Morphological System and Urban Settlements.

Coimbra (Portugal): A City from the Roman Times to the Present*

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Abstract The vision of the 21st-century sustainable city unquestionably requires an interdisciplinary analysis in urbanism. The issues concerning physical support systems in land-use planning must be regarded as essential pieces in urban design and due to their weight in the environmental components of sustainable urbanism.

On a time matrix that shows the pathways of change in the urban setting of Coimbra, and being aware of the integrated vision as the ultimate goal, we systematise the "morphological system" —geomorphology; lithology; tectonics; slopes; exposure— that conditioned the urban development (in harmony for centuries and disruptive in the last decades). The findings highlight a consistent path of deep change with a consistent path, with increasingly complex patterns, and limited dependence on the physical variables. The sustainability of space built in the past was transformed by the recent expansion of buildings on the slopes, consequently leading to natural risks and climate changes.

Keywords Coimbra (Portugal), morphological system, sustainable urban design, urban development, urban settlements

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Sistema morfológico y asentamientos urbanos.

Coimbra (Portugal): una ciudad desde la época romana hasta el presente

Resumen La necesidad de un análisis interdisciplinar en urbanismo es un hecho incuestionable desde el punto de vista de la ciudad sostenible del siglo XXI. Las cuestiones relacionadas con los soportes físicos de la ordenación del territorio deben abordarse como elementos centrales del diseño urbano y del peso que presentan en los elementos medioambientales del urbanismo sostenible.

En una matriz temporal, que muestra las trayectorias de la transformación del asentamiento urbano de Coímbra, y conscientes de que la visión integral es el objetivo, se sistematiza el *sistema morfológico* —geomorfología, litología, tectónica, declives y exposiciones— que condicionó el crecimiento urbano (sintonía durante siglos y disrupción en las últimas décadas). Los resultados apuntan a un flujo constante de cambios profundos con trayectorias diferentes, con patrones cada vez más complejos, y con una dependencia limitada de estas variables físicas. Frente a la sostenibilidad del espacio construido en el pasado, todo se transforma con la reciente expansión de los edificios por las colinas, y la consiguiente aparición de riesgos naturales y cambios climáticos.

Palabras clave asentamiento urbano, Coímbra (Portugal), diseño urbano sostenible, evolución urbana, sistema morfológico

Sistema morfológico e assentamentos urbanos.

Coimbra (Portugal): uma cidade da época romana ao presente

Resumo A visão da cidade sustentável do século 21 certamente requer uma análise interdisciplinar do planejamento urbano. Questões relacionadas aos sistemas de suporte físico para o planejamento do uso do solo devem ser consideradas elementos fundamentais do desenho urbano e mesmo pelo peso que têm nos componentes ambientais do planejamento urbano sustentável.

Com uma matriz temporal que mostra os percursos de mudança da configuração urbana de Coimbra, e tendo como meta final a visão integrada, fizemos uma sistematização do "sistema morfológico" —geomorfologia, litologia, tectónica, encostas, exposição— que condicionou o desenvolvimento urbano (harmonioso durante séculos e disruptivo nas últimas décadas). Os achados destacam um caminho consistente de mudanças profundas com padrões cada vez mais complexos e dependência limitada das variáveis físicas. A sustentabilidade do espaço construído no passado foi transformada com a recente expansão das edificações nas encostas, gerando, como consequência, riscos naturais e alterações climáticas.

Palavras-chave Coimbra (Portugal), sistema morfológico, desenho urbano sustentável, desenvolvimento urbano, assentamentos urbanos

Introduction

Land use planning policies in relation to the understanding of the environment and the landscape came up in the scientific literature in 1961 in the work published by landscape architect Ian McHarg, *Design with nature*. The book substantially changed the way we understand the relation between the natural environment and the changes in land use, which had been neglected to that point[1]. The change is thus assumed through the environmental rationale of the transformation processes of land use, offering an alternative outlook on the economic weight of issues concerning planning, even taking into account the philosophy in the Athens Charter.

In urbanism, this is organised planning of the physical environment available to human populations in their numerous activities, granting safety in harmony with the environmental, social-economic and cultural needs of these groups. What we call today sustainable cities (and territories) must be perceived as the result from human settlements globally constituted by a society aware of their role as a transforming agent of the space, whose relationship is to be observed through the synergistic action between environmental protection, energy efficiency and inclusive social space (Romero, 2007; Farr, 2013). Considering the theoretical framework of the history and evolution of urbanism (Conzen, 1978; Álvarez, 1989; Angulo & Domínguez, 1991; Whitehand & Larkham, 1992; Moudon, 1997; Vernez, 1997; Mugavin, 1999; Kostof, 2001; Goitia, 2003; Avial, 2015; Hall & Barrett, 2018), this paper focuses on how the process associated to the construction of the humanized space should present an holistic approach.

The different planning processes for a sustainable territory, incorporating an analysis of a variety of units and complex systems, that Christofoletti (2015) regarded as key components for shaping environmental systems, must be analysed under a holistic vision of the different elements that embody it, addressed according to the many topics it is composed, even if in different scientific areas. This vision, only seldom sought, should be understood through an integrated response based on truly interdisciplinary work (Abreu, 1989; Magalhães, 2001; Cordeiro, 2017; Ashmore & Dodson, 2017).

