

# MAP: a methodology for Morphological Analysis and Prescription

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**Abstract.** *Bringing together different approaches to understand the complex physical form of cities and exploring the potential of this scientific knowledge for planning practice are crucial tasks for urban morphology. Yet these have so far been insufficiently explored. Over recent years, these two challenging issues – comparative studies and the relation between research and practice – have been brought to the centre of the morphological debate. This paper presents a new methodology to address these challenges, based on the integration of historico-geographical, process typological and configurational approaches. It aims to inform planning decisions on the transformation of urban form. The procedural framework of the methodology for Morphological Analysis and Prescription (MAP) includes six stages; three concerned with analysis and three related to prescription. The methodology has been applied to the city of Porto, Portugal.*

*Keywords: urban form, comparative studies, integrated approaches, morphological research, planning practice, Porto*

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Cities are always changing. Clearly related to many other urban dimensions, urban form plays a key role in the quality of urban life. This presents many challenges for urban morphology. This paper addresses two of them: the need to undertake comparative studies to support the conception of an integrated morphological approach for a better understanding of urban settlements; and the need to bring together morphological research and planning practice.

Over the last 2 decades there have been a number of comparative studies, mainly within two lines of research. A first line of research involves the application of one morphological approach in different geographical contexts.

Some notable examples are the collections of morphological regionalizations applied in different continents (Oliveira and Yaygin, 2020; Whitehand, 2009); the application of the fringe-belt concept in, and outside, Europe (M. P. Conzen, 2009; M. P. Conzen *et al.*, 2012); and the study of different axial maps of cities in the same country (Medeiros, 2013) and worldwide (Hillier, 2002). A second line of research involves the comparison of different approaches in the same geographical context. Within this line, the relationship between the historico-geographical and the process-typological approaches has been particularly explored (Kropf, 1993; Maffei, 2009; Maffei and Whitehand, 2001; Marzot,

2005; Pereira Costa and Netto, 2015). For example, Whitehand *et al.* (2014) have compared the morphological period with the typological process in two applications, one in China, the other in England. While less developed, the relationship between the historico-geographical and configurational approaches has also been explored (Griffiths *et al.*, 2010; Larkham, 2006; Oliveira, 2013; Pinho and Oliveira, 2009), as has that between typomorphological (urban tissue analysis that combines historico-geographical and process-typological concepts) and configurational methods (Kropf, 2017a; Osmond, 2010).

The second line of research had a significant development a decade ago. In 2009, Kropf established a common ground for the dominant approaches (historico-geographical, process typological, configurational and spatial analysis) that could be used to build an integrated view. Indeed, he opened a path to comparative and critical analysis in order to build 'a composite view in which the different approaches support each other to provide a better understanding of urban settlements' (Kropf, 2009, p.105). Yet his paper does not offer any application or illustration of how this bridging process can take place. Oliveira *et al.* (2015) develop the framework proposed by Kropf (2009), seeking to understand how to combine the different approaches in the application to a case study in Porto. They explore the points of contact between the four approaches that can support a co-ordinated framework, based on the elements of urban form, levels of resolution and time. However, they did not go further in the establishment of an integrated view. Despite this important work, the main goal of this line of research is still unfulfilled (Whitehand, 2019).

The second challenge addressed in this paper is the weak relationship between morphological research and planning practice. For too long these two fields have developed separately, progressively increasing the gap (Barke, 2015). The need to build a solid bridge has been recognized by the creation of the ISUF task force on research and practice, and paths for development have been synthesized

in a report by Samuels (2013). The debate promoted by the task force has been intense. It included the publication of manuals in urban morphology (Kropf, 2017b; Oliveira, 2016); of identifying good practices of morphological inputs into planning (Barke and Hancox, 2014; Oliveira *et al.*, 2014; Maretto and Scardigno, 2016; Pattacini and Samuels, 2014); and of a number of viewpoints on the subject, published in *Urban Morphology*, between 2013 and 2014 (for example Barke, 2013; Oliveira and Monteiro, 2014a). Parallel to both this debate within ISUF, and to a number of practical applications of historico-geographical, process typological and configurational approaches, it is also important to mention the New Urbanism movement and, in particular, its form-based codes that have gained an important place in planning practice in the United States (Panerai *et al.*, 2004; Talen, 2011).

Yet, despite the increasing interest in the subject (Gu *et al.*, 2019; Kropf, 2017b), the application of morphological methods and concepts in planning is still very limited. Overcoming this situation depends on renewed efforts by urban morphologists, but there is also a difficult institutional barrier to cross, in getting academic concepts understood, accepted and implemented by local governments (Alexander, 2005). Among the major challenges related to the particular professional contexts of researchers and planners marked by different languages, interests and purposes, there is also a need both to build political consensus and to assure the economic feasibility of a planning practice supported by morphological evidence. Finally, it is important to mention the need to strengthen the relationship between the plan preparation and the plan implementation teams (Barke, 2015; Oliveira 2020; Samuels and Pattacini, 1997).

This paper addresses these two challenges. It is in three main parts. The first part introduces the methodology for Morphological Analysis and Prescription (MAP), the second presents its application in the city of Porto and the third part promotes a discussion of results.

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### **A methodology for Morphological Analysis and Prescription (MAP)**

The design of the MAP methodology draws on the combination of three different approaches (historico-geographical, process-typological and configurational) and, in particular, three methods within these approaches (morphological regionalization, typological process and angular segment analysis). According to the scientific debate, these approaches were in privileged positions to answer the challenges of integration (Kropf, 2017a; Oliveira *et al.*, 2015; Whitehand, 2016) and of applicability into planning (Karimi, 2012; Oliveira and Monteiro, 2014b; Strappa, 2018; Whitehand, 2009; Whitehand *et al.*, 2011). The scientific debate highlights the shared structural basis of these approaches. This has been confirmed by a pilot comparative study developed by the authors in a smaller area within the case study. The MAP methodology was developed based on the literature and on the pilot study.

MAP is intended to describe, explain and prescribe urban form, informed by different morphological views and aiming to support the design of the zoning map that is commonly used in urban planning. The complementary use of qualitative and quantitative morphological methods is based on the three fundamental components of morphological research (Moudon, 1997; Oliveira *et al.*, 2015): form (the physical elements that define urban form), resolution (the levels of resolution that explain the urban form) and time (the dimension of constant change and transformation of the urban form). MAP brings together the specific contributions of each of the three approaches and methods, through the integrated vision of the parts and the whole, composed of different scales of analysis and the complementary ways of approaching the elements of urban form.

