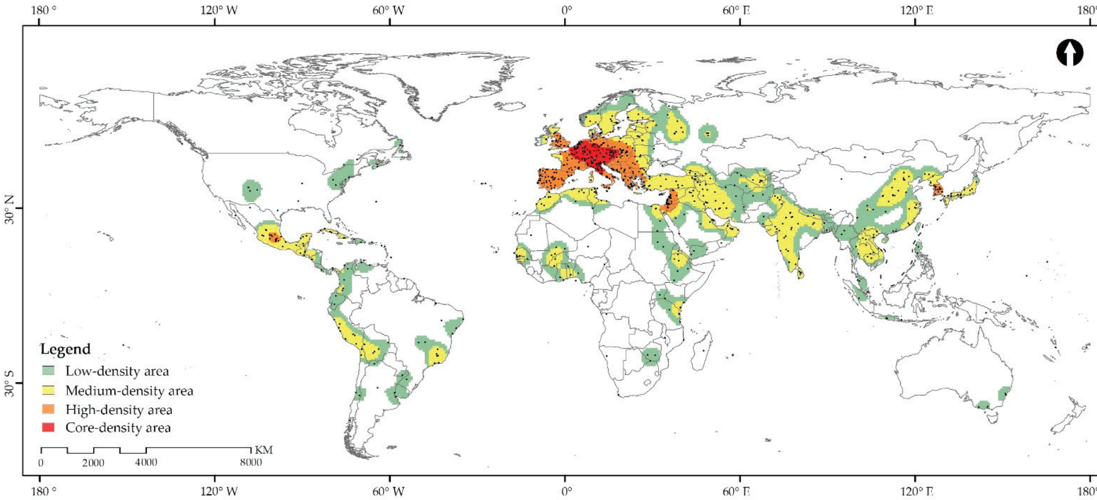

Figure 2. Kernel density distribution map of the world architectural heritage. Note: The Antarctic plate is not shown in the picture because it does not feature any sites from the World Heritage List.

In Figure 2, we see that the world architectural heritage sites cluster and form a core-density zone in Western Europe and two high-density zones in Eastern Asia and Northwestern Latin America, which shows obvious agglomeration characteristics. The spatial agglomeration forms are mainly of two types: zonary and cluster distribution. They are banded in Northeast and South Asia, Western South America and Mexico in North America, and clustered in Midwestern Europe and the Eastern and Northern coastal areas of the Arab States.

3.1.3. Distribution Differences between Various Regions

The world architectural heritage sites are divided into five global politico-economic and cultural zones by UNESCO [36]. According to Formula (4), after calculation and analysis of the data of heritage amounts, proportions, and cumulative proportions in each zone in Table 2, it can be concluded that the imbalance index S of the world architectural heritage is 0.53. It shows that the distribution of architectural heritage sites in the five zones of the world is imbalanced, and there are obvious differences in each region.

Table 2. Statistics on the distribution of the world architectural heritage in various regions.

Region	Heritage Amount	Proportion	Cumulative Proportion
Europe and North America	457	51.99%	51.99%
Asia and the Pacific	191	21.73%	73.72%
Latin America and the Caribbean	103	11.72%	85.44%
Arab States	81	9.22%	94.65%
Africa	47	5.35%	100.00%
Total	879 [1]	100.00%	405.80%

[1] There is one architectural heritage site shared by Europe and North America, Asia and the Pacific, Latin America and the Caribbean.

The number of European and North American architectural heritage sites accounts for 51.99% of the global world architectural heritage, which is much higher than even distribution (20%). Asia and the Pacific account for 21.73%, and the other three regions are all below the even distribution. Antarctica has no architectural heritage listed in the World Heritage List (Table 2). With the results, we generated the world architectural heritage distribution map in Figure 3.