This paper that, if taken superficially, could be regarded as reductive (and even contrary to the arguments mentioned before), considering the need for a complex and holistic analysis, seeks to objectively highlight that component we have called "*physical supports in urbanism and land-use planning*" —the endogenous factors—, which claims to be a key piece in a whole systemic study of the physical constraints on land-use planning and urbanism[2].. A special feature herein is the introduction, as a case study, to the urban development of Coimbra over thousands of years (a medium-sized city in the centre region of Portugal, near the coast), reflecting a clear link between the morphological system and urban instalment and development, well before the last century's technological innovation.

The primary assumption providing the grounds for this approachis the existence of two sets of structuring factors providing physical support to planning (Cordeiro, 2017): "endogenous" (directly or indirectly associated with the

morphological structure) —geomorphology; geology/lithology; tectonics (and seismicity); slopes declivity and their exposures; morphometry of slopes and drainage basins; soil structure— and "exogenous" (climate-related), such as radiation, temperature, wind, and rain, inter alia. It seems clear that the other factors constituting the natural constraints on urbanism and land-use planning are, to a lesser or greater degree, tied to the interconnection *between* these two structural factors (figure 1).

The inclusion of the "morphological system" in what was called, in an integrating manner, "endogenous factors", has to do with the fact they are often called by different names —depending on the academic training of the authors, or even the goal in each research work—, which inspired this analysis to be conducted in keeping with António Christofoletti's overview from 1999, that these factors are regarded as one of the "complex systems" of the environmental systems (see Christofoletti, 2015), or the "intrinsic quality (IQ) analysis" of Martínez-Graña et al. (2017).

Although realizing that the changes are caused by "exogenous factors", the relationship between the two sets of factors is considered to give rise to the issues associated with hydrology (regionally or locally) and risk prevention. In relation to environmental tools, usually analysed separately, they may also be found to be related to the

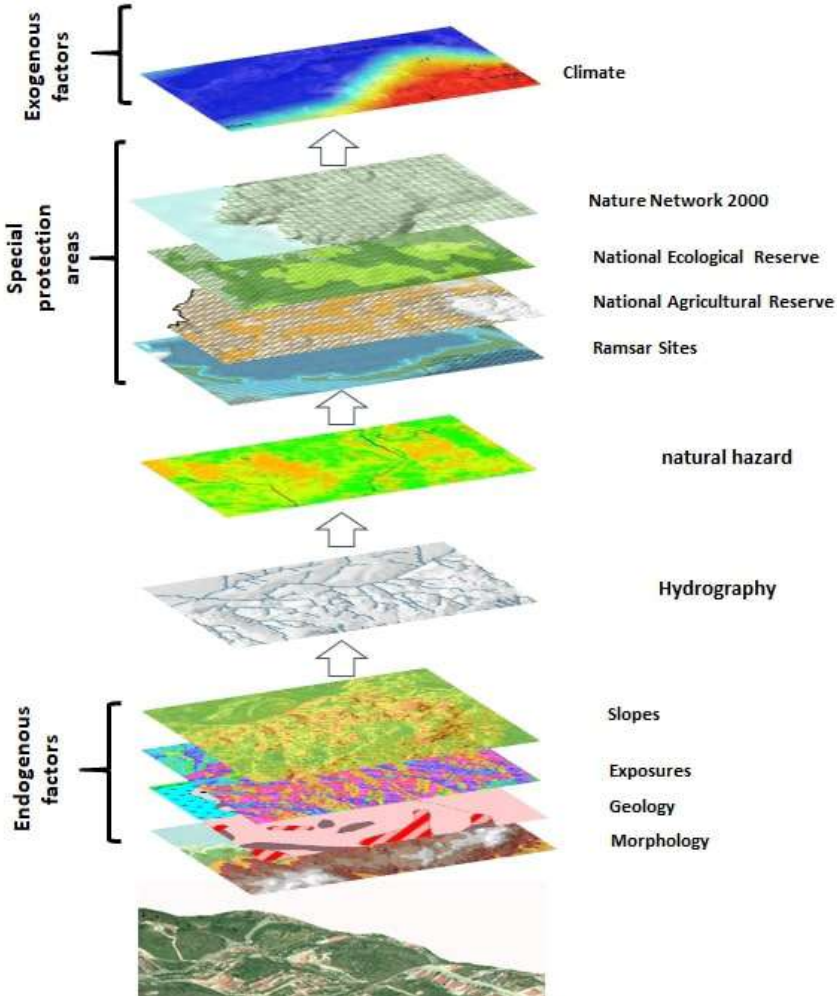

Figure 1. Overview of links between physical supports in land-use planning

Source: own work

structuring factors —endogenous and exogenous. In the case of Portugal, and focusing on the latter factors, it is not only due to what is observed in regard to the factors integrating the National Ecological Reserve and the Urban Ecological Structure, or the biotopes, but there are many other circumstances where endogenous factors are partially or fully responsible for the origin of the environmental space, being good examples the estuarine marshes or river bogs (Cordeiro, 2017).

Coimbra provides a good example for addressing the key role of endogenous factors in the layout and development of an urban space over the centuries. This urban space grew for more than a thousand years, clearly by adapting to these factors. Consequently, from the "settlement" to half way into the 20th century, the built environment evolved through the perfect empirical adjustment of its population to the physical features, everything changed with the societal challenges of the 1960s, as observed in some medium-sized cities in Portugal (Portas et al., 2003) or in Lisbon and Porto (Oliveira, 2013). Breaks in the sustainable growth and the complete harmonisation with the territor's physical features then became visible, which caused the disruption of that harmony, especially with the increase in natural hazards.

