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MAIN SECTION

Patterns in Morphological Evolution: Comparing Changes in Six Medieval City-Centres in the Low Countries (1720-2020)

Sahar Abdollahi — Erasmus University Rotterdam
Contact: abdollahi@ihs.nl

Jurian Edelenbos —Erasmus University Rotterdam
Contact: edelenbos@essb.eur.nl

Martin de Jong — Erasmus University Rotterdam
Contact: w.m.jong@law.eur.nl

Jan Fransen — Erasmus University Rotterdam
Contact: j.fransen@ihs.nl

ABSTRACT

To the perceptive observer, similarities in the urban structures and architecture of medieval city centres in the Netherlands, Belgium, and a strip of North-Western France will stand out. Indeed, they have been part of the Low Countries for a long time until separation led them to be governed by different institutional regimes for the past few centuries. This paper offers a novel qualitative method to examine the evolution of urban form through time, based on Kevin Lynch's urban form elements. It systematically compares the changes in the morphology of the historical centres over the past three centuries with the help of digitised maps. Changes in Lynch's morphological elements (nodes, edges, landmarks, and paths) are analysed to understand the characteristics of the urban evolution in six cities. In this contribution, we have studied three large cities (Amsterdam, Antwerp, and Lille) and three mid-sized ones (Leiden, Leuven, and Arras), all of which have well-preserved city centres. Our findings are based on a unique way of using well-developed historical cartography for mapping the morphological evolution over time and allow for further in-depth investigation of which trends and events cause these changes.

KEYWORDS

Urban Morphology Evolution, Kevin Lynch, Medieval Cities, Low Countries, Historical Comparative Analysis

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Mapping Morphological Evolution in Medieval Cities in the Low Contries

Cities are dynamic entities that show which morphological evolution over time can be examined. Some expand, some decline, yet others remain reasonably constant over time. More specifically, city centres in urban communities dating from medieval times show relative continuity, allowing us to study alterations due to military conquest, industrial or technological revolution, or demographic growth to be examined much more closely and precisely. Historical maps can help us shed light on the long-term evolution of city developments and their physical shape. They allow us to spot continuity and change in morphological elements over time and, if combined with the systematic application of a suitable conceptual framework, to analyse these changes and make sense of them.[1]

Medieval cities in Europe have their original footprint in a particular era and, unless destroyed in the course of time, continue to share specific characteristics and patterns related to that origin with each other. Comparing the texture of their urban cores with each other, as well as the transformation they go through across the centuries, tells us a lot about what morphological evolution took place. In this contribution, we apply this idea to continuity and change in cities of which the current city centres emerged in the Low Countries of the later Middle Ages, usually at the intersection of important waterways and trade routes. In those days, what is now known as the current Netherlands and Belgium, but also that strip of North-Western France, which comprises the departments of Nord and Pas-de-Calais, constituted a loosely united historical unity with a common style of architecture, shared urban patterns, and similar lifestyles.

Many important morphological changes in medieval city centres relate to the demolition of urban construction in response to or accommodating military, technological, economic, or demographic incentives. While some of that heritage has been entirely preserved or has at least had a lasting impact on the morphological patterns of these cities, other elements may have vanished from view. For instance, the star-shaped citadel in Lille, built as the city's fortification, has been preserved and is still used as a French military base today. But in Antwerp, the citadel and an enceinte around the city were completely dismantled in 1859. Defensive walls protected cities from military conquest in the past and thus acted as fixation lines but were, in some cases, more recently experienced as constraints to economic and demographic expansion and removed.[2,3] Leuven preserved some of its walls, while Arras completely dismantled them. We

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1 Elvin K. Wyly, "Continuity and Change in the Restless Urban Landscape," *Economic Geography* 75, no. 4 (1999), 309-338.

2 J. Le Goff, "Costruzione e distruzione delle torri della città murata," in *La città e le mura,* De Seta G. e Le Goff J. (eds), (Roma-Bari, Laterza 1989), 1-10.

3 Guido Zucconi, *La Città Dell'Ottocento* (GLF editori Laterza, 2005).

used the six maps four times to show the morphological basis with their key elements in each of the cities. Subsequently, we indicated which of these elements had been removed or added to the map roughly 100, 200, and 300 years later. This allowed us to systematically analyse long-term morphological changes in medieval cities, shedding light on the factors that shape urban development. Identifying continuity and change is vital for urban historians, planners, and geographers, particularly to understand how cities adapt to external pressures and allow policymakers and planners to make informed decisions about preserving historical urban cores while managing socio-economic development. Previous studies about urban form have mostly focused on geographical and typological approaches, and the evolution of urban morphology based on Kevin Lynch's elements in urban form has rarely been studied using historical maps. Nor does existing academic work on the topic simultaneously consider the morphological evolution of medieval cities crossing long time scales while comparing several ancient cities in the Low Countries.[4,5,6,7] That makes our contribution, despite its exploratory nature, new to the field. To our knowledge, this is the first study in which a combined diachronic and synchronic approach rooted in Lynch's framework is applied to investigate changes in ancient urban forms using historical cartographies. This unique intersection of urban morphology and evolutionary theory provides new perspectives on the adaptive dynamics of medieval cities, allowing for a more profound understanding of how urban morphology evolved across the centuries under the influence of the external environment.

In the rest of this article, the following steps will be taken. Section 2 introduces the currently dominant strands in morphological theory and clarifies why we chose Lynch's main thoughts in 'The Image of the City' as the backbone of our analytical framework. The third section clarifies the methods we used to collect and analyse our findings. We subsequently present our collection of 24 cartographic maps along with a systematic overview of their changing morphological elements in section 4. Finally, section 5 offers a broader discussion of the findings and looks at future implications of this study.

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4 Pierre Gauthier and Jason Gilliland, "Mapping Urban Morphology: A Classification Scheme for Interpreting Contributions to the Study of Urban Form," *Urban Morphology* 10, no. 1 (2006), 41.

5 Karl Kropf, *The Handbook of Urban Morphology* (John Wiley & Sons, 2018).

6 Anne Vernez Moudon, "Urban Morphology as an Emerging Interdisciplinary Field," *Urban Morphology* 1, no. 1 (1997), 3-10.

7 Vítor Oliveira, *Urban Morphology: An Introduction to the Study of the Physical Form of Cities* (Cham: Springer, 2016).