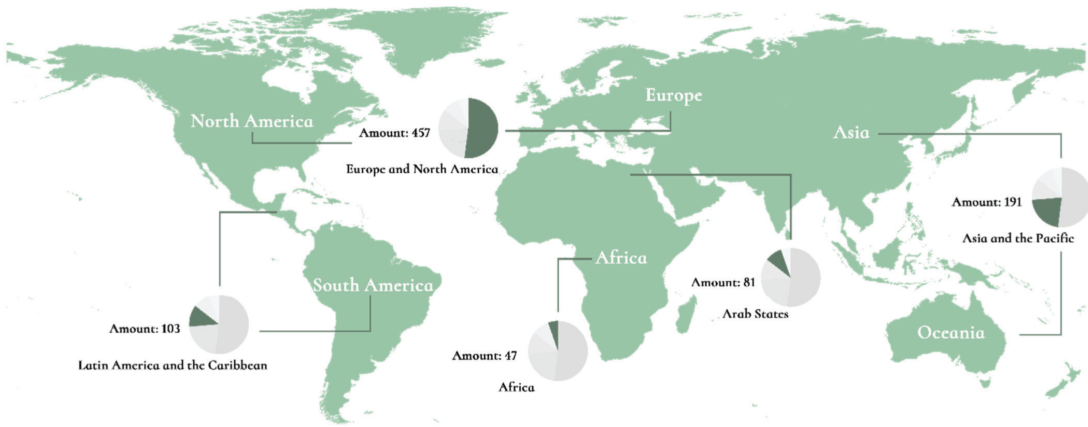

Figure 3. World architectural heritage distribution map. Note: The Antarctic plate is not shown in the picture because it does not feature any sites from the World Heritage List.

3.1.4. Analyses of Aggregation Areas

We calculated the Gini coefficient of the number of the world architectural heritage sites distributed in the five geographical divisions of the world to judge the uniformity of their distribution. We used Formulas (5) and (6) to calculate the Gini coefficient G = 0.81 and the distribution uniformity C = 0.19. The result shows that the concentration degree of the world architectural heritage is strong and the distribution uniformity is low in the five regions.

The 877 architectural heritage sites are distributed between 148 countries and regions, accounting for 63.52% of the total number of 233 countries and regions of the world. The results for each country within each region show the characteristics of imbalanced distribution and strong concentration in Table 3.

Table 3. The imbalance index and the Gini coefficient of architectural heritage sites in each region.

Region	Heritage Amount	Country and Area Amount	Inequality Index	Gini Coefficient	Uniformity Coefficient
Europe and North America	457	49	0.51	0.87	0.13
Asia and the Pacific	191	32	0.62	0.80	0.20
Latin America and the Caribbean	103	24	0.58	0.82	0.18
Arab States	81	19	0.32	0.94	0.06
Africa	47	24	0.35	0.94	0.06

The specific distribution is as follows:

1. The largest concentration of the world architectural heritage is in Europe and North America. This region has 457 architectural heritage sites in 49 countries, with Italy (52), Germany (47), Spain (42), and France (40) leading the list.
2. For Asia and Pacific, there are 191 architectural heritage sites in 32 countries, mainly in Northeast and South Asia: China (36), India (32), Iran (the Islamic Republic of Iran) (24), Japan (19).
3. The world architectural heritage sites of Latin America and the Caribbean (103) are distributed between 24 countries, mainly in Mexico (27) and Brazil (16).
4. Most architectural heritage sites in the Arab States are in Morocco (9) and Tunisia (7). In Africa, Ethiopia (6), Senegal (5), Kenya (4), and Mali (4) have the largest concentration of architectural heritage sites.

3.2. The Characteristics of Time and Type Distribution

3.2.1. Distribution of the Registration Time

We used spatiotemporal statistical analysis methods to research the spatiotemporal distribution (Figure 4). It was found that the number of registered architectural heritage sites shows a trend of fluctuating growth during the last 44 years, from 1978 to 2021, and its development can be roughly divided into three periods. From 1978 to 1988, the number of registered architectural heritage sites maintained a steady growth. From 1989 to 2000, a period of rapid growth was observed, which reached a peak in 2000 when the number of registered architectural heritage sites reached 49. Since 2001, the number has been stable, and the annual number of registered architectural heritage sites has decreased slightly compared with the previous period.