Objectives and Methodological Aspects

It is in the context of an approach oriented to endogenous factors, analysing the whole (complex system) based on the individual units, that we propose to carry out a combied approach to the physical elements, in particular the endogenous factors (morphological system) guiding the human settlement and the development of the city of Coimbra for centuries, with an integrated view of these adjustments to the morphological "skeleton". The links between the factors identified as "endogenous" and an explanation of the role that geomorphology and/or topography, geology/lithology, tectonics (and even seismology), the slopes declivity and exposure, and colluvial and alluvial deposits or soils (considering at all times the cross relationships between them) are the essential goals in understanding the city's development.

One of the analyses with an advantageous application is the identification of thresholds and the building of maps (sometimes composite in nature) that highlight the areas favourable and having a high potential for the various forms of use and occupation of the land. It includes an approach to the different elements, often in view of learning the lessons taught by each discipline, while analysing the intrinsic relations. In this case —Coimbra—, we move from the classical analyses like in geology (Tavares, 1999; Soares et al., 2005), to the geotechnical charts (Narciso & Andrade, 2010), or bearing capacity charts, including cartography of lytic materials, understanding geomorphology as the sum of morphogenetic processes, and the interpretation of vulnerable sectors regarding the natural hazards (Ganho et al., 1992; Rebelo, 1999; Cunha et al., 1999), the interpretation of the factors associated with biourbanism based on the slopes and their exposure (Marques et al., 2008). The main goal is to conduct an integrated analysis providing an overall basis for urban settlement in a well-defined territory[3].

A principle must be objectively assumed as the basis of all discussion on urbanism and land-use planning: reducing citizen-nature conflicts and the environmental impacts thereof. Consequently, the collection and assessment of data necessary to draw the maps of support to the plans was the starting point, also seen here as a planning project that is adjusted to policies and laws in force today. Arranging the territorial mosaics is an "art" that must take into account the different influences of the physical

environment, in view of obtaining the decisive point in the context of Portuguese territorial planning, a "map of easements and conditions" on land-use planning (Cordeiro et al., 2012)[4].

Much of the methodology herein developed has as its basic principles, among others, the contents of the methodology on territorial units —pattern, unit, component and evaluation, according to which any "land fragment" can be described based solely on its model— lithology, structure and tectonics of the substrate and soil features and the vegetation (Sanejouand, 1972; Diniz, 2012), which is why the analysis herein follows the same methodology[5].

This paper is, therefore, one of the pieces of a broader project on physical supports in sustainable urbanism, and is organised into different phases: critical review of the literature, practices and case studies on the topic of physical supports in urban design and, in particular, those associated with the morphological system, the development of a conceptual structure and an integrated approach model (using different case studies on an urban territory). This conceptual framework is developed based on different maps drawn according to the methodologies linked to each topic under analysis and will provide, in integrated terms, the basis for a summary-map, always in direct relation to the urban development of Coimbra throughout the centuries.

Endogenous Factors of the Physical Supports in the Urban Design of the City of Coimbra

The expression of the landscapes that record and identify the social, cultural, economic, technological and political processes of land use is, among other things, the consequence of a variety of physical supports, specifically, morphological structures (Fadigas, 2007). When Aldo Rossi contextualises the architecture of a city in regard to the existing dialectics between built environment, the natural environment and culture, the "locus" is a fundamental component of the city (Rossi, 1965). In historic terms, a city evolves undeniably as a result of (pre)-existing favourable conditions: defensible territorial position, trade, movement of resources and, more recently, the environment itself (Waller & Waterman, 2010), so the analysis must be initially guided by issues concerning the "locus" and the regional context. Considering the histori path of the city of Coimbra, two separate phases were identified in the relations between the morphological system and the symbiosis with the urban settlement. Many cities in the Iberian Peninsula, and in Europe, have developed based on, and its evolution has been interpreted (Ennen, 1979; Pardo, 1984; Álvarez, 1989; Benevolo, 1995; Rossas, 2001, 2002; Portas et al., 2003; Medina & Valverde, 2006; Oliveira, 2013; Rita & Häuber, 2015; Marino & André, 2017), although rarely mentioning, the issue of physical supports.

Coimbra's regional geographical setting in the Iberian Peninsula

From antiquity Coimbra has enjoyed a strong geostrategic position in the western sector of the Iberian Peninsula. This city in the central coastal region of Portugal has been long ago an important node in the network of north/south connections (thanks to the level terrain of the coastal platform facilitating mobility) and coastal/interior communications (with the Mondego River serving as a waterway), a position that was further reinforced when it became the capital of the Kingdom of Portugal, even before 1179 (the year of Papal recognition), a status it kept until 1255.

Located in the transition between the Old Massif and the Western Meso-Cenozoic Border, its

territory has a morphostructural base, being the western and central sectors made up of sedimentary materials, with the marly limestone hills and the alluvial plain of the Mondego River and the eastern sector, with a low mountain developed in metasedimentary rock. With a morphology resulting not only from the complex relationship between the regional geology and tectonics, but the fluvial dynamics as well, which shaped this territory during the Quaternary Period, the city developed and expanded by adapting to all this morphological and lithic complexity. The tectonic step that forms the edge of the eastern mountainous terrain contrasts with the level planes of the limestones and (very compact) Mesozoic sandstones and the valley bottoms (those in the Mondego plain, as well as those in the fingers of its affluents), offering very unique changing conditions for the installation and development of a city (figure 2).

The perfect adaptation of the historic city to the morphological system

In the city of Coimbra, as in many others in the old world, the favourable character of its defensible territorial position was clearly taken advantage of from the times it was founded up to the consolidation of the borders of the Kingdom of Portugal. The didactical discussions on the role of "locus" and "position" in the historic urban centre of Coimbra when dealing with the subject of how the morphological and lithological features are important in the interpretation of its medieval urban design, are perfectly outlined in this adaptability (figures 3 and 4)[6].