Urban Morphology

Morphology, as a discipline, studies the physical shapes and structures of organisms to reveal the mechanisms driving their evolution and the development of their constituent parts.[8] The analogy between organisms and urban morphology is rooted in the idea that cities, like living organisms, grow, adapt, and evolve in response to internal dynamics and external conditions.[9] Similarly, urban morphology investigates the various elements of urban form, such as streets, plots, and buildings, and their interconnections. It is rooted in urban ecology and seeks to understand the processes that shape cities and their adaptation over time.[10] In yet other words, urban morphology encompasses the study of urban form, actors, and their processes of emergence, evolution, and transformation.[11] According to the latter definition, urban 'morphology' is much broader than 'form' alone since it involves the social context around that physical shape, including actors and institutions leading to their emergence and transformation. However, in this article, we will merely focus on the process of change in the urban form elements as such and disregard their socio-institutional context even though it offers many clues as to mechanisms explaining the underlying dynamics for transformation. We will come to this point in the final section.

Cities are, in morphological terms, extremely complex systems, knowledge of which is pursued by a wide variety of academic disciplines. Massive efforts have been made to define this organised spatial structure to understand the basics of urban evolution.[12,13,14,15,16,17] Urban morphology is a growing cross-disciplinary field of research, attracting worldwide interest among scholars in architecture, geography, and planning. More recently, it has also attracted attention from sociologists, economists, and experts in cultural heritage conservation and restoration. It provides knowledge about urban form, its constituting elements, and the processes leading to their evolution over time by facilitating rigorous cross-city comparisons of different cities to identify the similarities and differences in their evolutionary patterns. The outcomes of such analyses are also an

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8 Stephen Jay Gould, "D'Arcy Thompson and the Science of Form," *New Literary History* 2, no. 2 (1971), 229-258.

9 Patrick Geddes, *Cities in Evolution: An Introduction to the Town Planning Movement and to the Study of Civics* (London: Williams, 1915).

10 *Moudon, "Urban Morphology as an Emerging Interdisciplinary Field," 3-10.*

11 Oliveira, *Urban Morphology: An Introduction to the Study of the Physical Form of Cities*.

12 Michael Batty, "Complexity and Emergency in City Systems: Implications for Urban Planning," *Malaysian Journal of Environmental Management* 10, no. 1 (2009), 15-32.

13 *Gauthier and Gilliland, "Mapping Urban Morphology," 41.*

14 Kropf, *The Handbook of Urban Morphology*.

15 *Moudon, "Urban Morphology as an Emerging Interdisciplinary Field," 3-10.*

16 Oliveira, *Urban Morphology: An Introduction to the Study of the Physical Form of Cities*.

17 Amos Rapoport, *Human Aspects of Urban Form: Towards a Man—Environment Approach to Urban Form and Design* (Elsevier 2016).

essential tool for heritage protection and historical conservation since they reveal which urban elements have been preserved or eliminated and how this has happened.[18]

Morphologists can be classified in their knowledge contribution to the field by the kind of data, the methodology they apply, the tools they use, the interpretative concepts they adopt, and their specific interpretation of urban form. Moudon has categorised the field of urban morphology as initially consisting of three main schools: a British, an Italian, and a French one, based on the different kinds of data they generally utilise to analyse places and the patterns they identify and use in their comparisons. [19,20,21,22,23]

In the twentieth century, two mainstream schools were developed parallel, led by M. R. G. Conzen (1907-2000) and Gianfranco Caniggia Muratori (1933-1987), with concerns in diverse disciplines, namely geography and architecture.[24] In the British School, the main aim of urban morphology is to describe and explain. Their approach is primarily historical and geographical and focuses on town planning. Its main analytical ingredients are the plot, block, street, building types, and land use.[25,26] On the other hand, the Italian school hails from an architecture-oriented approach. It developed the fundamental concepts of type and fabric, as well as the idea of the organism, by highlighting the spatial arrangement of the form as a synthetic unit of material, structure, and compositional plan. Its prescriptive and design-driven approach has been labelled 'typo-morphological'.[27] Like the Italian school, the French school emerged in opposition to the modernist movement in promoting historicity and the traditional inheritance of cities. As a sort of intermediary between the British and Italian schools, it expanded the morphological perspective by blending design with geography, incorporating insights from literature and the social sciences. What all three schools have in common, however, is that they all consider the plots and the buildings located on them as the main units for analysis for studying urban patterns. Form, resolution, and time constitute the three fundamental components in any urban morphological research on any

18 Kropf, *The Handbook of Urban Morphology*.

19 *Batty, "Complexity and Emergency in City Systems: Implications for Urban Planning," 15-32.*

20 *Gauthier and Gilliland, "Mapping Urban Morphology: A Classification Scheme for Interpreting Contributions to the Study of Urban Form," 41.*

21 Kropf, *The Handbook of Urban Morphology*.

22 *Moudon, "Urban Morphology as an Emerging Interdisciplinary Field," 3-10.*

23 Oliveira, *Urban Morphology: An Introduction to the Study of the Physical Form of Cities*.

24 *Yina Sima and Dian Zhang, "Comparative Precedents on the Study of Urban Morphology" (2009).*

25 Michael Robert Gunter Conzen, *Thinking about Urban Form: Papers on Urban Morphology, 1932-1998* (Peter Lang 2004).

26 Michael Robert Gunter Conzen, "Alnwick, Northumberland: A Study in Town-Plan Analysis," *Transactions and Papers (Institute of British Geographers)*, no. 27 (1960), iii-122.

27 Gelareh Sadeghi and Baofeng Li, "Urban Morphology: Comparative Study of Different Schools of Thought," *Current Urban Studies* 7, no. 4 (2019), 562-572.

type of city, whether conducted by geographers, architects, or urban planners.[28] Due to growing international exchange in academia, the distinction between various 'schools', and in fact, even the very use of that term, has now largely disappeared.

In recent years, more quantitative strands in morphological research have been introduced and gained influence, leading to the emergence of morphometrics as a subfield within morphology. Bill Hillier's Space Syntax is a new and innovative system of theories and techniques for mathematically analysing spatial configurations. The tendency of space syntax for studying urban morphology is a diverse concern and is sometimes integrated with GIS. Through digital maps, Hillier attempts to measure and even quantify the relationship between social power and spatial form.[29] The approach introduced by Michael Batty is based on generating cities from the bottom-up and complexity theory that presents new kinds of computational models, such as cellular automata (CA), agent-based models, and fractal geometry. [30]