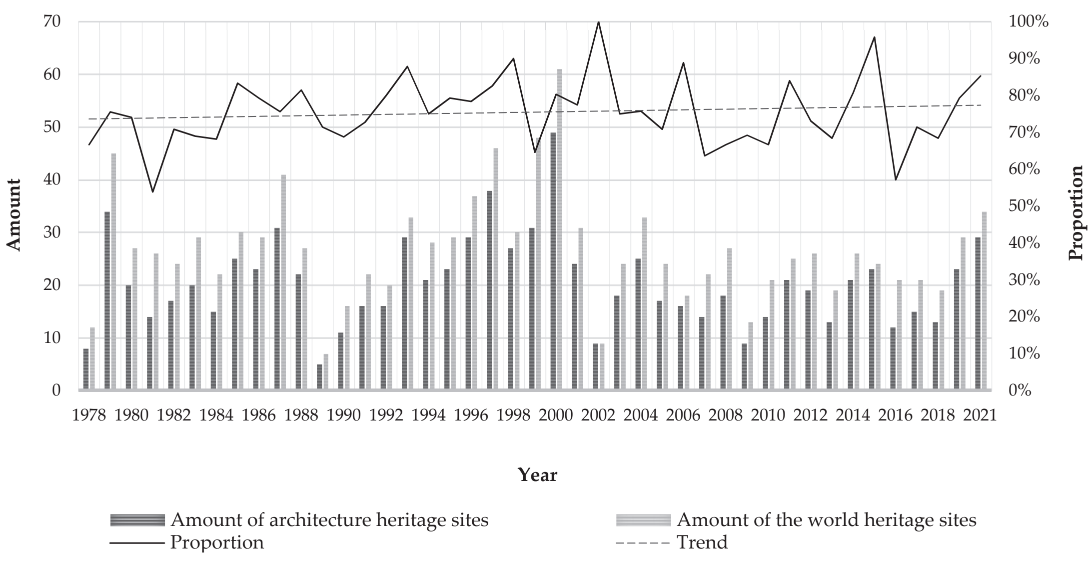

Figure 4. Statistics on the registration time of architectural heritage sites and the world heritage sites.

Analysis of the registration time of architectural heritage sites in the five regions (Figure 5) found that Europe and North America, as the region with the largest concentration of the world architectural heritage, has a dynamic trend similar to the overall trend of the world architectural heritage. In the 10 years from 1979 to 1988, the Arab States registered the largest number of heritage sites, accounting for 49.38% of the total number in the region. Asia and the Pacific have maintained sustained growth.

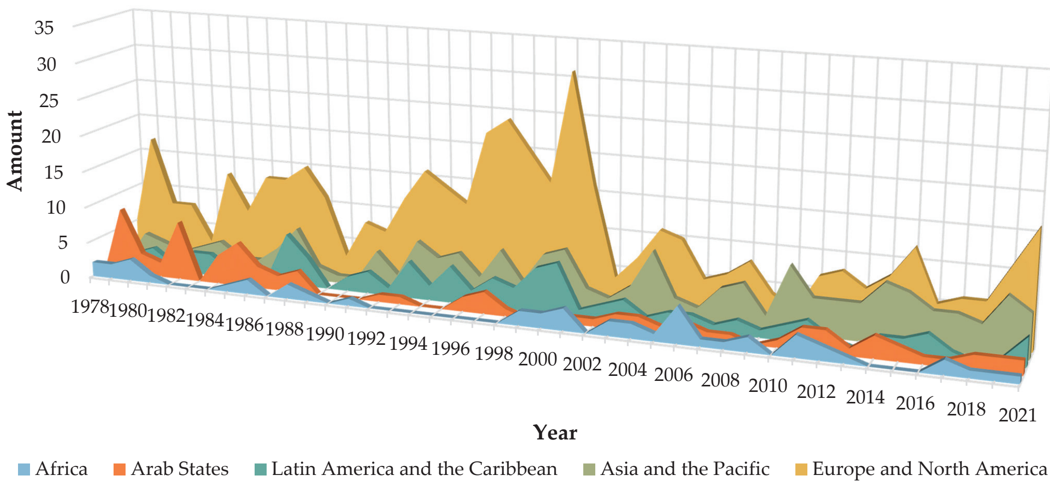

Figure 5. Statistics on the registration time of architectural heritage sites in various regions.

3.2.2. Distribution of the Construction Time

As for the construction time of architectural heritage sites, some sites have been rebuilt several times, and in some cases the construction process covered one or several long periods. To control the consistency of time variables, this study adopted the initial construction year uniformly. This allowed us to elaborate the construction time distribution map of architectural heritage sites of the world and each region in Figures 6 and 7.