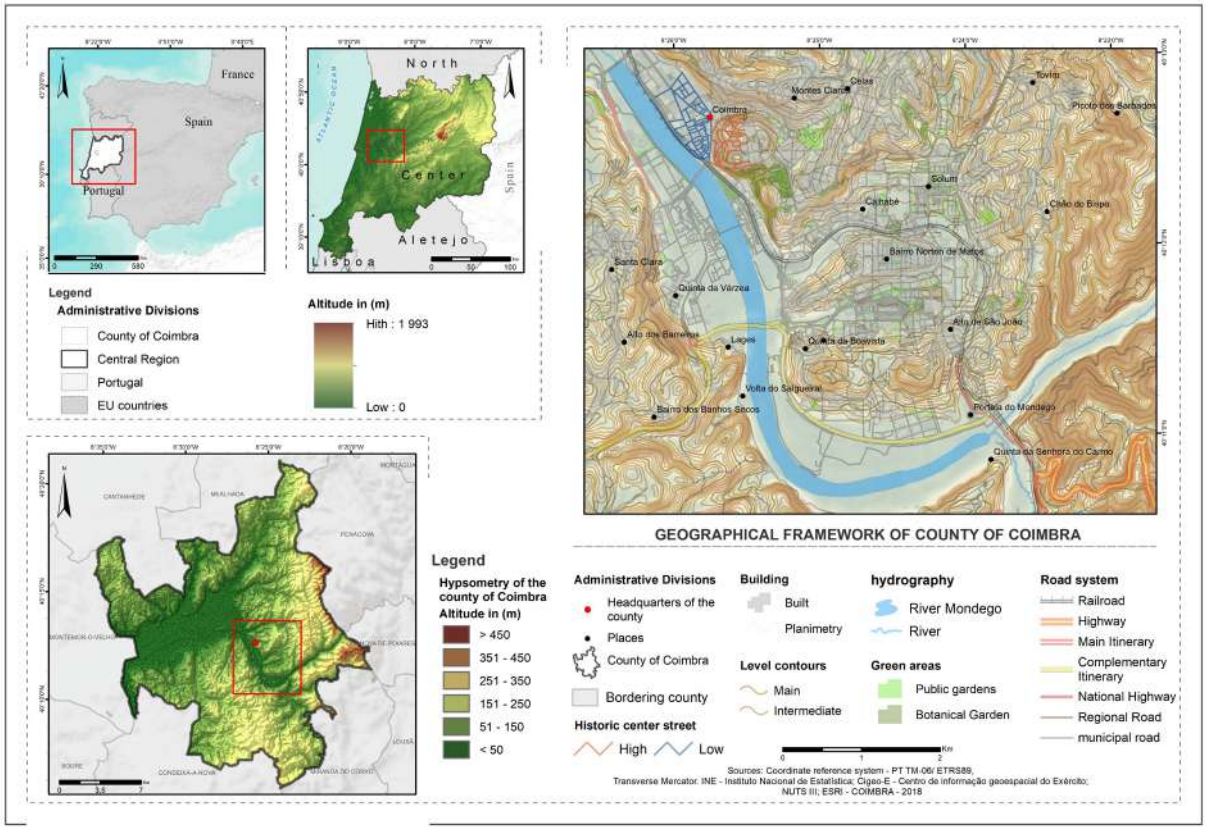

Figure 2. Geographical setting of the city of Coimbra on the Iberian Peninsula, in the Central Region of Portugal, municipality of Coimbra
Source: own work

The "hill city", very closely associated with the function of power and defence (figure 3, A and figure 4, A), was initially developed on a hill of compact Jurassic limestone, on which successive "layers" of civilisations were built —Roman, Mozarabs and Medieval[7],— in contrast to the medieval "suburbs" that grew up in the shadow of the protective castle, on a plain made up of alluvia (clays and silts) that may reach depths over 60 meters (figure 3, B). The urban expansion both during and after the 11th century —mostly due to the borders of the Portuguese Kingdom moving southward as a result of the Christian reconquest (the castle's defensive function lost its importance when the city changed from a border city to a crossroad city)— led to the expansion of the "suburbs" in the direction of the Mondego River (Martins, 1951; Alarcão[8], 1999; Rossas, 2001), thus creating an urban design quite different from the one previously adapted to the limestone hill on which the castle had been set up.

The radial-concentric design (the centre being the cryptoporticus of the Roman forum at the top of the University hill) with the main streets for traffic adapting to the contour lines and, therefore, being steeper and connected through alley or secondary streets consisting of stairways or very steep and narrow streets[9] (figure 3, C and figure 4, B) contrasts with a design that —even though somewhat irregular, beginning with a street that partially encircled the castle wall— has its main streets running parallel in the direction of the river, which are interconnected by small streets and alleys that run perpendicular to the main ones in an orthogonal design (figure 3, C and figure 4, C).