These latest quantitative approaches in urban morphology require very detailed digital and manipulable maps and extensive open data for processing. Since our analogue sources on city historical city centres date from past centuries, we were not able to apply these recent methods. Instead, we have chosen to adopt the classical terminology of Kevin Lynch (1960), whose work exemplifies a more psychological perspective of urban form as residents and visitors experience it as lay people. What sets Kevin Lynch's image of the city approach aside from the above schools is his attempt to fill the gaps in objective city forms by using mental maps that reflect 'general impressions' rather than 'detailed facts', which lend themselves well to interpreting the headlines of historical evolution based on a more limited sets of maps/data. Lynch's cognitive approach provided a framework to reflect on the complex synergy between the 'urbs' (built environment) and the 'civitas' (people and activities changing over time).[31] For Lynch, the physical environment was an embodiment of time, providing an opportunity to sense continuity with past periods, the present, and the future. Conservation of that environment was a prerequisite conditional to protecting that continuity. Lynch mentions three aspects of urban morphology: spatial relations in physical form, relations between humans and the built environment, and historical relations that make up the formation and transformation processes. Lynch's work has offered environmental psychologists not just a topic of interest but also a feasible methodology to study the topic area through his five-part assessment of city form using mental maps. His perceptual approach to defining urban

28 *Moudon, "Urban Morphology as an Emerging Interdisciplinary Field," 3-10.*

29 *Tasos Varoudis et al., "Space Syntax Angular Betweenness Centrality Revisited" (2013).*

30 Luca D'Acci, "On Urban Morphology and Mathematics," *The Mathematics of Urban Morphology* (2019), 1-18.

31 Kropf, *The Handbook of Urban Morphology*.

form discerns paths, landmarks, edges, nodes, and districts as central elements of urban form that represent what the city's form means to the people who live there. They can be defined as follows:

- *Paths* are routes that people use to move throughout the city, including sidewalks, alleys, streets, roads, boulevards, railroads, and waterways.
- *Edges* are boundary areas between two distinct phases, spaces, or districts: linear breaks in continuity, including fortification walls, canals, shores, ports, and rails.
- *Nodes* are strategic focus points where various paths cross, which serve for orientation purposes but also as gathering points or attention points, including marketplaces, squares, public spaces, and junctions.
- *Landmarks* are external physical objects that can be used as reference points, including monuments, churches, castles, belfries, and city halls.
- *Districts* are areas characterised by common characteristics. Since the districts selected in this study are all historical city centres of medieval cities, they will not be treated as a variable below. Instead, they are the complete spatial unity in which the other four are analysed.

We consider the four Lynchian concepts of paths, edges, nodes, and landmarks as the most appropriate urban form elements for studying century-long morphological evolution to be contextualised to any culture since they are most straightforward to highlight and best to remember for users of urban space. They help us comprehend what changes materialise and where. In the section below, the operationalisation of these concepts for our study will be developed based on Lynch's approach.

Methodology

In longitudinal studies, changes in variables are examined during the passage of time. While a substantial body of literature has focused on urban morphology, work on the evolution of urban morphology over long periods of time is relatively thinly spread and experience with modern methods and techniques to measure it is rare.[32,33,34] Among the large variety of possible approaches to dealing with morphological change, we have selected historical maps to depict overall processes of change. We have collected maps of the urban cores of six cities from the former Low Countries through the centuries. They all have relatively well-preserved city centres, which can be conveniently analysed in terms of alterations

32 *Conzen, "Alnwick, Northumberland: A Study in Town-Plan Analysis," iii-122.*

33 Oliveira, *Urban Morphology: An Introduction to the Study of the Physical Form of Cities*.

34 Peter J. Larkham, "The Study of Urban Form in Great Britain," *Urban Morphology* 10, no. 2 (2006), 117.

in their morphological elements. We have done this for two cities in each of the three involved countries, one large and one mid-sized in each country: Amsterdam (large) and Leiden (mid-sized) in the modern-day Netherlands, Antwerp (large) and Leuven (mid-sized) in current Belgium and Lille (large) and Arras (medium-sized) in the part of France that used to have close ties with (or was part of) the former counties Flanders and Hainaut. We collected detailed, originally analogue, but recently digitised cartographic maps of the city centres of all six cities at four key moments in time (1720, 1820, 1920, and 2020). These periods were selected to capture significant socio-economic and technological shifts that influenced urban morphology: the pre-industrial era (1720), the early industrial period (1820), the height of industrialisation and urban expansion (1920), and the contemporary era of post-industrial urban transformation (2020). Using these maps, we created inventories of morphological changes across three critical intervals (1720–1820, 1820–1920, and 1920–2020) and conducted detailed analyses to identify patterns and drivers of urban form adjustments. This study is a comparative historical study that is longitudinal (diachronic) and (synchronic) at once. It is longitudinal in the sense that it follows the evolution of medieval cities over time employing historical maps, and it is synchronic and comparative in that this same evolution is examined for six different medieval cities. Historical maps are excellent resources for various research applications, especially for the explicit investigation of morphological change over time and are generally regarded as valuable for showing the past and the present situation in a spatial format. The exponential growth of available map scans, stored and maintained in digital archives and on the Internet, that could be easily accessible and downloadable enables researchers to analyse and process data in various scientific studies disciplines. Although their adequacy has sometimes been criticised for being insufficiently valid or reliable, this problem seems to apply to a much lesser extent to historical maps topographically representing smaller local areas.[35] While the reliability issue depends on not only scale but also the measuring techniques used in surveying and the purpose for which the map was produced, Elwin Koster introduced the Virtual Cities project, which visualises the errors that are generated in the process of geo-referencing. Using the RMS error viewer shows the level of accuracy of the map and identifies how much a chosen point will deviate from its real coordinates.[36] On the other hand, because of the low quality of the ancient maps, it is not possible to generate reliable knowledge on the size and shape of ancient blocks and streets and the advanced digital processes of that information. Considering these limitations, historical maps are likely to be the best possible source when it comes to displaying the correct features in the correct locations at the

35 A. Kent, "No Title," *The Value of Historical Maps: Art, Accuracy and Society* (1998).

36 E. Koster, "Urban Morphology and Computers 10 Years on E. Koster," *Urban Morphology* 13, no. 1 (2009), 74-76.

correct time. Therefore, in this study, historical maps have been selected for the longitudinal comparative study of medieval city centres in the Low Countries. The urban cores of the six cities originated in the late Middle Ages and were located in economically and culturally loosely coupled Low Countries. The selection of historical city centres was based on three indicators: (1) having a medieval structure, (2) the current population size of the entire city, and (3) having cities represented from all three different countries which the historical Low Countries now straddle. This resulted in our choice for Amsterdam, Antwerp, and Lille as cities with current populations (500,000 - 1,000,000) and well-preserved medieval city centres in the Netherlands, Belgium, and France, respectively and Leiden, Leuven, and Arras (50,000-100,000) as cities with medium-sized populations in those same countries. Alternatives for the large ones would have been Rotterdam and Brussels, but the historical cores of both have been subject to enormous damage or renovation over time, making them unsuitable for our purposes. Among the medium-sized ones, there would have been many alternatives in the Netherlands and Belgium and only one in France (Dunkirk), but we have simply selected one well-known and suitable example in each of the three countries. A systematic comparison of maps representing the topography of these six city centres in different centuries enables us to visualise the changes in their 'Lynchian' morphological elements in relative detail. Additionally, the secondary data, in the form of contemporary and historical maps, has been derived from bibliographical studies, formal data, photographs, and documentary records on websites. The three websites used for old maps in this study include collections of scanned maps modelled by cartographers a century ago:

www.oldmapsonline.org: Old Maps Online is a portal that allows easy access to historical maps in libraries worldwide.