The basis of MAP is the division of the urban landscape into morphological regions. A morphological region is an area with formal unity, distinct from its neighbours. The creation of a map of morphological regions is supported by the maps of the three form complexes (ground plan, building fabric and land and building

utilization) in a hierarchical way, considering different priorities (M. R. G. Conzen, 2004). MAP only recognizes first-order morphological regional boundaries, mainly based on ground plan characteristics – streets, plots and block-plans of buildings (M. R. G. Conzen, 1969, 2004; Whitehand, 2007). These options are justified by being more effective in their articulation with other approaches and in their application in planning. In addition, and bearing in mind both simplification and operationalization, a higher order was introduced in the hierarchy – a ‘zero order’ – which consists of the authors’ personal interpretation of the concept of morphological region. While it corresponds to the first order in most of its characteristics, it differs from it in that it does not assume the principle of continuity underlying the concept of region. Being a variation of the original concept of morphological region, it has been given the designation ‘morphological unit’.

MAP will be complemented in the analysis and prescription phases, by the typological process of basic buildings (buildings for residential uses) and with the angular segment analysis of the street system. The typological process characterizes the evolution and adaptation of type over a sequence of time periods (phases). Starting from the identification of the basic type (monocellular building), it explores the succession of building types up to the most complex ones (Caniggia and Maffei, 2001). Following Caniggia and Maffei, MAP applies the typological process, by interpreting the building, and the derivation of the different building types, as an integral part of the aggregate – types of urban fabric – that, in turn, make up the urban organism and, therefore, the territory.

Angular segment analysis, in different metric radii, measures the spatial accessibility of the street system, quantifying the configurational relationships. By considering street segments (instead of axial lines) it offers a more detailed analysis of the system. Space syntax uses several syntactical measures to analyse the street system. MAP uses the two measures that better represent the components of human movement: the destination selection

or ‘to-movement’ (integration) and the route selection or ‘through-movement’ (choice). Integration and choice consider the shortest path (least angular paths) between every pair of segments within a given metric distance. The angular distance is a topological measure that also considers the angular changes from one segment to another. This concept of distance is closer to the way in which people move in the urban space (Hillier and Iida, 2005; Serra and Hillier, 2019).

These three methods together provide an important contribution to the characterization of the territory, at different levels of resolution, and to the delimitation of the boundaries of the morphological zones, that together support the prescription for urban transformation. Urbanity is a central concept to frame prescription based on the detailed analysis of urban form. Urbanity is exposed in the relationship between the social and spatial dimensions, between people and the physical structure (Holanda, 2011). This relationship seems to be enhanced by high values of accessibility (configuration of the street network, small street blocks), diversity (typological and social, uses, agents), density (plots, buildings) and spatial continuity of the elements of urban form (Jacobs, 1961; Hillier and Hanson, 1984; Oliveira, 2013).

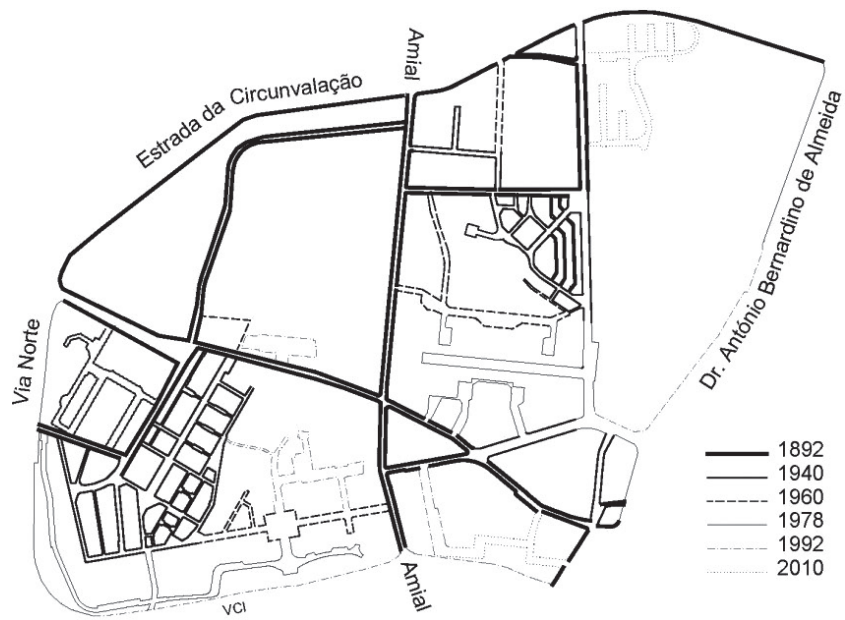
MAP is based mainly on the characteristics of the ground plan, which contains the most permanent elements that characterize the morphological units. MAP is informed by the typological process of buildings, that helps to formulate transformation proposals based on the notion of process – existing forms offer guidance for the design of the new forms to be created in the following time period (Whitehand, 2001; Strappa, 2018). Together with angular segment analysis, this allows the assessment of different alternatives for the improvement of the accessibility of the street system. MAP is applied in six phases. The first three focus on analysis and the last three focus on the prescription and definition of transformation rules (Table 1).

#### Application to the Porto case study

MAP has been applied in Porto, Portugal, in an area selected for its morphological diversity and its clear physical boundaries. The area is located in the northern part of Porto, between the inner ring road (VCI) and the outer ring road that delimits the city to the north (the *Circunvalação*) (Figure 1). This 1300 km<sup>2</sup> area includes 95 street blocks (the largest block is 228,600 m<sup>2</sup> and the smallest

**Table 1. MAP procedural framework**

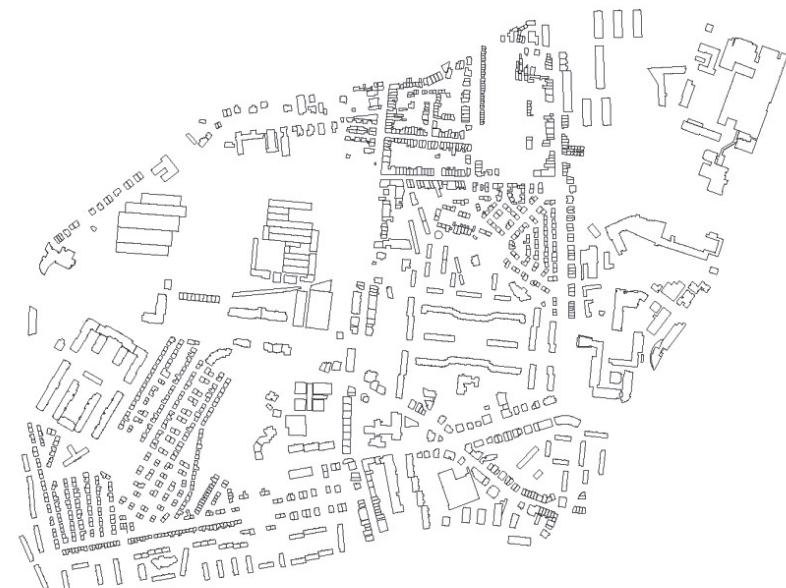
	Phase	Approach	Method
Analysis	1 Delimitation and characterization of morphological units	historico-geographical (process-typological)	morphological regionalization (typological process)
	2 Identification of the typological process	process-typological	typological process
	3 Development of angular segment analysis	space syntax	angular segment analysis
Prescription	4 Regulation of the street system	space syntax	angular segment analysis
	5 Definition of guidelines for urban form transformation	historico-geographical process- typological	morphological regionalization typological process
	6 Contribution to the zoning map and regulation		



Streets



Plots



Buildings

**Figure 1. Maps of ground plan elements (streets, plots and buildings).**

is 350 m<sup>2</sup>), 1270 plots and 1312 buildings. The development of this area was facilitated by the *Rua do Amial*, which had a structural role in the growth of the city, and which was an ancient route linking Porto to the north of Portugal. Although the area has rural origins, the process of urban transformation, which took place more intensely in the second half of the twentieth century, has completely changed its character.