The oldest building also reflects these limitations. Therefore, on the hill, the foundations of the buildings are set directly on the limestone, but in the area of the alluvium, the foundations are mainly on pilings. There is also a difference in the typology of the buildings, with the number

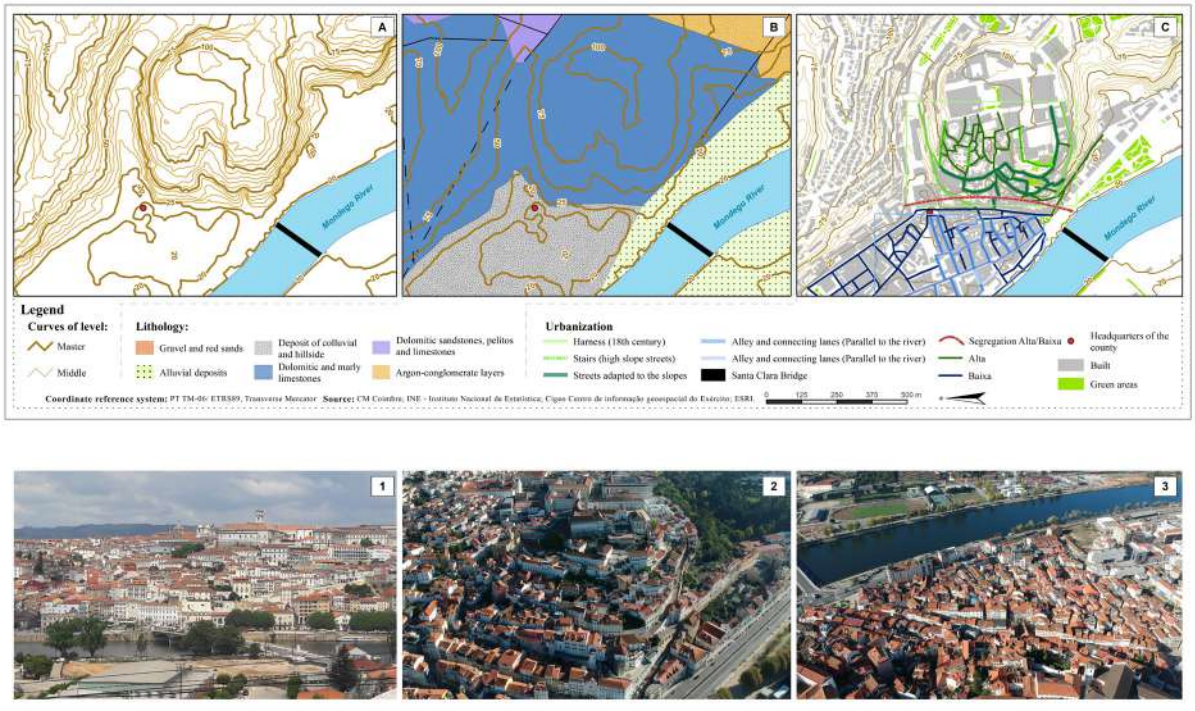

Figure 3. Integrated approach to the historic urban settlement of Coimbra; A - Elevations of the medieval spaces (Upper and Lower City); B - Relationship between the morphology and lithology; C - Urban design of the medieval town centre