https://www.davidrumsey.com: online map archives and libraries such as the David Rumsey Map Collection contain more than 150,000 maps ranging in date from around 1550 to the present. The site is free and open to the public.

https://commons.wikimedia.org: Wikimedia Commons is a media file repository that makes available public domain and freely licensed educational media content (images, sound, and video clips) to everyone. It comes from various archaeological museums and sites around the world.

https://earth.google.com/web/search: the current maps of the cities have been downloaded from Google Earth with the advanced feature of providing images and street views.

We use online historical maps because scanned map processing is the most efficient and effective method to extract historical information by overlaying and toggling back and forth between different maps. The advantage of using online maps is having free access to high-resolution maps that can be easily downloaded and used digitally. Moreover, the

applications of Photoshop and PowerPoint have been employed to analyse and process maps.

Topographic maps of all six city centres (Amsterdam, Antwerp, Lille, Leiden, Leuven, and Arras) depicted in four different years (1720, 1820, 1920, and 2020), resulting in 24 maps assisted us in making a diachronic and synchronic comparison of the six cities in four different centuries possible. Using the specific symbol (see legends below the maps) and yellow colour, we inserted and highlighted the morphological elements (node, edge, landmark, and path) into the historical maps of the year 1720. We followed the same procedure for all subsequent maps (1820, 1920, and 2020). However, there we gave the elements a green colour if they were new and made a first appearance on the map, a yellow colour if they had been preserved or consolidated from before, and a red colour if they had disappeared from the map (in comparison with the map of the previous century. After analysing the maps with the green, yellow, and red elements depicted on them, we made overview tables listing each city for each timeframe (1720-1820, 182-1920 and 1920-2020) and how many alterations of each type of Lynchian element had taken place. We were able to discern various specific subtypes (for the interval 1720-1820, for instance, landmarks could be subdivided into castles, churches, libraries, houses, warehouses, hospitals, banks, and hotels). Still, since these were somewhat variable and tended to change over time, we included them in our overview tables for completeness but did not process them for further analysis. The result of this exercise was a numerical indication of the changes that had occurred in each city per morphological type in each timeframe.

Studying the history of medieval cities revealed that these cities developed around marketplaces on which monuments such as cathedrals and city halls emerged where people convene for their socio-cultural and economic activities. Specific time-bound spatial elements, such as fortification walls, trading halls, narrow zigzag street patterns, abbeys, and castles, define what medieval cities represent in morphological terms. The major streets radiated from a central square to the gates with secondary arteries. [37]Although most medieval cities had the same essential urban structure, they underwent divergent processes of transformation in their spatial texture as they evolved through the centuries. All six case studies selected in our analysis followed complex evolutionary paths due to diverse military, political, industrial, economic, and demographic factors, which profoundly influenced their urban development. However, the broader societal developments and trends do not explain the morphological transformations in each timeframe as such (there are multiple intermediary institutional and other variables between those macro-developments and the morphological micro-adjustments), but they provide

37 Leonardo Benevolo and Carl Ipsen, *The European City*Blackwell Oxford, 1993).

general indications of how large-scale transformations and on-the-ground urban restructuring may hang together.