### *Phase 1. Delimitation and characterization of morphological units*

The first phase of MAP is the division of the urban landscape into morphological units. The primary sources for this process are cartography (the earliest available map is of 1892, prepared by Telles Ferreira, and the subsequent maps are of 1903, 1932, 1937, 1948, 1960, 1978, 1992, 1997 and 2010), historical documents (including aerial photographs) and field survey. The identification of morphological units is based mainly on the ground plan characteristics, that is on the most permanent urban form elements. The redesign of the contemporary cartography for use by MAP allowed isolation of the components of the ground plan and the mapping of its three elements: streets, plots and the block-plans of buildings (Figure 1). The combination of these plan elements defines the urban patterns that support the delimitation of the different morphological units (the building fabric and the land and building utilization are considered to have less importance).

Each morphological unit is characterized according to a limited number of criteria, considering the geometry and composition of ground plan elements (Figure 2). The differences between urban form elements of different periods of formation provide the basis for the identification of three morphological periods: i) traditional (Monarchy/ First Republic), up to 1925; ii) authoritarian (National Dictatorship/*Estado Novo*), between 1926 and 1959; and iii) modern (late *Estado Novo*/ Democracy), after 1960. Three main residential morphological units have been identified,

directly related to these morphological periods: i) continuous frontage (MU1); ii) discontinuous frontage (MU2); and iii) fragmentation (MU3). One fringe-belt unit, named 'exceptional' (MU4) (Figures 1 and 2) was also delimited.

Analysis of the 1892 and 1903 maps enables understanding of the urban transformation of the study area, revealing the most important streets, the primitive rural paths, as well as those streets that are part of the early urbanization process along the main arterial ribbon, *Rua do Amial*. The street system represented in these two maps has a structural role in the construction of this part of the city and it has survived to the present day. These traditionally-formed streets, together with the corresponding street-blocks, the narrow and deep plots, and the buildings facing the street and defining a continuous frontage, characterize the morphological unit of continuous frontage (MU1).

The 1940 aerial photograph of Porto shows the changes of the second time period that characterize the morphological unit of discontinuous frontage (MU2). Distinct from the traditional formation process, this morphological unit is characterized by planned streets and urban expansions made of regular streets and small street blocks. This corresponds largely to single-family housing neighbourhoods. Plots tend to have a larger frontage and a more regular structure than those of MU1. Detached or semi-detached buildings, with frontages that are not coincident with plot frontages, create an urban landscape of discontinuous façades.

The third morphological unit, of fragmentation (MU3), is created by the changes introduced in the modern period. It is dominated by isolated apartment blocks. This transformation began in the late-*Estado Novo* (from 1960), was intensified in the democracy period (1974), and continues to the present day. Contrary to what is seen in the previous morphological units (particularly the first), the street as an element of urban form loses importance; new streets are not integrated in the street system, culs-de-sac are dominant, and large street blocks are created. The size


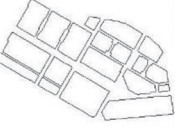



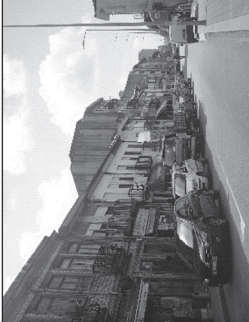




		Mainly residential areas			Fringe-belt features	
		MU1 <i>Continuous frontage</i>	MU2 <i>Discontinuous frontage</i>	MU3 <i>Fragmentation</i>	MU4 <i>Exceptional</i>	
Criteria for ground plan characterization	street/ street block	Traditional (Monarchy/ 1 <sup>st</sup> Republic) up to 1925	Authoritarian (National Dictatorship / <i>Estado Novo</i> ) 1926 – 1959	Modern (Late <i>Estado Novo</i> / Democracy) 1960 –	Variable	
	street segment	medium	small / medium	medium / large	large	
	block size	medium	small / medium	medium / large	large	
	perimeter	built	fenced	fenced / open	fenced / open	
	plot division	uniform	uniform	variable	variable	
	dimension	small / medium	small / medium	large	large	
	width x depth (narrow x long)	regular polygon	regular polygon	irregular polygon	irregular polygon	
	street frontage	small	small	large	large	
	plot access	private	private	private / semi- public	mixed	
	dimension	small / medium	small / medium	large	mainly large	
	buildings per plot	1	1	1 or more	1 or more	
	relation with plot frontage	coincident	not coincident	not coincident	not coincident	
	n° of frontages	mainly 2	mainly 3 or 4	mainly 3 or 4	mainly 4	
	building					
						

Figure 2. Morphological units.

of plots increases exponentially. This morphological unit is also characterized by large apartment blocks, which become significant features in the urban composition. Buildings often stand in the middle of plots, without a clear relationship to the street alignment.