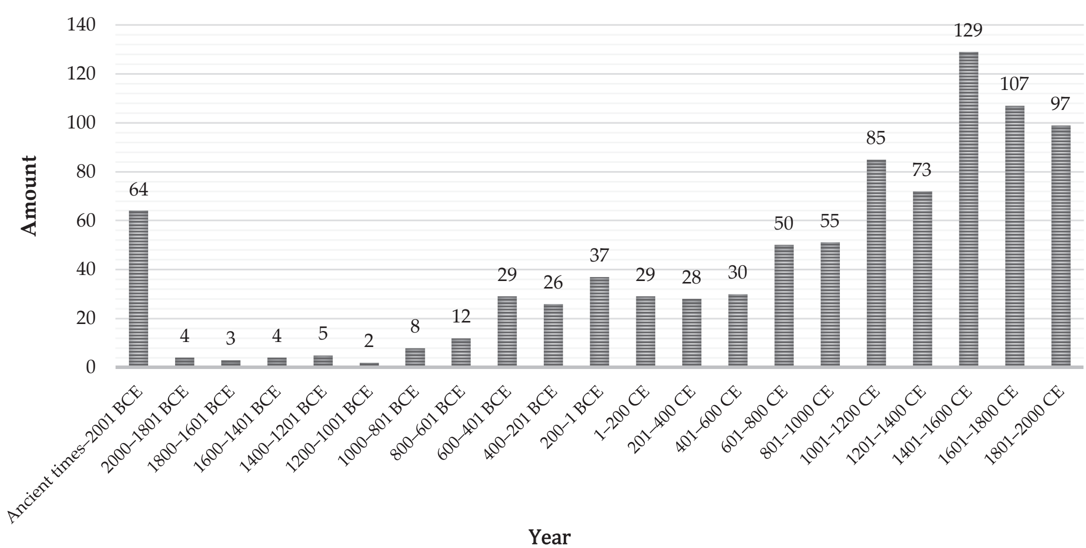

Figure 6. Statistics on the construction time of the world architectural heritage. Note: The construction times of five heritage sites cannot be determined: one is in Africa, and the other four are in Europe and North America.

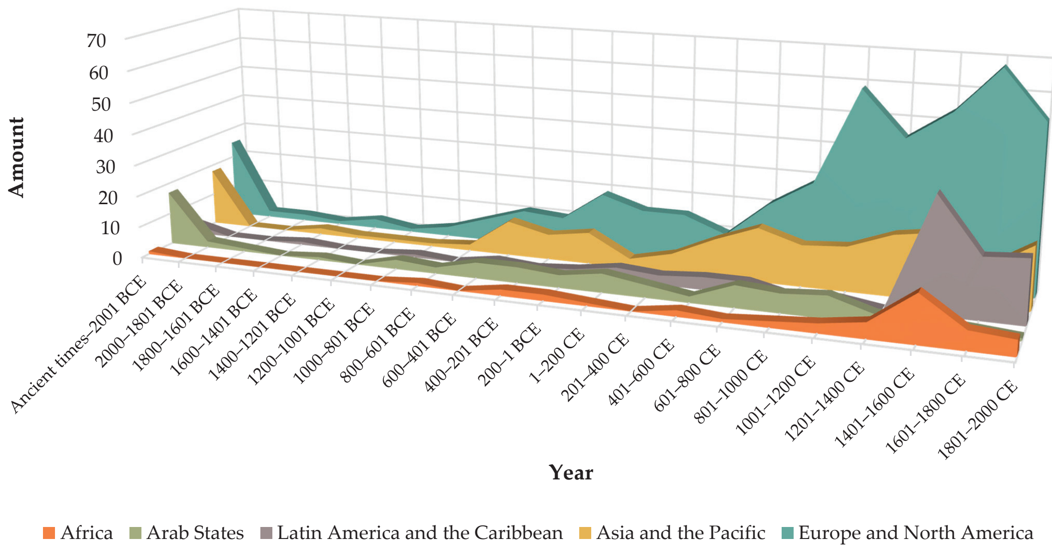

Figure 7. Statistics on the construction time of architectural heritage sites in various regions.