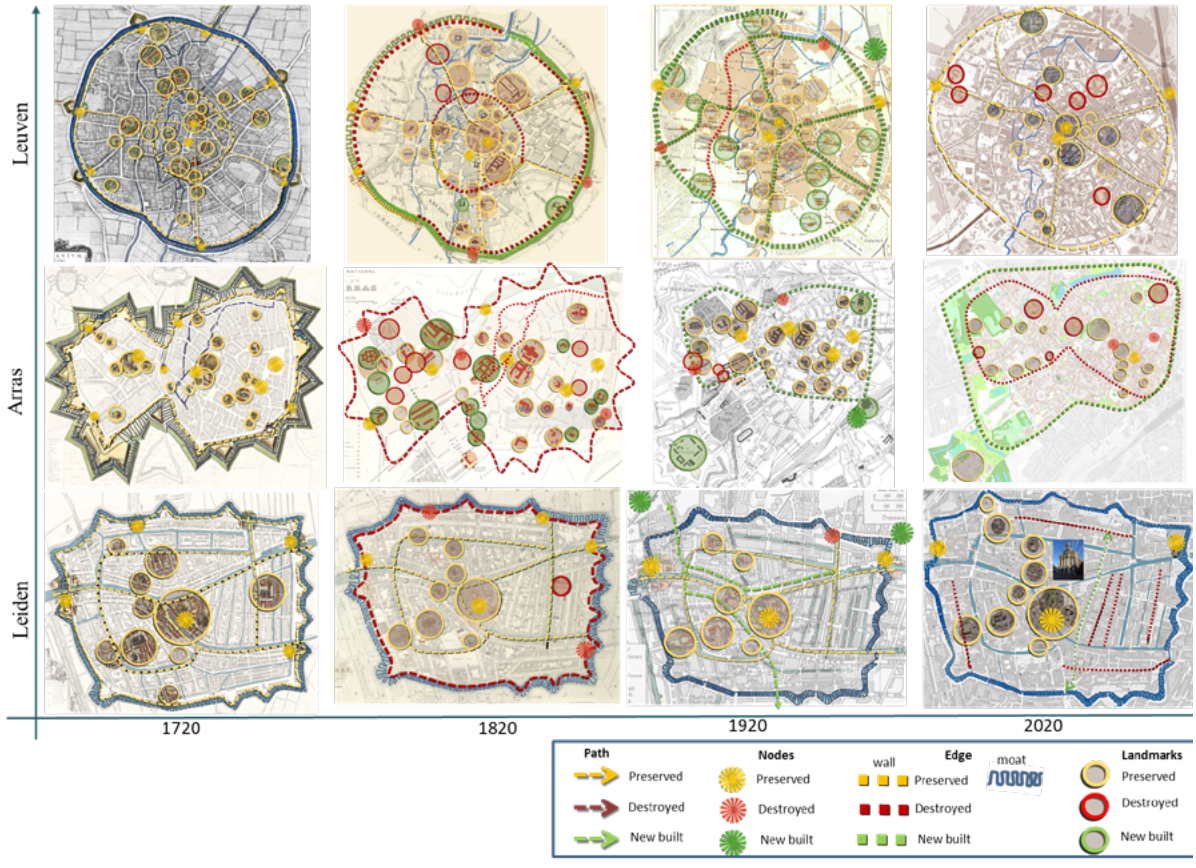
Findings

This study focuses on medieval city centres in local communities dating back to the late Middle Ages in the territories representing the Netherlands in those days. The maps presented in this section contain all 24 maps (six cities at four different moments in time), which serve as basic empirical evidence and then proceed to describe the main findings that can be gleaned from them: Which Lynchian morphological elements (paths, nodes, edges, and landmarks) changed in the historical inner city district of Amsterdam, Antwerp, Lille, Leiden, Leuven, and Arras and when did these changes occur? Map 1 presents the maps of all three large cities (Amsterdam, Antwerp, and Lille) for the years 1720, 1820, 1920, and 2020, and Map 2 does the same for the three medium-sized cities of Leuven, Arras, and Leiden.

The maps in the first column show the starting positions of all three cities in 1720. What stands out in these maps is the impressive fortification walls, especially in Antwerp and Lille, the high number of landmarks in Amsterdam and Antwerp, as well as the location of water on the Southern shore of Amsterdam and Antwerp and the prevalence of the local canals in Amsterdam that already present in those days. Moving towards the right, the maps show that many new elements, particularly landmarks and nodes, appear in green. At the same time, several 'old' monuments appear in red, implying they have been removed from the urban tissue. This pattern is more distinct in Antwerp and Lille than in Amsterdam, showing lower dynamic change levels in Amsterdam. This trend continues into the maps of 1920 in all three cities, with the major difference in fortifications having been torn down (displayed in red). However, overall, Amsterdam and Lille have better-preserved cityscapes than in Antwerp. The final result of this balance between continuity and change is shown in the maps for the year 2020: the essential morphological structure is still the same in all three cities as it was in 1720, complemented by a relatively rich collection of original buildings and urban spaces. Although there were few changes in the street network, the width of streets has often changed, and some canals have disappeared. On the other hand, the fortifications have been replaced with more functional edges (transition to new surrounding districts), and a substantial part of the landmarks and nodes have changed over time.

Map 2 repeats the same exercise for the historical cores of medium-sized cities Leiden, Leuven, and Arras. The maps indicate that traditional landmark architecture and cultural heritages incurred severe damage, especially in Arras and (to a lesser extent) Leuven. On the other hand, as shown in green, a remarkably high number of development projects inside the historical city centres

MAP 1 Morphological changes in Antwerp, Lille and Amsterdam



MAP 2 Morphological changes in Leuven, Arras and Leiden

		1720 - 1820						1820 - 1920						1920 - 2020					
Antwerp	Path	-Canals -Streets -Railroads	5 0 0	5	-Canals -Streets -Railroads	0 0 2	2	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	0 0 2	2	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	0 0 2	2
	Edge	-Coastline -Fortification -Moats	0 2 0	2	-Coastline -Fortification - Moats	0 2 0	2	-Coastline -Fortification -Moats	0 0 1	1	-Boulevard -Fortification -Moats	1 0 0	1	-Coastline -Fortification -Moats	0 1 1	2	-Boulevard -Fortification -Moats	1 0 0	1
	Node	-Squares -Marketplace -Entrance gates	0 0 2	2	-Stations -Port -Entrance gates	1 2 0	3	-Squares -Marketplace -Entrance gates	1 1 2	4	-Stations -Port -Entrance gates	2 0 0	2	-Station -Marketplace -Entrance gates	1 0 2	3	-Stations -Port -Entrance gates	0 0 0	0
	Landmark	-Castles -Churches -Libraries -Houses	1 5 0 5	11	-Service(hospital bank-hotel -Churches -Militaries -Warehouse- houses	6 4 7 5	20	-Castles -Churches -Militaries - Services(post- hotel-state)	1 7 5 5	18	-House -Churches -Militaries -Services(hospital bank- museum)	0 4 4 4	12	-Castles -Churches -Militaries -Services(post- hotel-state)	0 3 4 0	7	-House -Churches -Militaries -Service(hospital- bank- museum)	0 1 0 0	1
Amsterdam	Path	-Canals -Streets -Railroads	1 0 0	1	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	12 0 0	12	-Canals -Streets -Railroads	0 0 1	1	-Canals -Streets -Railroads	5 0 0	5	-Canals -Streets -Railroads	0 0 0	0
	Edge	-Coastline -Fortification -Moats	0 0 0	0	-Coastline -Fortification -Moats	0 0 0	0	-Coastline -Fortification -Moats	0 1 0	1	-Boulevard -Fortification -Moats	0 0 0	0	-Coastline -Fortification - Moats	0 0 0	0	-Boulevard -Fortification -Moats	0 0 0	0
	Node	-Squares -Marketplace -Entrance gates	0 1 2	3	-Stations -Port -Entrance gates	1 0 0	1	-Squares -Marketplace -Entrance gates	0 0 0	0	-Stations -Port -Entrance gates	2 0 0	2	-Station -Marketplace -Entrance gates	0 0 0	0	-Stations -Port -Entrance gates	0 0 0	0
	Landmark	-Castles -Churches -Hotel -Warehouses- houses	0 3 1 2	5	-Churches -Militaries -Service(institute palace-hotel) -Warehouse- houses	7 3 6 2	18	-Castles -Churches -Militaries - Services(post- hotel-state)	1 1 0 0	2	-House -Churches -Militaries -Services(hospital bank- museum)	0 0 0 0	0	-Castles -Churches -Militaries -Services(post- hotel-state)	0 3 0 0	3	-House -Churches -Militaries -Beurs	0 0 0 1	1
Lille	Path	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	4 0 0	4	-Canals -Streets -Railroads	0 4 1	5	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	0 0 0	0
	Edge	-Coastline -Fortification -Moats	0 0 0	0	-Coastline -Fortification - Moats	0 0 0	0	-Coastline -Fortification -Moats	0 2 0	2	-Boulevard -Fortification -Moats	1 0 0	1	-Coastline -Fortification - Moats	0 0 1	1	-Boulevard -Fortification -Moats	1 0 0	1
	Node	-Squares -Marketplace -Entrance gates	0 0 1	1	-Stations -Port -Entrance gates	0 0 0	0	-Squares -Marketplace -Entrance gates	0 0 0	0	-Stations -Port -Entrance gates	1 0 0	1	-Station -Marketplace -Entrance gates	0 1 1	2	-Stations -Port -Entrance gates	0 0 0	0
	Landmark	-Castles -Churches -Libraries -Houses	0 2 0 0	2	-Churches -Militaries -Warehouse- houses -Service(hospital bank-hotel	0 2 7 0	9	-Castles -Churches -Militaries - Services(post- hotel-state)	0 1 1 0	2	-House -Churches -Militaries -Train station -Services(hospital bank- museum)	0 2 2 1 0	5	-Castles -Churches -Militaries -Services (theater)	0 2 5 1	8	-Grand palace -Churches -Militaries -Service (theater)	1 2 1 1	5