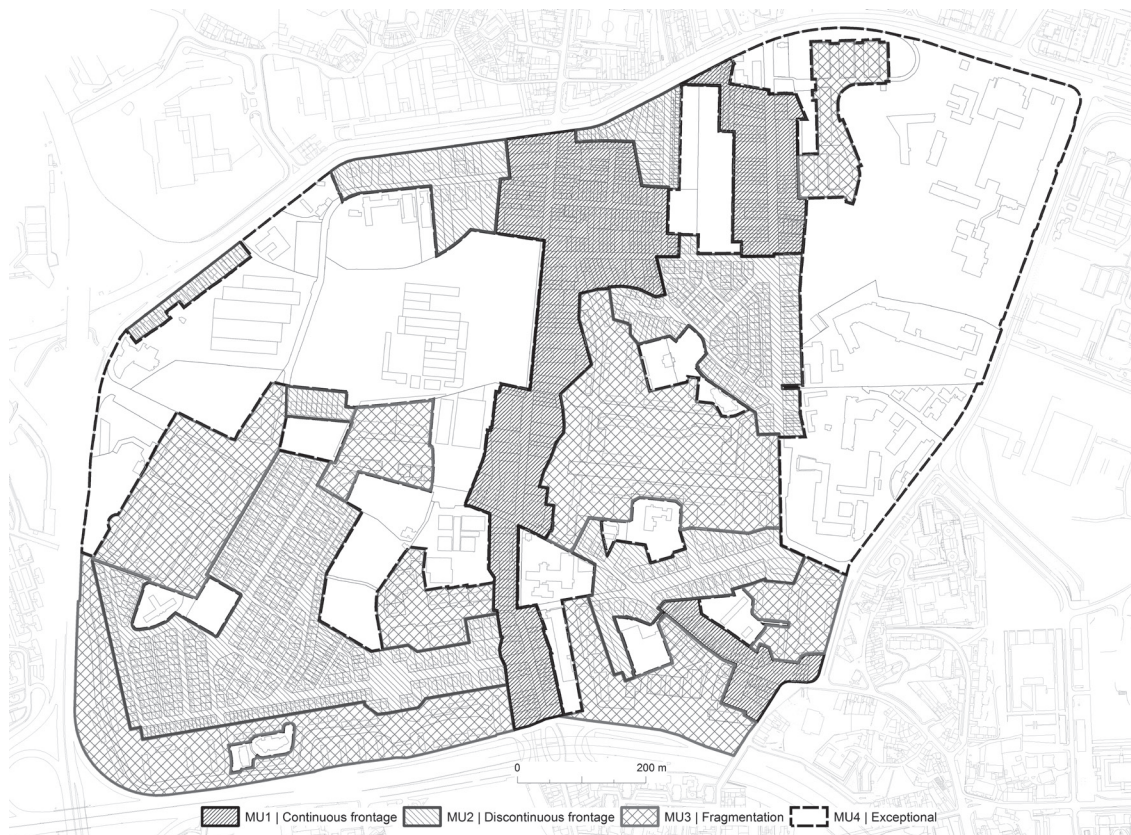
The last morphological unit (MU4) is part of a fringe belt. This unit is conditioned by forms and activities originally located in a peripheral position, and its formation is associated with pauses in urban growth. It is mainly composed of institutions, industry and open space. Figure 2 demonstrates the characterization of the four morphological units; Figure 3 presents them in map form.

### *Phase 2. Identification of the typological process*

The second phase of MAP identifies the typological process of basic buildings. The three

residential morphological units have specific building types. Each building type reflects different relationships with the limits of the plot and with the street. A diachronic typological process (changes in the same cultural area over time) for each building type is presented here. These are the typological processes of: i) row building, which characterizes the morphological unit of continuous frontage (MU1); ii) detached/semi-detached building, which characterizes the morphological unit of discontinuous frontage (MU2); and iii) apartment block building, which characterizes the morphological unit of fragmentation (MU3).

Supported by field research and historical documents, the basic type has been identified – a single-family house, with a 6 m frontage, composed of one or two rooms with flexible utilization. The main adaptations and transformations from the end of the nineteenth century onwards were also identified. The main typological transformations are related



**Figure 3. Boundaries of morphological units.**

to plot size (depth and/or width), position of building within the plot and type of housing (the transformation of single-family housing into multi-family housing).

The typological process of row buildings starts with the basic type (phase 1). The first phases represent the adaptation of the existing buildings based on the traditional narrow plot (6 m width) that has remained quite stable. The extension of the house to the back yard allowed the introduction of a staircase and the transformation of a single-storey row house (phase 2) into a two-storey row house (phase 3). The increased plot and building depth (phase 4) changed the position of the staircase, resulting in a fundamental typological change. The introduction of two independent accesses transforms the type into a two-family house (phase 5). The sixth phase corresponds to the change to multi-family housing, dividing the building into one dwelling per floor with common access. Subsequent phases are marked by multi-family housing. Important plot changes (by amalgamation) generate subsequent building transformation. The amalgamation of two traditional plots allowed changing the staircase position and building two dwellings per floor (phase 7). The increase of plot width changed the type through new access systems and several dwellings per floor (phase 8). The multi-family housing is characterized by a general increase of floors, up to four storeys (Figures 4 and 5).

The semi-detached/detached buildings that characterize the morphological unit of discontinuous frontage have developed within small and shallow plots (wider than traditional nineteenth-century plots), mainly for single-family housing up to two floors. The typological analysis is structured from the basic type: this is an elementary matrix from which all the complex types derive (phase 1). The first phases of the transformation process show the adaptation of existing single-family housing. Phase 2 typifies a mutation of the basic type, in a wider plot, keeping a simplified organization of two rooms. The extension of the house into the back yard allowed the introduction of a staircase to an upper floor (phase 3). The side access and the staircase at the back made the

main façade more flexible. Subsequent phases are characterized by increasing depth and width of plots and buildings. Semi-detached buildings, with a staircase at the core, transform the type into a two-family house with independent access (phase 5) or into a multi-family house of one dwelling per floor (phase 6). Larger plots also had a change of type into detached single-family houses (phase 4) and then to small multi-family buildings (phase 7), of up to three floors, characterized by flexible interior organization.

In the typological analysis the progressive differentiation between types is more evident in older buildings than in recent buildings. The apartment block (mainly of four to six floors), exclusively for multi-family housing, emerged in Porto at the end of the 1950s in a clear rupture with the urban tradition. The variable geometry of the plot, the global increase of plot and building, and the freedom of position of building in the plot, introduced important variations in relation to the previous types. Although it is possible to verify the typological continuity with the previous types (phase 1 to 3), phases 4 and 5 introduce major typological changes in the organization of the building. The rupture of the typological process occurs essentially at the level of the ground plan, resulting in a new building type.

### *Phase 3. Development of angular segment analysis*

The third phase of MAP studies the accessibility of the street system through segment analysis and considers the correlation with the morphological units. The angular segment analysis in local metric radius (750 and 1000 m) describes movement at the neighbourhood-scale through the chosen measures of integration ('to-movement' potential) and choice ('through-movement' potential). The overlap of each syntactical measure with the morphological zoning results in a map in which the boundaries of the morphological units are characterized by the average values of integration and choice for each unit (Figure 6). On the one hand, these syntactical measures