Source: own work

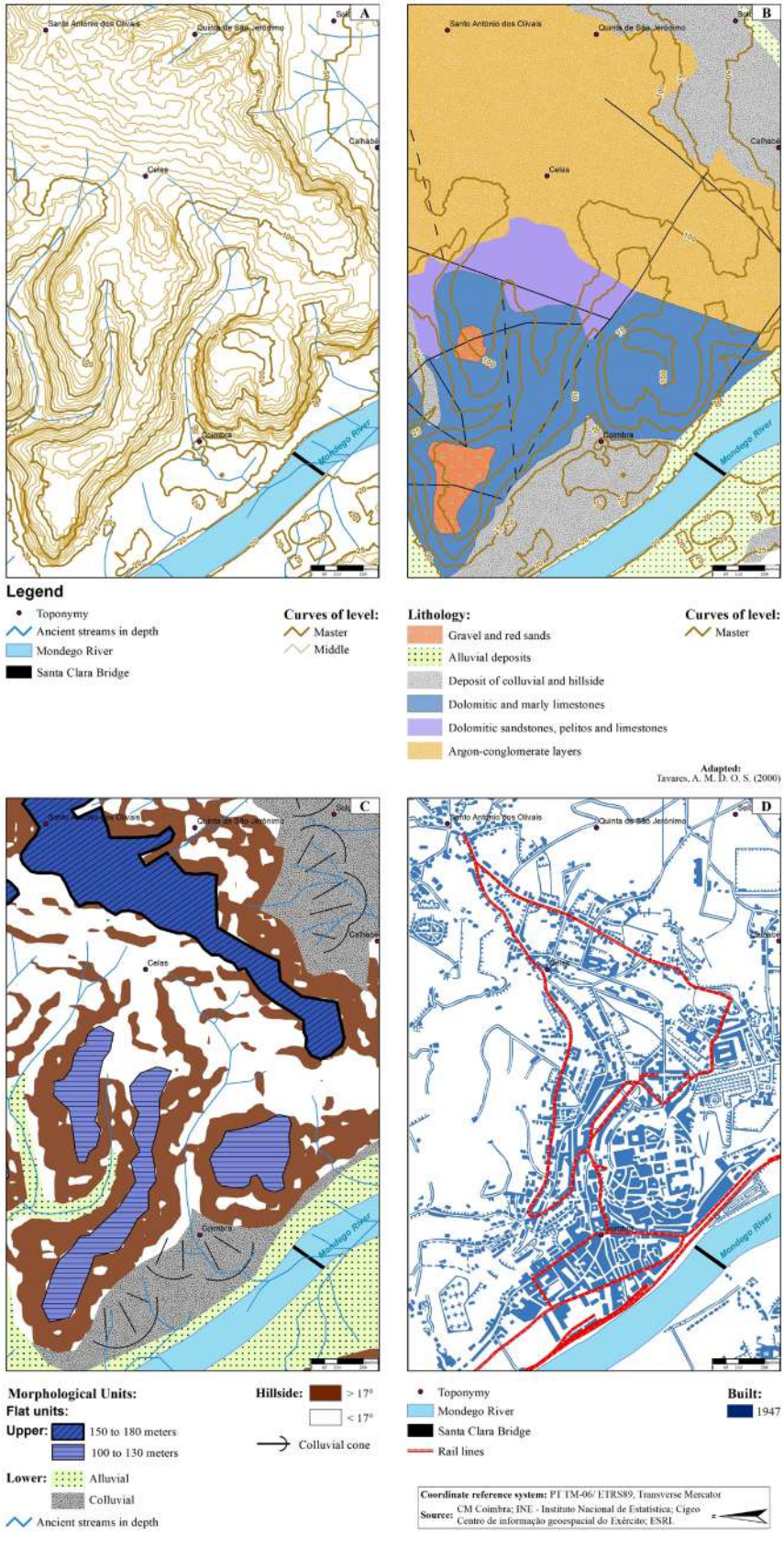

Figure 4. Integrated approach to the historic urban settlement of Coimbra: 1 - "Hill City" associated with the walls of the Castle; 2 - Radial-concentric design of the hill - "Alta" (Upper City); 3 - Orthogonal design of the "Baixa" (the Lower city)

Source: own work

of floors in the "Baixa" being the same (both overall, as well as within the same city blocks), while on the hill —the "Alta"— the adaptation of the buildings to the declivity of the slopes results in a different morphology in the buildings, some having more than three floors below street level in the sector where the declivity is steepest, and when they are analysed in terms of their climatic interactions, there are very clear alterations between the south-facing buildings and the shaded facades.

Up until the end of the 19th century, the growth of the city and its buildings was closely linked to the two centres mentioned above, the "Alta" on the hill, and the "Baixa" on the plain, interrupted in 1537 by the northern expansion of the Street of Sofia. João III of Portugal decided to create there the University colleges, maintaining a confined urban structure (Rossas, 2001). During this century, the city grew in the shadow of the hill dominated by the old university (and the important role of the river in that relationship) and with the transformations associated with the newly installed railroad line, the city at this point slowly turned to the north and northeast (figure 5). By the end of this century (between 1888 and 1892), the Bairro de Santa Cruz was restructured, and along the terminus of a stream —the "Ribela", which comes down from the Olivais levels and forms the north border of the hill of the Upper city (figure 5, A)— the current *Sá da Bandeira* avenue and Republic square were built and the *Santa Cruz* garden was preserved. The city grew and was restructured around the hill where the university stood (Santana, 1996; Lobo, 2000; Dias, 2015)[10].

At the beginning of the 20th century, technological transformations brought communications and transportation structures, offering a way to advance the expansion beyond the medieval and 19th-century axis. The setting up of different electric tram lines, especially on the level ground of consolidated sandstone and limestone (figure 5, B), enabled connections with new outlying neighbourhoods. There was a growing urban development in formerly rural territories during this time: *Cumeada, Montes Claros, Conchada, Calhabé* (the latter in the area southeast of the old town centre), and *Tovim*, thus increasing the city's population[11].

While it is true that the progress of the city of Coimbra up to the beginning of the 20th century was associated with its medieval heritage and the endogenous factors mentioned above, it seems undeniable that the urban expansion of the first half of this century again reflects the factors associated with the morphological system: geomorphology and lithology. It was, therefore, on the level ground surrounding the "Ribela" that the city grew during this stage (figure 5, C). Level ground consisting of very hard rock, highly consolidated sandstone and slightly marly limestone, was used in that period for the city to grow with the layout of streets along the axis of those level areas and where the tracks for the electric trams were laid (figure 5, D), resulting in a continuous urban growth in these areas with low declivity (Macedo, 2006)[12].

As can be seen, the whole process of the establishment and growth of the city up to the mid-20th century developed in a close relationship to the physical bases, in particular, the morphological system. It was in the 1940s that we find the preparation of the first major urban management plan for the city, carried out by the Belgian architect Étienne De Gröer[13]. Expansion began at the end of the 1940s in the sector to the southeast of the city centre (one of the four territories of that plan), which defined and built what can be deemed as a network of anchor installations intended as a thought-out expansion of the city (figure 6). Along with education (female high school, primary teaching school and industrial and commercial school), sports (Municipal Stadium and swimming pools) and religious (chapel of São José) facilities, there