TABLE 1 Morphological changes (1720-1820, 1820-1920, 1920-2020) in three large medieval cities in the Low Countries.

can also be observed in Arras and Leuven. In Leiden, higher levels of stability and continuity can be observed in terms of demolition and new construction: nearly all urban elements are yellow on all its maps. In Arras and Leuven, the city walls have been totally removed and leave limited trace on the urban form (in Leuven, city walls were preserved in some places, but moats and rivers were filled and transformed into motorways). The historic inner city of Leiden is still surrounded by its ancient moats (but without the walls).

To further systematise the general impression obtained based on the maps above, we have generated two tables displaying the amount of change in each city. These tables detail the type of morphological elements, the timeframe, and the extent of both "red" destructions and "green" new constructions. The "yellow" preserved areas are excluded from the tables, as they represent unchanged elements. Table 1 shows this count for three large cities in three periods of time.

What stands out from Tables 1 and 2 is that during the 18th century, few changes occurred (and consequently, continuity was high) in Leiden and Lille. The

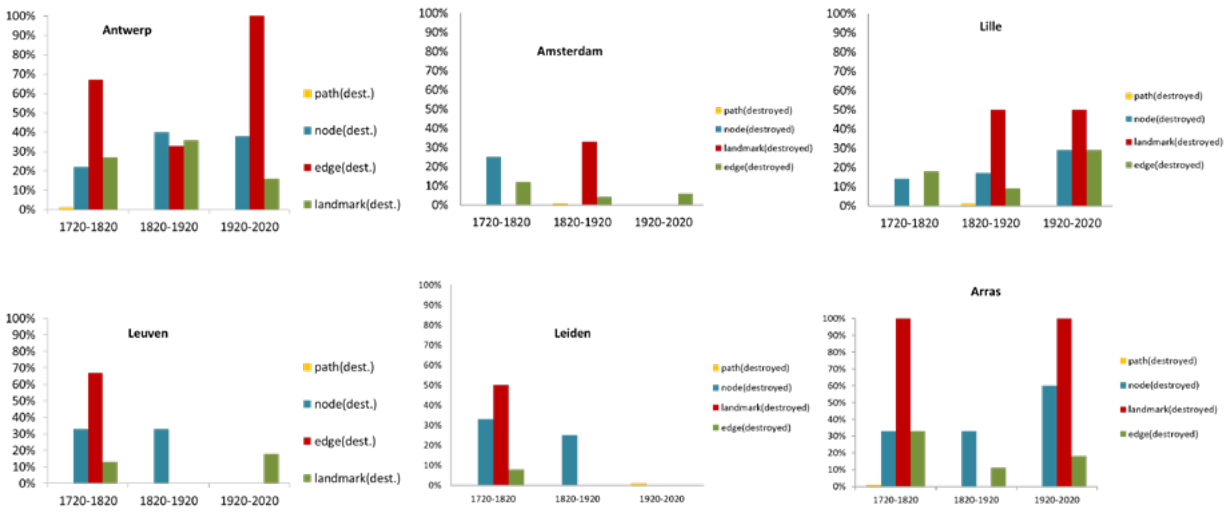
		1720 - 1820						1820 - 1920						1920 - 2020					
Leuven	Path	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	1 0 0	1	-Canals -Streets -Railroads	0 0 1	1	-Canals -Streets -Railroads	1 0 0	1	-Canals -Streets -Railroads	0 0 0	0
	Edge	-Coastline -Fortification -Moats	0 2 0	2	-Lineal Park -Fortification -Moats	1 0 0	1	-Coastline -Fortification -Moats	0 0 0	0	-Boulevard -Fortification -Moats	0 0 0	0	-Coastline -Fortification - Moats	0 0 0	0	-Boulevard -Fortification -Moats	0 0 0	0
	Node	-Squares -Marketplace -Entrance gates	0 0 3	3	-Stations -Port -Entrance gates	0 0 0	0	-Squares -Marketplace -Entrance gates	0 0 2	2	-Stations -Port -Entrance gates	1 0 0	1	-Station -Marketplace -Entrance gates	0 0 0	0	-Stations -Port -Entrance gates	0 0 0	0
	Landmark	-Castles -Churches -Collages -Houses	1 0 0 2	3	-Service(hospital bank-hotel -Churches -Militaries -Warehouse- houses	0 1 1 0	2	-Castles -Churches -Militaries - Services(post- hotel-state)	0 0 0 0	0	-House -Churches -Militaries -Services(hospital -Institution	0 2 0 1 6	9	-Castles -Churches -Militaries -Library -Palace	0 1 3 1 1	6	-House -Churches -Militaries -Service(hospital- bank- museum)	0 0 0 0	0
Leiden	Path	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	0 0 2	2	-Canals -Streets -Railroads	6 0 0	6	-Canals -Streets -Railroads	0 1 0	1
	Edge	-Coastline -Fortification -Moats	0 1 0	1	-Coastline -Fortification - Moats	0 0 0	0	-Coastline -Fortification -Moats	0 0 0	0	-Boulevard -Fortification -Moats	0 0 0	0	-Coastline -Fortification - Moats	0 0 0	0	-Boulevard -Fortification -Moats	0 0 0	0
	Node	-Squares -Marketplace -Entrance gates	0 0 2	2	-Stations -Port -Entrance gates	0 0 0	0	-Squares -Marketplace -Entrance gates	0 0 1	1	-Stations -Port -Entrance gates	2 0 0	2	-Station -Marketplace -Entrance gates	0 0 0	0	-Stations -Port -Entrance gates	0 0 0	0
	Landmark	-Castles -Churches -Libraries -Houses	0 1 0 0	1	-Service(hospital bank-hotel -Churches -Militaries -Warehouse- houses	0 0 0 0	0	-Castles -Churches -Militaries - Services(post- hotel-state)	0 0 0 0	0	-House -Churches -Militaries -Services(hospital bank- museum)	0 0 0 0	0	-Castles -Churches -Militaries -Services(post- hotel-state)	0 0 0 0	0	-House -Churches -Militaries -Service(hospital- bank- museum)	0 0 0 0	0
Arras	Path	-Canals -Streets -Railroads	3 0 0	3	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	0 0 0	0	-Canals -Streets -Railroads	0 0 0	0
	Edge	-Coastline -Fortification -Moats	0 1 1	2	-Coastline -Fortification - Moats	0 0 0	0	-Coastline -Fortification -Moats	0 0 0	0	-Boulevard -Fortification -Moats	1 0 0	1	-Boulevard -Fortification - Moats	1 0 0	1	-Boulevard -Fortification -Moats	1 0 0	1
	Node	-Squares -Marketplace -Entrance gates	0 0 3	3	-Stations -Port -Entrance gates	0 0 0	0	-Squares -Marketplace -Entrance gates	0 0 2	2	-Stations -Port -Entrance gates	1 0 0	1	-Station -Marketplace -Entrance gates	0 3 0	3	-Stations -Port -Entrance gates	0 0 0	0
	Landmark	-Castles -Churches -Libraries -Houses	0 7 0 0	7	-Churches -Militaries -unknown -Service(hospital	2 4 6 1	13	-Castles -Churches -Militaries - Services(post- hotel-state)	0 3 0 0	3	-Institution -Churches -Militaries -Train station -Services(hospital bank- museum)	1 0 1 1 0	3	-Castles -Churches -Militaries -Services (Hospital)	0 3 1 1	5	-Grand palace -Churches -Militaries -Service (hospital)	0 0 0 0	0