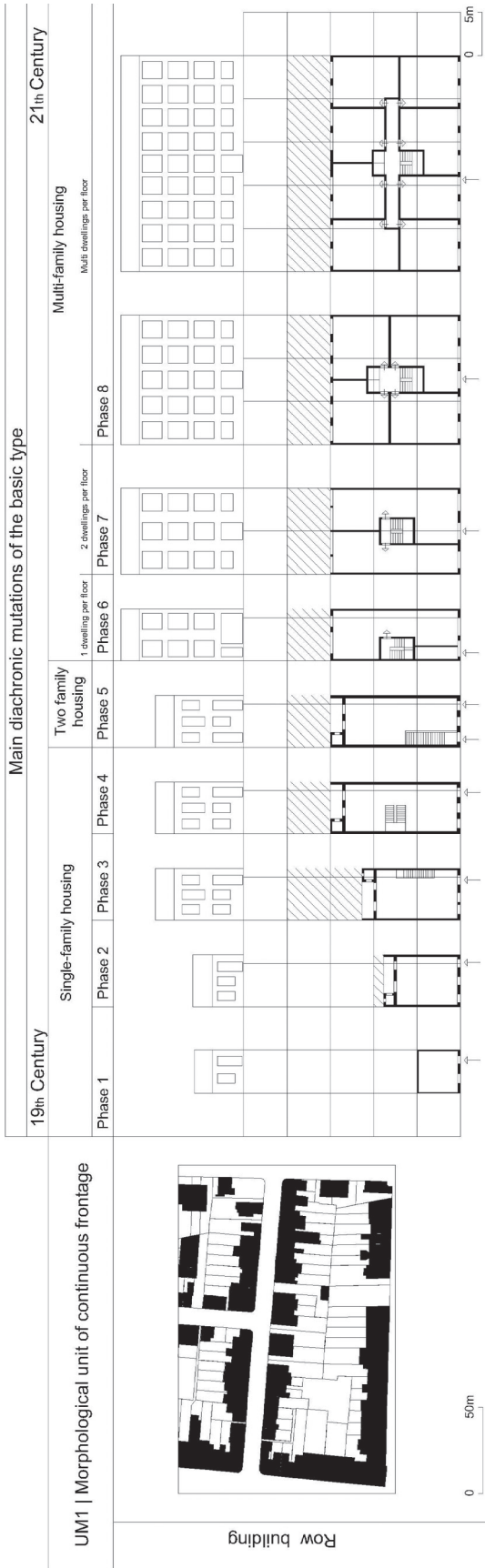


Figure 4. Row building typological process (morphological unit of continuous frontage, MU1).

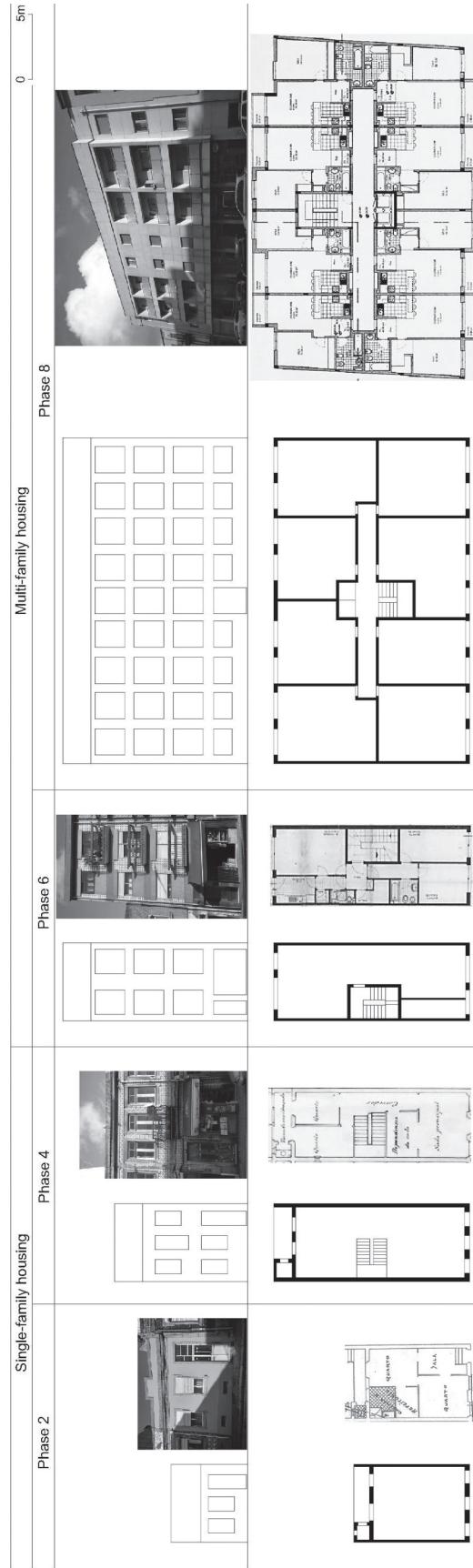
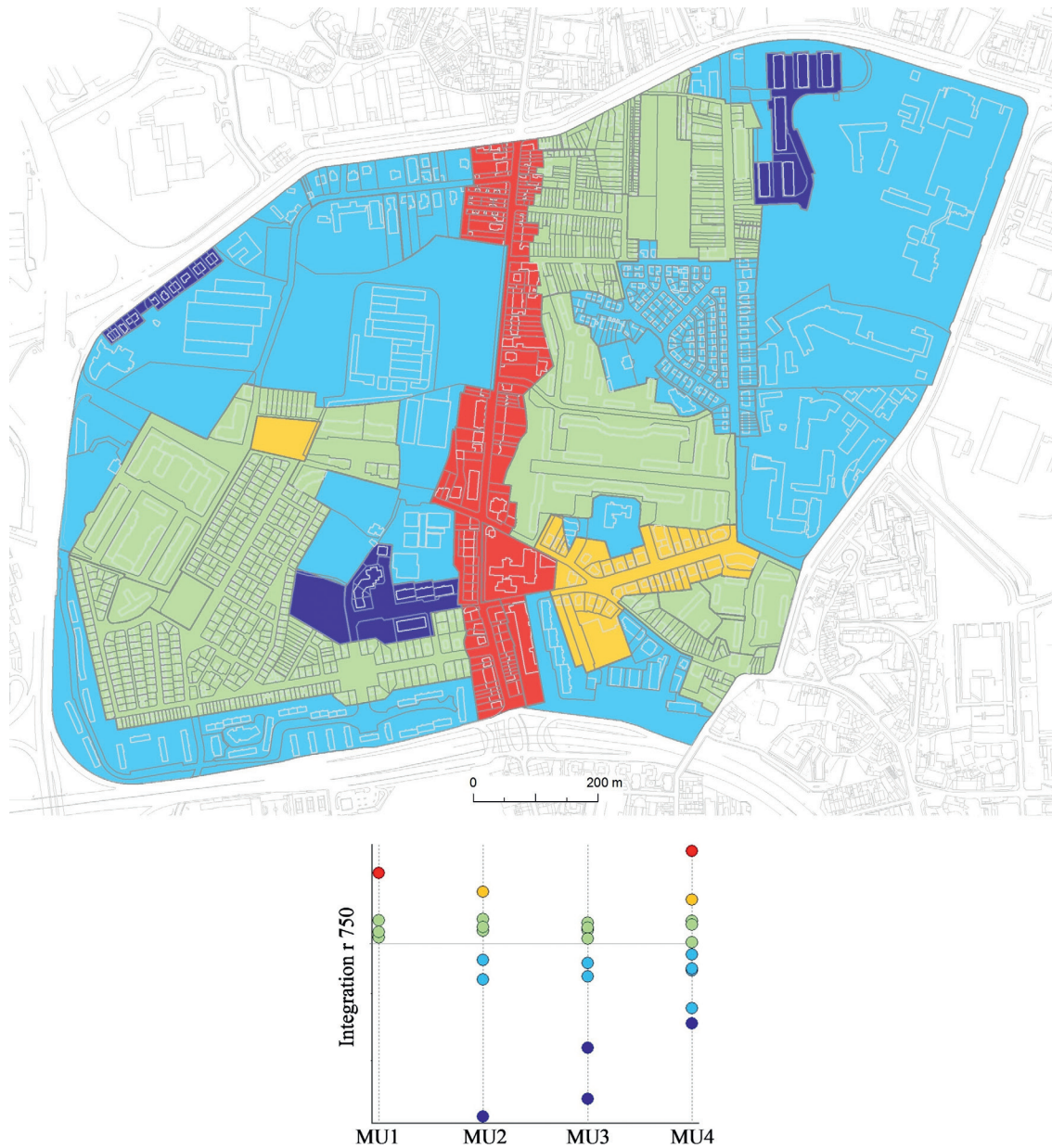


Figure 5. Examples of row buildings (source: Arquivo Municipal do Porto).