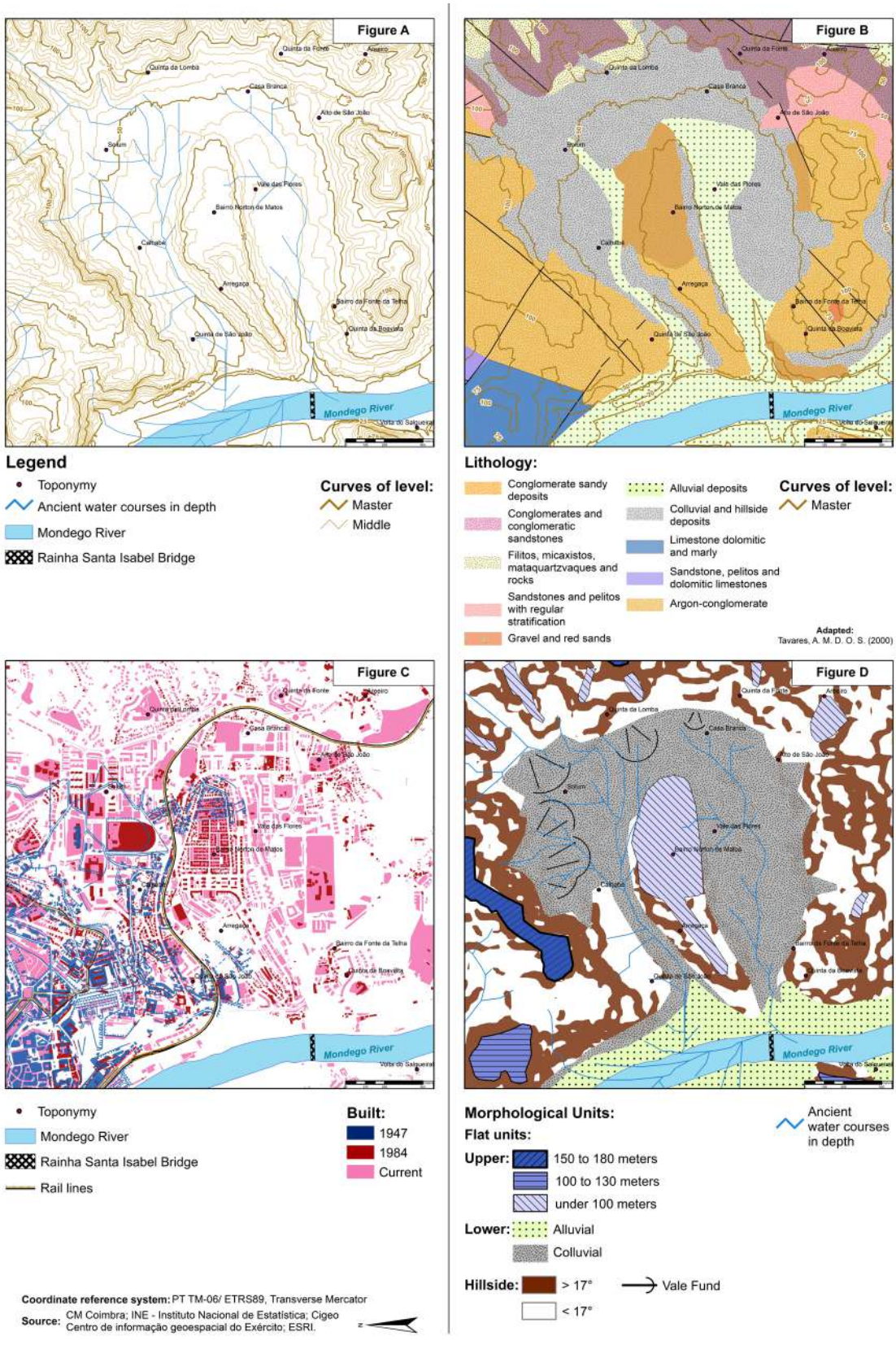

Figure 5. Framework of the urban growth in the early 20th century in the area surrounding the "Ribela" stream: A - Relationship between the morphology and the lithology; B - Morphological Units; C - Load capacity of the built heritage; D - The city in 1947 and its relation to urban rail lines

Source: own work

was also the construction of a low-cost residential neighbourhood, initially associated with housing for families displaced from the Upper City[14].

The paradigm of urban evolution in the areas of low declivity (and therefore, those with significant levels of ventilation and solar exposure) continues, although the issue of lithology changes here, as this sector is located in the "abandoned meander" of the Mondego River, where the consolidated Mesozoic sandstone base is covered by deposits associated with fluvial dynamics —alluviums and terraces— and slopes dynamics - colluviums (figure 6). In fact, while the various public installations are built on the old bed, the first residential space was built in the sector of the "interior convex" plane of the old meander, where there is a rather shallow cover of coarse fluvial deposits (Soares et al., 2005).

However, beginning in the 1960s, demographic pressure and a significant growth of the real estate market caused the urban expansion to no longer follow the connections it formerly had and the territory evinced some relationships that were not as easily explained in terms of the physical supports, mostly due to an expansion carried out based on both the spaces still unoccupied and the accessibility. In other words, spaces on slopes with rather significant declivity. This occupation of land represents a greater weight of the economy in the rapid urban expansion. The 98,027 residents in 1950 grew to 148,443 by the beginning of this century[15], a growth poorly regulated, and only the Municipal Master Plan of 1993 instituted well-defined rules.

Thus, taking the medieval urban settlement of Coimbra as the starting point for the analysis of the importance of the morphological system, the intention was to demonstrate how two of the factors, morphology and lithology, are decisive and differentiating elements in the resulting urban design over the centuries[16]. With the recent