TABLE 2 Morphological changes (1720 -1820, 1820-1920, 1920-2020) in three medium-sized medieval cities in the Low Countries.

numbers indicate that in Antwerp and Arras, urban expansion occurred at a rapid pace and consequently affected the historic inner city with a higher rate of irreversible damage to fortification walls, canals, and historical monuments. At the same time, Amsterdam and Leuven occupied a middle position. Landmarks made the most considerable contribution to the number of changes among the removals and the new appearances. Moreover, the edges, including fortification walls, have been destroyed in almost all cities except Amsterdam and Lille.

The tables also show the morphological changes in the period from 1820 to 1920. The dominant picture seems to be very much the same, with few changes in Leiden and many in Antwerp; however, within this period of time, the number of morphological adjustments dwindled significantly in Arras, while their amount actually increased in Lille (but still remained significantly below that of Amsterdam and especially Antwerp). Again, landmarks were the main contributors to morphological transformation.

Table 2 then shows the changes in urban form elements in medium-sized ancient cities over time. As we can see, in the 20th century, there was more



GRAHP 1 Comparison of Kevin Lynch's urban form elements across three time periods (1720–1820, 1820–1920, 1920–2020) in six medieval cities of the Low Countries.

stability, and the number of changes declined significantly. Nonetheless, the figures for the disappearance of landmarks still express that a respectable number of historical monuments were sacrificed in all cities except Leiden. On the other hand, Leiden and Amsterdam lost several paths, a loss not experienced elsewhere.

The graphs above illustrate the morphological changes in six cities, providing insights into which elements underwent significant transformations and which remained relatively unchanged within the analysed timeframes.

Century-wise, we can conclude that the 18th century had the most dynamic changes in the removal and appearance of morphological elements in medieval city centres, followed by the 19th century. The 20th century, on the other hand, has shown far more clemency to the preservation of ancient Lynchian urban elements in the cities. Among the cities, we have established that Antwerp has been most subject to urban transformation, while Leiden turns out to be best preserved. Arras was particularly hard-hit in the 18th century, while the 20th century has been soft on it. For Lille, the exact opposite is true. Amsterdam (vis-à-vis Antwerp and Lille) and Leuven (vis-à-vis Leiden and Arras) occupy middle positions considering their relative size. Regarding the elements, landmarks underwent rather frequent alterations and thus seemed the most vulnerable element to destruction and replacement. This is potentially not surprising, given the fact that they are point constructions, the removal of which is most conveniently realised without damaging the entire urban tissue. The same does not apply to paths and nodes, which are more defining for the entire morphological structure of city centres: they also underwent a change in all cities but to a far lesser extent.

Moreover, although most paths remained at their original locations, we were unable to determine, based on Kevin Lynch's typology of elements

on maps, whether their pavements or breadth had changed over time. Lastly, the number of edge changes, but especially the nature of their transformation, was the most dramatic: the elimination of fortifications, city wall structures, and potentially the moats around them had enormous consequences for how the boundaries of the (historical) districts are perceived. Only Leiden escaped far-reaching change here, but even here, only the moat, not the fortifications, were preserved. More generally, in all cities, the most impressive (visible) destruction of historical heritage has occurred at the edges, such as with military infrastructure and fortification walls that appeared useless and obsolete.

Discussion

City centres located in municipalities with a long history play an important role as cultural hubs for the entire municipality or region in which they are located and reflect much of its local or regional identity. They have a distinct urban shape (through nodes, paths, and edges), which residents and visitors easily recognise as the main structure of a central district. They contain major monuments and buildings of architectural and historical significance (landmarks) and attract a variety of activities and services. However precious they may be, city centres are not impervious to the tooth of time. Periods of revolution and response to modern industrial society affected the future development of the cities and changed the face of many European medieval cities.[38] We have shown through maps the massive transformations they have gone through in response to complex challenges created by the macro-environment in which they operate. Although these challenges can be of a military, economic, technological, demographic, cultural or other nature, and this nature can vary per era, continuity and change are inherent features of urban morphological evolution through the centuries.

In some cases, such as in Amsterdam in 1872, impressive fortification works with high historical value were dismantled. However, conscious efforts were made to restore its character by digging the canals in line with the original shape for water management and defence purposes, and the monumental features of the city centre were largely preserved. Time did not favour all cities equally: Arras and Leuven were damaged considerably during the 18th century. For instance, Arras's fortification walls and historical monuments were almost entirely destroyed, primarily due to war and industrialisation. German troops burned its university library to the ground during World War II. In the 19th century Antwerp, the fortification walls, and the castle, as well as various landmarks, were demolished, including churches, authentic ancient houses, and military buildings, while several new buildings, an impressive and expansive port infrastructure,

38 Tonkao Panin, "The Politics of Style: Vienna and the Ringstrasse," *NAJUA: Architecture, Design and Built Environment* 30 (2016), C-03.

and a railway station were erected during these years. In Lille, on the other hand, although the city walls were torn down and the moats and rivers were filled, the castle still exists, and it is currently a major tourist attraction in the city. Not all six cities we have examined have gone through the same macro-societal trends and events. Some have been more war-stricken than others, and some have expanded more due to economic production development and population increases than others; however, each step of the way, they have had to make trade-offs between continuity and change. Some have favoured dramatic transformation and have chosen to dismantle the old and build the new, while others have been more cautious. It turns out that although one might have expected larger cities to be tilting more toward change than medium-sized ones, given the higher pressures they were subject to, this is only true to a limited extent. Antwerp has indeed been drastically redeveloped, but Lille is much less so. Leiden has shown remarkable continuity, but Arras, albeit still beautiful and impressive, has not. Amsterdam and Leuven occupy a middle ground here.