**Figure 6. Integration values (r 750) of morphological units.**

characterize quantitatively the street system of the morphological unit. On the other hand, the accessibility values can be related to the different formal elements that distinguish the street patterns in each type of morphological unit, and how they are related to each other in the street network.

Segment angular integration quantifies the degree of centrality, related to the movement of destination. It measures how close each street segment is to all other segments for a

local radius. The overlap of local integration values (750 m) with the morphological zoning (Figure 6) points to high integration in morphological units of continuous frontage (MU1), low integration in morphological units of discontinuous frontage (MU2) and even lower integration in morphological units of fragmentation (MU3). MU1 presents a clear street structure, with many street segments, corresponding to medium to small street blocks, all well connected with their

surroundings. Intrinsic to the ‘traditional city’, this street structure contributes to the centrality of these areas and to the aggregation of different functions. Although having a well-defined street structure, MU2 has a dual performance, with high integration values in streets that are connected with the global street system, and low integration values in single-family neighbourhoods. These urban areas have their own internal structure, isolated from the surrounding structure, fulfilling the premise of an exclusively residential and single-family neighbourhood. The lowest values of local integration belong to morphological units of fragmentation (MU3). Their characteristic street patterns often comprise disconnected streets, with long street segments and large street blocks, without a clear delimitation. This follows the logic of the building access, where culs-de-sac often prevailed, and devaluates the street connection with the surrounding network. Associated with the modernist city, this conception has introduced strong physical impacts in Porto’s urban structure since the mid-twentieth century. The lower integration of these areas is also visible in the lack of other uses, in addition to the residential utilization. MU4 is an exceptional unit, more heterogeneous and distinct from the other residential morphological units. While the MU4 areas structured by traditional street patterns have high integration values, areas composed of large street blocks and long street segments have low integration values.

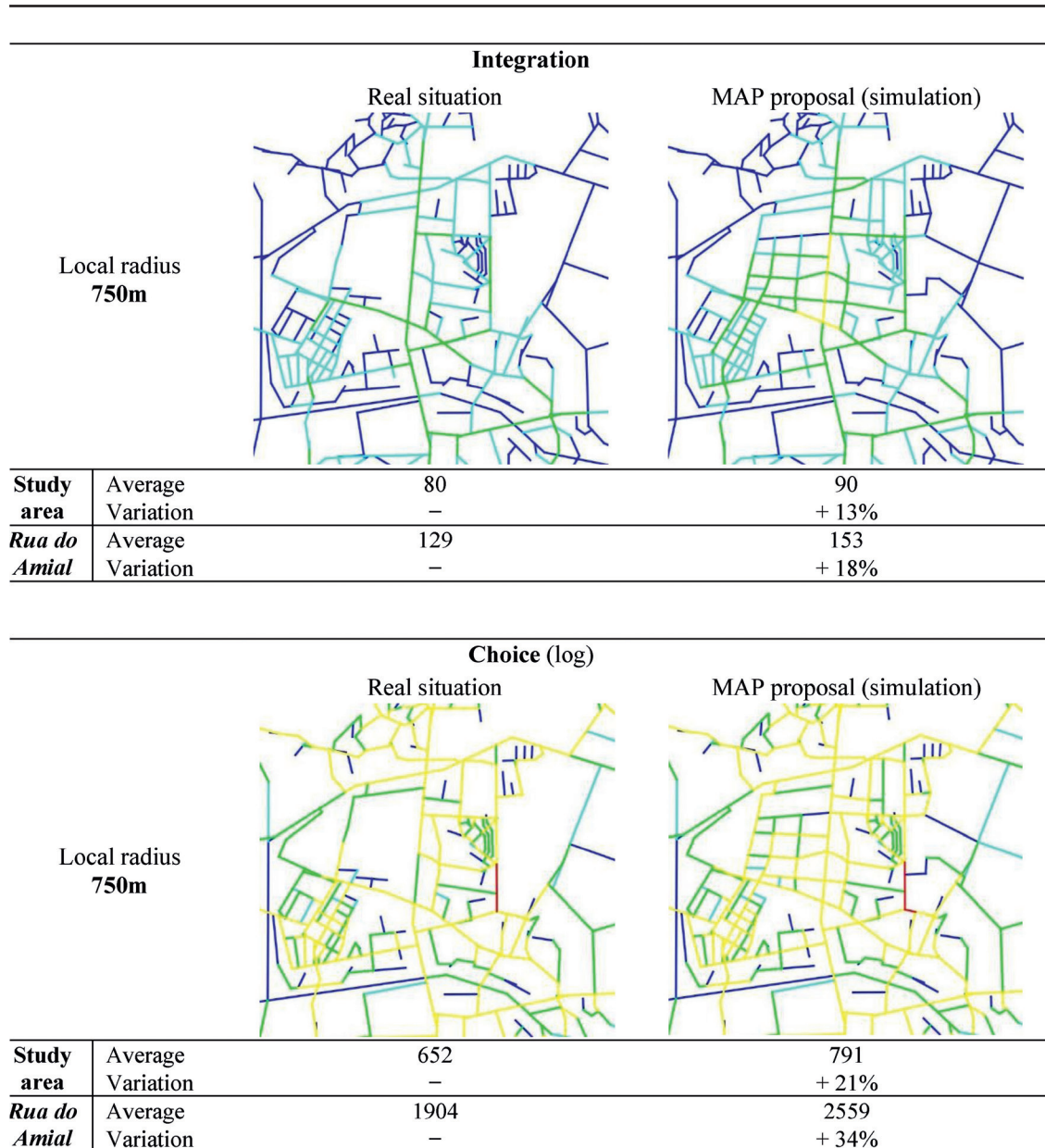
Segment angular choice quantifies the route potential. It measures how many shortest paths lie between every pair of segments for a particular local radius. The overlap of local choice values (1000 m) with the morphological zoning suggests that morphological units with higher local integration potential also have higher choice potential. This indicates that certain street patterns may be more accessible than others. Segment angular choice points to larger route potential in morphological units of continuous frontage (MU1), lower in morphological units of discontinuous frontage (MU2), even lower in morphological units of fragmentation (MU3) and, in general, in

exceptional morphological units (MU4). The route potential is higher with well-connected street patterns, linked with the overall street structure, with small street segments (small to medium street blocks). The local choice values are lower in areas with large street blocks (often with internal streets to the building accesses, without exit routes) with long street segments and few crossings, isolating these areas from their surroundings and reducing the chances of route movement.