Analyzing the construction time of the architectural heritage of the whole word and of each region, we found that the heritage construction time can be divided into four stages. The first stage is the ancient historic site stage before the 20th century BCE. Architectural heritage sites built during this period are mainly distributed in Europe and North America (25), Asia and the Pacific (18), and the Arab States (17). The second stage is the uniform and stable stage from the 20th century to the 6th century BCE. The number of heritage sites built during this period was small and remained stable. The third stage is the Asian and European growth from the 6th century BCE to the 6th century CE. The architectural heritage of Asia and the Pacific and Europe and North America began to grow significantly during this period. Compared with the previous period, the number of heritage sites in this period increased and maintained a stable trend. The fourth stage, from the 6th century to the present times, is the growth stage for Europe, America, and Africa. The number of heritage sites grew rapidly, reaching its peak in the 15th and 16th centuries.

3.2.3. Distribution of Architectural Heritage Types

Referring to the UNESCO version of the modern heritage classification standards [37] combined with archaeology, sociology, natural geography, architecture, urban planning, and other disciplines and classification systems [38], we formulated the following classification standards for architectural heritage. There are five major categories and 15 subcategories (Table 4).

The statistical results show that residential (428) and public architecture (308) are the main types, which account for 83.92% of the total number of architectural heritage sites. Among the residential architecture, cities and urban agglomerations have the largest number of sites (289), accounting for 67.52% of this category. Religious architecture (167) has the largest amount public architecture sites, with a proportion of 54.22% (Figure 8).

Table 4. Classification and number of the world architectural heritage sites.

Category	Amount	Subcategory	Amount
1. Residential architecture	428	1.1 Cities and urban agglomerations 1.2 Towns and villages 1.3 Groups of building 1.4 Single buildings	289 45 82 12
2. Public architecture	308	2.1 Commercial facilities 2.2 Cultural and educational facilities 2.3 Transportation facilities 2.4 Civil affairs facilities 2.5 Religious architecture 2.6 Landscape architecture 2.7 Memorial buildings	9 14 24 30 167 16 48
3. Industrial architecture	67	3.1 Civil industry 3.2 Military industry	33 34
4. Agricultural architecture	30	4. Agricultural architecture	30
5. Royal architecture	44	5. Royal architecture	44
Total	877	Total	877

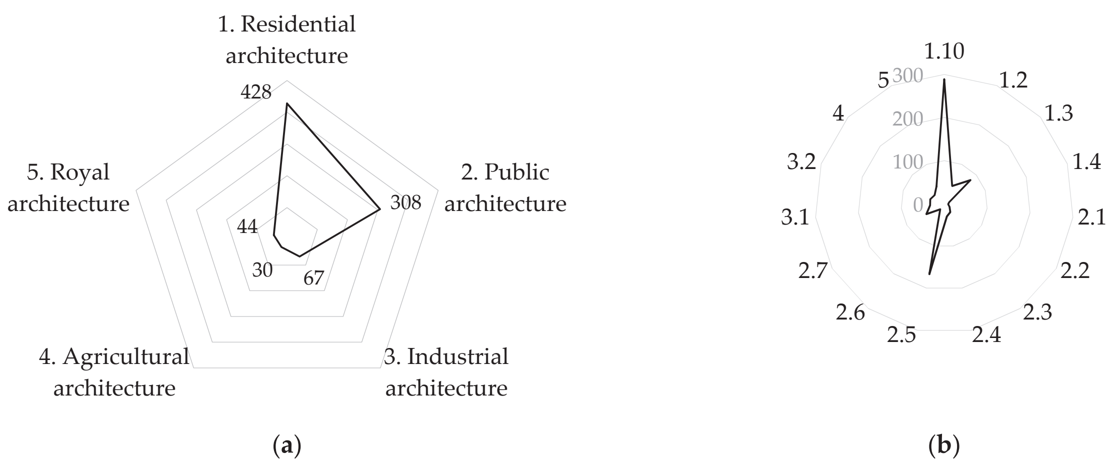

Figure 8. (**a**) Statistics on the categories of the world architectural heritage. (**b**) Statistics on the subcategories of the world architectural heritage.