This study is a combination of collecting historical maps and analysing changes in Lynchian morphological elements that have helped us systematise what has changed in the period 1720-2020 in six cities of the ancient Netherlands, now located in three different countries. Although it is not high-tech, our combined diachronic and synchronic analysis of morphological transformation over time is certainly an innovative way to study and represent urban spatial characteristics and systematically portray the changes in historical city centres to identify points of continuity and change. Thus, the method applied in this research is fully replicable and reproducible for other cities and areas since it only requires the presence of historical maps and Kevin Lynch's concepts and relies on a comparison of cross-temporary and cross-spatial mutations.

Previous studies in urban form have focused on a much shorter timescale, generally covering only the last few decades, and rarely addressed the situation dating from before World War II. Nor does existing academic work on the topic simultaneously consider morphological evolution crossing long time scales while comparing various locations. That makes our study, despite its exploratory nature, a new contribution to the field. [39,40,41,42] Thus, this research offers a novel qualitative method to examine the evolution of urban form through time using mapping city images based on Kevin Lynch's urban form elements. It also contributes to the area of historical map analysis by offering a systematic morphological approach

39 *Gauthier and Gilliland, "Mapping Urban Morphology: A Classification Scheme for Interpreting Contributions to the Study of Urban Form," 41.*

40 Kropf, *The Handbook of Urban Morphology*.

41 *Moudon, "Urban Morphology as an Emerging Interdisciplinary Field," 3-10.*

42 Vítor Oliveira, *Urban Morphology: An Introduction to the Study of the Physical Form of Cities* (Cham: Springer, 2016).

that can be applied to older maps dating from before the digital era and yet allows them to be fruitfully used to analyse continuity and change through time. That said, there are obviously also limitations to the study conducted above. Although the outcome is that across the board, there were numerically comparatively few changes in the paths, nodes, and edges of city centres, this provides limited insight into how their dimensions (length, breadth, and width) have evolved or whether their functions have shifted significantly over time. The lack of data on functional transformations in urban elements from the Middle Ages makes it difficult to determine whether deliberate functional changes have occurred in sites that appear preserved. Arras, for instance, has no less than two gigantic central squares in its urban core, but one serves mainly as a parking lot while the other serves as an occasional marketplace and otherwise as a tourist attraction. Lynch's analytical method does not allow for viewing such functional subtleties but merely focuses on whether a node or landmark as such has emerged, remained or disappeared. Additionally, the analysis also lacks a comprehensive exploration of the cause-and-effect relationships underlying the observed transformations. While we have identified the mutations that occurred during three historical timeframes (1720–1820, 1820–1920, and 1920–2020) using green, yellow and red markers to denote paths, nodes, landmarks, and edges across the six central districts, we have not fully examined which macro-societal changes drove these micro-morphological alterations. Based on national and local histories, we can hypothesise the influence of factors such as military technological advancements, industrial expansion, and demographic growth. However, establishing concrete connections would require more detailed meso-level analyses to trace how macro-level developments translate into specific urban transformations. For example, the transformation of edges, such as fortification walls, in medieval cities like Amsterdam, Leiden, Antwerp, Leuven, Lille, and Arras is closely linked to the evolution of military technology and strategies. These changes reflect shifting priorities in urban defence, the obsolescence of medieval fortifications, and the gradual integration of former defensive boundaries into the urban fabric. This process illustrates the dynamic interplay between military innovations, technological progress, and urban expansion, emphasising how evolving societal needs shape urban morphology.

To deepen this understanding, future research should focus on unravelling the complex relationships between macro-level forces—such as socio-economic changes, technological advancements, and political dynamics—and micro-level urban transformations. Such studies could also explore practical applications for contemporary urban planning and heritage conservation, ensuring that historical insights inform sustainable urban development.

Sahar Abdollahi, abdollahi@ihs.nl, is a PhD researcher specializing in the evolution of urban morphology, with a particular focus on medieval cities in the Low Countries. Sahar's academic interests encompass urban sustainability, climate change resilience, and the intersections of historical urbanism with contemporary challenges. She holds her master's degree in urban management and development, and she is currently in the final stages of her PhD at the Institute for Housing and Urban Development Studies (IHS), Erasmus University Rotterdam. Passionate about the legacy and future of cities, her work bridges the past and present to explore sustainable urban evolution.

Martin de Jong, w.m.jong@law.eur.nl, (ORCID 0000-0001-6554-2458) is the scientific director of the Erasmus Research Initiative for the Dynamics of Inclusive Prosperity and professor at Rotterdam School of Management and Erasmus School of Law (Rotterdam, Netherlands). He is also a visiting professor at the Institute of Global Public Policy, Fudan University (Shanghai, China) and the Smart City Institute of HEC-Liège (Belgium). He holds Bachelor's and Master's degrees in public administration from Erasmus University/Leiden University (joint degree) and a PhD in systems engineering and policy analysis from Delft University of Technology. He publishers and lectures extensively on topics of urban governance, smart and sustainable urban development, city branding, cross-cultural management and cross-national institutional comparison.

Jurian Edelenbos, edelenbos@essb.eur.nl. (ORCID: 0000-0002-8070-4547), full professor at Erasmus University Rotterdam, School of Social and Behavioral Sciences, The Netherlands. Jurian Edelenbos is the team lead of the Governance & Pluralism team at the Department of Public Administration and Sociology. He is also the Academic Lead of the Erasmus interdisciplinary group of Vital Cities and Citizens. His research interests are network governance, the democratic legitimacy of governments, urban (re)development, trust in government, boundary-spanning leadership, public participation, community-based initiatives and public engagement in academic research.

Jan Fransen, j.fransen@ihs.nl, (ORCID 0000-0003-1127-7307), senior researcher urban governance and economics, Institute of Housing and urban development Studies (IHS), Erasmus University Rotterdam, Netherlands. Jan studies, lectures, and offers advice on the inclusion of marginalized communities in urban development, with a focus on local economic development, smart cities, and resilience. He has worked in 30 countries in Africa, Europe, and Asia. His present research interests include the resilience of informal settlements in Kenya, inclusion in smart city programs in Kenya, India and Indonesia, frugal innovation, and inclusive knowledge sharing processes.

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