#### *Phase 4. Regulation of the street system*

The fourth phase of MAP is the first step in moving from analysis to proposal. Based on the previous analysis (phases 1 and 3), this phase explores the regulation of the street system, including the possibility of designing new streets. The new streets proposed by MAP are assessed through angular segment analysis that offers a simulation of the proposed scenarios. Angular segment analysis, at local and global radius, allows assessing the accessibility potential of future scenarios, in terms of destination movement (integration) and route movement (choice). The potential movement variation is assessed in two different ways: the impact of proposed changes on the accessibility of the study area (comparison of the average value of the study area, for each measure) and of *Rua do Amial*, the street with higher integration and choice values (in comparison with the average value of *Rua do Amial*, for each measure) (Figure 7).

Through the set of new streets, MAP aims at increasing accessibility and urbanity. As inferred by the analysis, these are related to the traditional urban formation principles, characterized by well-connected streets and permeable street patterns, with small-to-medium size street blocks. Based on these principles, the proposed set of streets considers the opportunities for change and the accessibility of each morphological unit. This comprises: i) the development of particular interventions, including extending existing disconnected streets to integrate them into the overall street system; ii) the division of large street blocks,



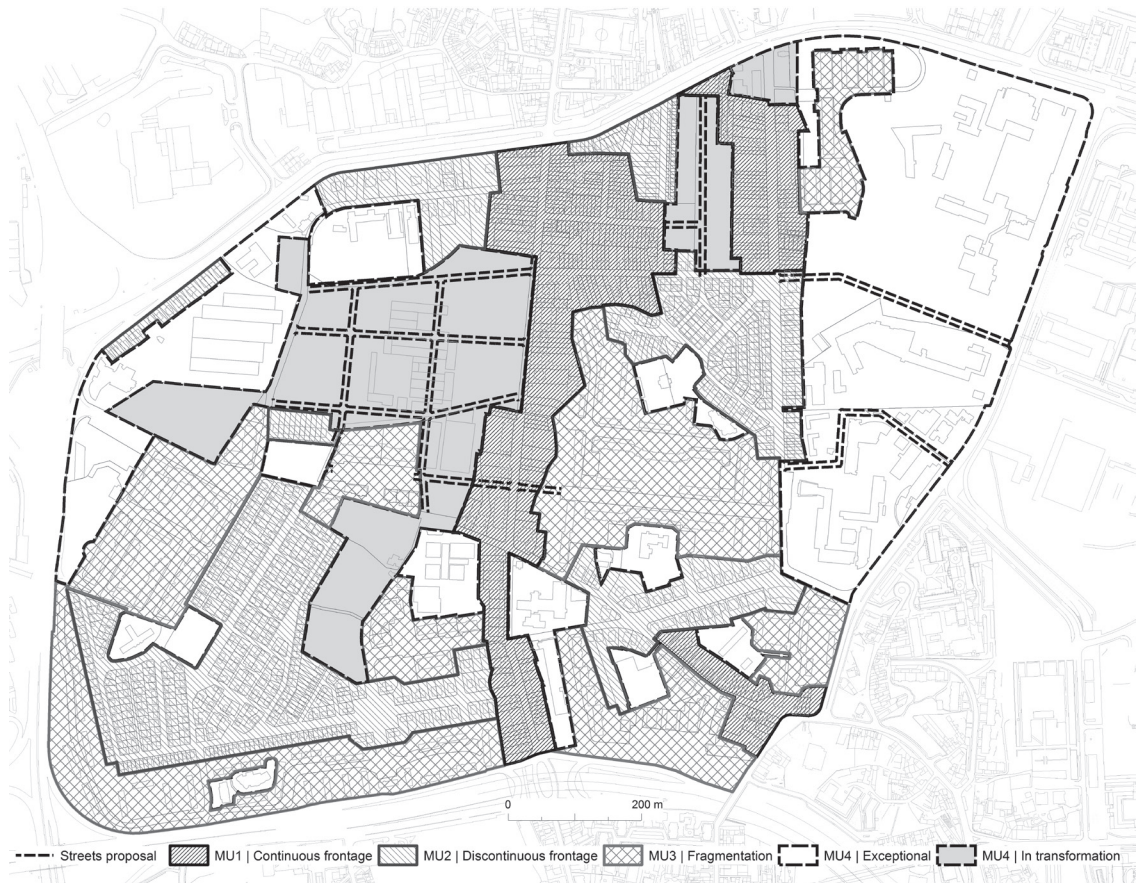
**Figure 7. Angular segment analysis. Comparative analysis of existing street system and that proposed by MAP.**

including the transformation of existing private accesses into streets; and iii) the design of new street patterns, including the restructuring of street networks in large areas with potential for change (Figure 8).

The angular segment analysis shows the advantages of the MAP proposal in relation to the existing situation, expressed in the increase of accessibility potential (Figure 7). Local integration reveals that the MAP

proposal increases the average value of the study area (14 and 13 per cent) and of *Rua do Amial* (14 and 18 per cent) at radius 1000 and 750 m respectively. Local choice shows that the MAP proposal increases the average values of the study area (11.5 and 21 per cent) and of *Rua do Amial* (27 and 34 per cent) at radius 1000 and 750 m.

The local values show that the proposed street system increases the study area



**Figure 8. Zoning map.**

accessibility and underlines the potential of centrality and of the route of *Rua do Amial*, which has a structural role in the study area.

At a global scale analysis (radius 5000 m) the new street proposal does not have a significant impact on the global structure of Porto as it does at the neighbourhood-scale. Even so, the impact is positive. Global integration shows that the MAP proposal increases the average value of the study area by 3 per cent and of *Rua do Amial* by 0.5 per cent. Global choice shows that MAP proposal increases the average value of the study area and of *Rua do Amial* by 4 per cent.

The MAP proposal aims at reinforcing the ground plan, specifically the street and the street block, as the main structural elements of urban settlements. The angular segment analysis allows the assessment of those planning intentions and confirms the benefits of

the urban development scenario supported by MAP.

#### *Phase 5. Definition of guidelines for urban form transformation*

The typo-morphological (morphological regionalization and typological process) and configurational analysis (angular segment analysis) identified and characterized the morphological units of the study area, based on the different elements of urban form, and on their different weights. The fifth phase of MAP converts the main criteria of analysis of urban form into guidelines for transformation.