Then, we conducted statistical analysis of the quantity distribution of various types of architectural heritage in various regions (shown in Table 5) and found that various regions are significantly different and have regional uniqueness:

1. Cities and urban agglomerations occupy the largest proportion of heritage sites in all the regions.
2. Religious architecture is mainly distributed in two regions, namely Europe and North America (60.48%) and Asia and the Pacific (28.74%).
3. In Africa, memorial architecture (7) is second only to the cities and urban agglomerations (17) and groups of buildings (8), accounting for 31.82% of the total number of all heritage sites.

4. In the region of Asia and the Pacific, royal architecture (17), towns and villages (11), and memorial buildings (11) occupy a considerable proportion.

Table 5. The subcategories and the numbers of the world architectural heritage sites in each region.

Subcategory	Amount				
	Africa	Arab States	Asia and the Pacific	Europe and North America	Latin America and the Caribbean
1.1	17	45	50	128	49
1.2	4	9	11	14	7
1.3	8	9	13	44	8
1.4	0	0	3 [1]	10[1]	1 [1]
2.1	1	1	4	3	0
2.2	0	0	2	8	4
2.3	0	0	6	16	2
2.4	0	3	8	18	1
2.5	4	5	48	101	9
2.6	0	0	2	9	5
2.7	7	2	11	22	6
3.1	1	0	2	26	4
3.2	2	2	8	17	5
4	0	3	6	19	2
5	3	2	17	22	0
Total	47	81	191	457	103

[1] There is one architectural heritage site shared by Europe and North America, Asia and the Pacific, Latin America and the Caribbean.

4. Influencing Factors in the Spatial Distribution of the World Architectural Heritage

4.1. Influencing Factors of the Geographical Environment

The spatial distribution of the world architectural heritage is affected by climate, topography, and altitude.

In terms of geographical location, architectural heritage sites are concentrated in the land areas of middle and low latitudes, especially in the offshore land area near 30 degrees North latitude. Most of the architectural heritage sites are distributed in the lower altitude areas with relatively gentle terrain, where the climate is more suitable for human life and production activities and the intensity of human transformation of nature is greater, resulting in a large number of glorious heritage sites [39]. The architectural heritage of Europe, for example, is clustered in the temperate marine and the Mediterranean climate zones and other temperate plains of Western Europe. Asia's architectural heritage is concentrated in the southeastern coastal areas of the temperate monsoon and temperate continental climate zones at lower elevations. Architectural heritage sites of Africa are mostly distributed in the humid tropical rainforest and savanna climate zones and tend to be in the eastern and western coastal areas south of the Sahara Desert [40].

4.2. Influencing Factors of the Historical Development

Important nodes in the historical process often exert great influence on urban civilization and the built environment which interacts with human activities.

Historically, the fertile rivers and plains of the Middle East, India, China, and Europe gave birth to the greatest civilizations in history [41], including the Nile and Mesopotamia in the Middle East and the Iranian Plateau, the Yellow River valley in China, and the Northern Mediterranean region of Europe (including North Africa) [42]. Ancient humans established the earliest settlements and urban civilizations in these areas and gradually created a mature cultural form [43]. As a result, Europe and America, Asia and the Pacific, and the Arab States have a large number of prehistoric architectural heritage sites. Eurasia has become an important historical center of the world, and the architectural heritage in Europe, America, and Asia and the Pacific accounts for 73.72% of the total number of the world architectural heritage sites. Meanwhile, residential and memorial buildings came to be the main architectural heritage types in Africa.

From 600 to 800 CE, China was in the prosperous period of the Tang Dynasty. During this period, China enjoyed high social development and unprecedented social and economic prosperity [44]. At the same time, China had frequent exchanges with the East and the West and active cultural exchanges with Japan, India, and other countries.

In the 14th century, with the rise of capitalism in Europe, the Renaissance movement and the opening of new navigation routes brought the development of architecture in Europe, North America, and Latin America to a glorious age [45]. This was the peak of the rapid growth of architectural heritage sites in Europe and Latin America. Then, the development of the workshop and handicraft industry promoted the industrial revolution in the 18th century [46]. With the great development of industry, cities grew, and the urban civilization reached a new height, giving birth to a series of new architectural types such as industrial, municipal, and cultural buildings, including commercial facilities, cultural and educational facilities, transportation facilities, civil industrial and agricultural architecture.