The morphological understanding of the urban landscape allowed setting several intervention principles, where urban conservation, development and innovation follow the character of the territory. This aims

to be a morphological contribution to planning practice. It is argued that the degree of control and flexibility applied in urban planning must be adapted to each specific situation, enforcing the need to intentionally select the morphological contents to be regulated. Seeking out the necessary planning flexibility, MAP is selective in giving priority to the main formal elements that preserve the character of the city and enhance urbanity – the elements of ground plan pointed out by the morphological analysis. This means a strong control over the ground plan – streets, plots, and the relations between building and street, and between building and plot – and a more flexible control over the building fabric and the land and building utilization. MAP seeks a balance between innovation and the character and identity of each territory, based on the selection of the structural elements (perhaps the less visible elements).

Analysis has pointed to the advantages of a clearly-defined street, connected street networks, with medium-to-small street blocks, divided into medium-to-small plots, and buildings facing the street. The MAP proposal follows the idea of planning prescription based on the ground plan, and on the main traditional characteristics of each territory. It seeks to reverse the modern global cycle of large urban developments based on the excessive focus on the three-dimensionality of the building and architectural style (buildings positioned on large plots that are part of large street blocks).

#### *Phase 6. Contribution to the zoning map and regulation*

The sixth phase of MAP summarizes its morphological contribution to the realization of the zoning plan (Figure 8) and regulation (Table 2), the two main documents that are part of municipal plans in Portugal. The zoning plan proposed by MAP is in five morphological units: MU1, MU2, MU3, and the subdivision of MU4 (fringe belt) in two different prescription areas – MU4 exceptional and MU4 in transformation. MU4 in

transformation corresponds to plots alienated from fringe belt to residential use. These plots have a strong potential for urbanization. This provides an opportunity to consolidate the urban structure. The other specific urban elements that characterize MU4 exceptional, such as institutions, community spaces, open spaces and industry, which persist and are fundamental to the character and urbanity of the space, should be preserved.

MAP defines selective transformation rules for existing urban forms and expansion rules for new urban forms. For both stable and under consolidation morphological units (MU1 to MU3), prescription follows the recognition and continuity of the characteristics of the urban forms, emphasizing the importance of the plot as a differentiating element. For the morphological unit under development (MU4 in transformation), prescription follows the principles supported by the analysis of the surrounding territory, emphasizing the importance of the ground plan definition. The rules for transformation of this urban landscape are summarized in Table 2.

#### **Discussion**

MAP results are discussed from three perspectives: the application of the method, the extent of the analysis, and the contribution to prescription and planning. The first result is on the clear identification and explanation of the successive methodological phases, which simplifies its application process. This application demonstrated that MAP is easily reproducible, taking benefit of the clarification and simplification of each of the three approaches. Furthermore, considering not only its scientific value but also its ability to fit into planning practice and its real impact on the 'ground', it also demonstrated that the specific procedures it proposes are suitable for planning practice in terms of time and resources. This is a crucial issue. Making the advantages of such a methodology evident to practitioners will significantly increase its chances of adoption.

The second result to be emphasized is the comprehensive and detailed analysis obtained,

Table 2. Regulation

Morphological units	Regulation	
	Characteristics of the elements of urban form	Form complexes
MU1 Continuous frontage	Medium-size street block (division should be considered, if possible) (Maintenance of the) dominant plot division and plot frontage width Building frontage aligned with plot frontage (continuous street frontage) Building back frontage (predominant alignment) Building height (maximum and minimum height, related to surrounding buildings) (Consideration of the) phase of typological process that is more adequate Building heritage preservation, when applicable Housing and mix use (commercial)	Ground plan  Building fabric  Uses
MU2 Discontinuous frontage	Small- to medium-size street block (Maintenance of the) dominant plot division and plot frontage width (no amalgamation) Position of building in the plot (two or three frontages) Predominant alignment of building frontage Building height (maximum and minimum height, related to surrounding buildings) (Consideration of the) phase of typological process that is more adequate Building heritage preservation, when applicable Housing (single-family or small multi-family) and mix use (commercial)	Ground plan  Building fabric  Uses
MU3 Fragmentation	Connected street network (continuity should be promoted, if possible) Medium size street block (division should be considered, if possible) Division of plots should be considered, if possible (Establishment of) building frontage, by predominant alignment Building height (maximum and minimum height, related to surrounding buildings) (Consideration of the) phase of typological process that is more adequate Building heritage preservation, when applicable Multi-family housing and mix uses (commercial)	Ground plan  Building fabric  Uses
MU4 In transformation	Connected street network / small to medium size street blocks Equivalent to UM1 regulation (or MU2 in its surroundings) Equivalent to UM1 regulation (or MU2 in its nearby surroundings) Housing and mix use (commercial)	Ground plan Building fabric Uses
MU4 Exceptional	Recognition of exceptional urban elements Connected street network (continuity should be promoted, if possible) Street blocks should be divided, if possible Building heritage preservation, when applicable  Institutions, open spaces	Ground plan  Building fabric Uses

at different levels of resolution, as the result of an integrated reading of the different morphological methods. MAP takes advantage of the complementary use of different scientific morphological methods, suitable at each scale

of analysis. To accomplish this comprehensive analysis of the territory, different weights are attributed to the different elements of urban form. MAP provides a morphological zoning based essentially on the characteristics

of the ground plan as the fundamental element for maintaining the character of the territory, informed by the analysis and understanding of each building type and the accessibility of the street system.

The third outcome is that MAP provides a synthetic zoning plan appropriate to the definition of rules of conservation, transformation and expansion. The process of analysis made it possible to establish selective regulation based on the structural elements of urban form and applicable to planning. MAP defines morphological prescription for all morphological units, providing a strong control on the ground plan and a more flexible control on the building fabric and the land and building utilization.

## Conclusions

The comparison and integration of different views to improve the understanding of urban form and the capacity to inform its transformation process is a challenge for urban morphologists. This paper is a contribution to the growing body of research that has been trying to bring together morphological concepts and methods and to develop integrated approaches. It adds a fundamental step to the line of research proposed by Kropf (2009) and developed by Oliveira *et al.* (2015). MAP accomplishes the effective overlap and integration of three complementary ways of interpreting urban form – historico-geographical, process typological and configurational – and demonstrates its potential for both analysis and prescription.

This paper also contributes to the debate concerning the potential use of scientific morphological concepts and methods in cities through planning. MAP seeks to contribute to overcoming barriers between urban morphology and planning practice, pursuing the main goal of placing urban morphology firmly in planning priorities. Among the practitioners of urban planning, the current emphasis tends to be on building and land uses, or restricted to building form and individual buildings. There is a need for greater awareness of the

significance of the underlying morphological structure of cities. This underlines the challenge for urban morphology, through scientific knowledge, to contribute more to planning practice and to offer strategic and operational support to the practitioners who have responsibility for the urban environment. Integrated approaches, such as MAP, can contribute to meeting this challenge.

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