By the middle of the 19th century, Britain, France, Italy, and other European countries began gradually establishing a protection system with the national government as the main body. Subsequently, the discussion on the protection of the architectural heritage at the national level gradually extended to the whole world with Europe as the core. Therefore, a considerable part of the recent architectural heritage, especially since the Renaissance, has been well and timely preserved.

Subsequently, the two World Wars in the 20th century almost halted the global economic and social development and caused devastating damage to some historical buildings and cities, leading to a decline in the number of the world architectural heritage sites during this period [47]. However, with post-war reconstruction came some new modern architectural heritage and the diversity of building types.

4.3. Economic Strength and Discourse Power

The spatial distribution difference of the world architectural heritage is closely related to the development of regional social economy in history. Countries with a higher level of economic development tend to have a relatively stable domestic social environment and have the ability to provide greater support for heritage protection and attach more importance to the declaration and protection of the world heritage. Most of Europe is made up of developed countries with advanced concepts and technologies of heritage protection, as well as national attention and protection efforts, resulting in a high degree of architectural heritage aggregation.

On the other hand, countries or regions with weak economic strength and state power pay limited attention to architectural heritage protection. According to the statistics of the number of endangered architectural heritage sites in each region, it can be found that such a number in the Arab States is the largest, while that in Europe and America is the lowest (Table 6). According to the statistics, armed conflicts, poor management, and engineering construction are the biggest problems facing cultural heritage sites, including architectural heritage sites. In addition, the pressure of urban development and inappropriate protection and reconstruction also pose a threat to the protection of architectural heritage sites [48,49].

Table 6. The number of endangered architectural heritage sites in each region and the proportion of endangered architectural heritage in each region.

Region	Total	In Danger	Proportion
Arab States	81	21	25.93%
Africa	47	4	8.51%
Latin America and the Caribbean	103	4	3.88%
Asia and the Pacific	191	4	2.09%
Europe and North America	457	4	0.88%
Total	879 [1]	37	4.21%

[1] There is one architectural heritage shared by Europe and North America, Asia and the Pacific, Latin America and the Caribbean.

At the same time, the potential influence of national discourse power on the concept and value cognition of heritage often hides behind the economic development. The discourse power of developed countries affects the cognition and behavior of international organizations on heritage, making international organizations tend to conform to the will of developed countries in the formulation of heritage protection laws and practices. The World Heritage Convention adopted in Paris in 1972 reflects the basic concept of the world heritage, which is the embodiment of the European recognition of the universal significance of historical heritage sites for international protection [4].

4.4. International Heritage Protection Situation and Registration Policy

The heritage registration policy and system driven by the international heritage conservation background plays a decisive role in the number of the world architectural heritage sites.

On the one hand, since the establishment of the World Heritage List in 1976, UNESCO successively established and regulated the World Heritage Center and other international authorities, constantly adjusted the requirements and standards of the heritage registration system according to the changes in the global heritage protection concept, and promoted the world heritage registration system to be more authoritative, rigorous, comprehensive, and up-to-date to the direction of continuous optimization. For example, since the first batch of the world heritage sites was registered in 1978, various types of heritage sites have been added in succession: from historical towns to cultural landscapes, from heritage canals to cultural routes, and more recently, industrial heritage, modern architectural heritage, and holy mountains. The abovementioned types of architectural heritage sites have been listed, valued, and protected [50].

On the other hand, although the criteria for inclusion in the World Heritage List formulated by the World Heritage Committee are objective and reliable, the distribution of the world heritage sites is often unreasonable due to the great differences between different countries in the value and protection of heritage and their enthusiasm for participating in international actions. The spatial distribution of heritage sites in developed and developing countries is extremely imbalanced. However, to alleviate this situation, since around 1994, UNESCO has developed specific programs to correct the imbalance concerning the 19th and 20th century heritage. These actions led to the publication of a special issue in 2003 of the World Heritage Papers, under the title 'Identification and Documentation of Modern Heritage'. With the deepening of the theme of peace and development, the strengthening of the international cooperation, and the introduction of the various relevant documents to balance the types and global distribution of the world heritage sites, the gap in the number of the world heritage sites between the contracting parties will tend to narrow [14].

5. Discussion

In this article, we showed that the world architectural heritage sites are clustered with the imbalanced distribution. The number, registration time, construction time, and type distribution of heritage sites in each geographical division are different, which is related to the geographical environment, historical process, economic strength, international heritage protection situation, and registration policy.

Our research reveals that there are great differences in the protection of architectural heritage in different regions of the world and at the same time reflects the unfairness of the international heritage registration system. We hope to establish a more scientific registration and protection system of the architectural heritage internationally, build a balanced international architectural heritage protection environment, guide specific directions of heritage protection for all countries and regions, and provide timely and appropriate protection and preservation for more endangered heritage sites.

The problems of architectural heritage protection mainly exist in three aspects: inadequate protection, excessive development, and isolation:

1. When we counted up the architectural heritage list, we found that although some heritage sites were listed, the actual situation was that they were not well-used and faced the risk of destruction. In particular, the endangered heritage needs the attention of all the countries and regions.
2. Some of the properties have been overdeveloped. The most immediate example is the delistment of Liverpool—Maritime Mercantile City in 2021, an architectural heritage site in the UK registered in 2004. Liverpool's planning of large-scale development of the historic dockyard area north of the city center will threaten the harmonious relationship between the site and its surrounding environment. Heritage and its environment should be the focus of protection and conservation, and any development and construction should be carefully decided. Otherwise, the lack of protection or noncompliance with laws and protection plans would cause the loss of a world heritage site or put it at risk.
3. World heritage protection generally lacks regional linkage and cooperation. Based on independent protection, each country should form not only horizontal coordination of regional heritage protection, but also a vertical linkage of various levels to build an organic and integrated regional heritage protection system.

In addition, considering that the registration of the world heritage is a strong driving force for local employment and sustainable economic development, to alleviate the imbalanced distribution of the world heritage, the registration system should be more inclined towards less developed areas.

Although there are important discoveries revealed by this study, there are also limitations. First, the coordinates of the architectural heritage sites are not precise enough. Some transboundary architectural heritage sites like heritage routes and ancient city walls have more than one coordinate, but we only chose the core coordinates, which affects the visualization of the spatial distribution of heritage points to some extent. Second, the selection of the research methods is limited. The spatial analysis methods used in this paper are one-dimensional. In further research, we will consider the inclusion of the time dimension with the factors of population and regional area, adopt the multiple regression analysis and other methods to conduct a comprehensive analysis, and further explore the two-dimensional succession law of time and space. Third, the discussion on the influencing factors is relatively superficial. In the future, a mathematical–statistical analysis should be conducted to further verify the coupling between the influencing factors and the spatial distribution characteristics and enhance the persuasiveness of the explanations.

6. Conclusions

At the spatial distribution level, the spatial analysis method was used to reveal the cluster form in space and show the areas of different densities. Then, we used the statistic analysis to verify the conclusions with actual data, and more accurate and clear results were obtained.

At the temporal and type distribution level, we divided the registration time and the construction time into various stages according to the changes and trends of the number of heritage sites. The type distribution shows a peculiarly imbalanced pattern in each region.

We further explored the influencing factors of the spatial and temporal distribution characteristics of architectural heritage sites. We analyzed the geographical environment, historical development, economic level, discourse power, international heritage protection situation, and registration policy and drew the following conclusions:

1. The spatiotemporal distribution of the world architectural heritage is affected by climate, topography, and altitude, which are related to the suitability of settlement.
2. Important nodes in the historical process have a great impact on the human civilization, and the built environment is often the epitome of historical development. Therefore, historical development leads to the construction of the built environment and also directly affects the spatiotemporal distribution of architecture types.
3. The spatial distribution difference of the world architectural heritage is closely related to the development of regional society and economy in history and is always influenced by the national discourse power. Countries with stronger economic strength tend to have a greater say in the international platform of architectural heritage conservation.
4. The heritage registration policy and system driven by the international heritage conservation situation play a decisive role in the number of the world architectural heritage sites. The diversity of heritage categories and the balance of heritage distribution will be the main guidance for the world architectural heritage protection organizations or institutions to establish the requirements for heritage registration and standardize the criteria for heritage selection.

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