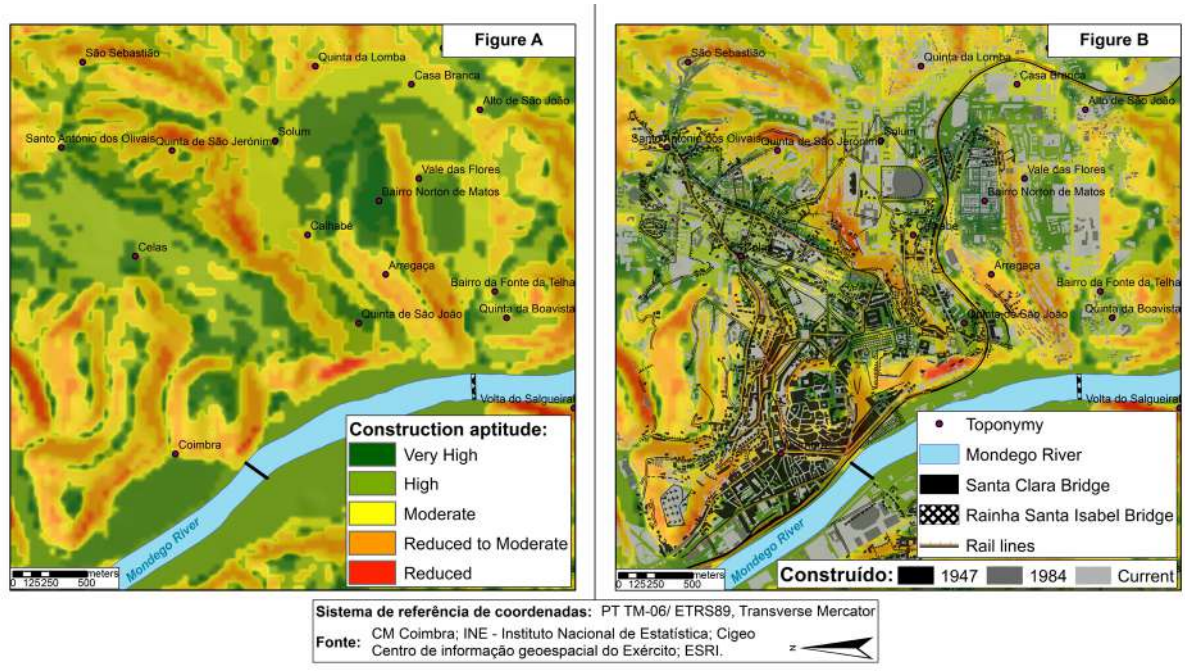

Figure 6. Context of urban growth in the 20th-century second half in the southeast sector of the city of Coimbra; A - Hypsometry; B – Lithology.

Source: own work

need for growing space in the city, everything has changed, seeing that the occupation of the slopes has increased, introducing the slopes and materials covering them unequally in the equation of the balance needed between the morphological system and the urban settlements.

Endogenous factors and Coimbra's urban expansion. The change in the base conditions

The urban growth that was first seen in the 1960s, now extending to sectors of territory that no longer have the base characteristics preferred for building, led to the intensification of a whole set of vulnerabilities associated with various natural risks or alterations in the topoclimate of the city.

The multidisciplinary analyses carried out in the last two decades have mainly sought to analyse situations that were occurring in the territory of the city of Coimbra, sometimes anticipating them. These cases include the natural risks —local flooding and shifts in ground mass (and even forest fires)— as well as questions related to "heat islands" and "cold air lakes" that have been intensifying with this growth. These facts have been analysed using disciplinary approaches by various authors with a variety of academic backgrounds, creating conditions for an overall analysis that looks at the new limitations in place, based on a precise (or not) definition of the endogenous physical bases.

Taking as our starting point the schematic articulation between the physical supports of a certain territory (see figure 1), and when looking at the other complex structuring system under consideration —the exogenous factors (those associated with the climate)—, direct relationships are found to exist with the morphological bases, especially when dealt with on a local scale.

In this context, the case of the cold-air lakes found in the bottoms of the valleys in the east and north sectors of the territory of Coimbra is clearly noted. Related to the cold (heavier) air that comes down the slopes of the Marginal Massif of Coimbra and accumulates in the valleys where the city has expanded, the differences in temperature between the bottom of the valley and the level terrain of *St. António dos Olivais* (a difference of about 60 metres in altitude) may be greater than 10º C. Similarly, there are the exposures of the slopes that the inclines can reinforce in the differentiated angle of incidence of solar radiation, or the importance of the constructed shapes in the appearance of ventilation corridors (Ganho, 1998; Marques et al., 2008).

As for the hydrology, the existing relationship is even more evident between the two complex systems that are considered as structuring. In the various sectors of the slopes, the relationship between the morphostructural bases and hydrology is focused, for example, on issues associated with the run-off. With their nuances in relation to the declivities, the materials that cover the slope (state of conservation of the rock, the greater or lesser thickness of the alterites, or even man-made landfills), the type of soil, the vegetable cover, and land use, in an integrated manner and in connection with issues associated with the infiltration rate, which sets limits on the efficiency of the waters that drain the slope. In the case of the city of Coimbra, and returning to the example of the "Ribela" and the territorial units that are included in it (see figure 5), these relationships are more than evident (Paiva, 2006). The small watershed, which is linear in shape, has been subject to the continuous waterproofing carried out on the various sectors of the slopes linked to the human settlements, because of the buildings and the roadways laid out on them, resulting in increased run-off and drainage that has caused local flash flooding on a somewhat regular basis that, in turn, has led to significant disruptions in the life of the residents.

In regard to other natural risks, and analysing here only those that are in a direct relationship with the endogenous bases (where these factors appear as crucial pieces for understanding them), we must call attention to the shifts of ground mass that are frequently seen on the slopes of the urban space. The declivity and lithic material seen that are more or less disaggregated, more or less plastic, should be considered as decisive endogenous factors in the context of shifting ground mass, although the exogenous factors function as "switches" in the triggering of the process. In the city of Coimbra, many events have occurred in the last decades, most particularly in the sectors of urban growth in rupture with those that were considered to have the preferential base conditions that marked the first phases of the development in the built area. The declivity came to integrate new nuances in the questions regarding the vulnerability of the urban space. So it was that, in the phase of urban growth of the second half of the last century, with the occupation (and resulting waterproofing) of sectors with slopes that were steeper and consist of coluvial materials, where the materials were less consolidated (and even man-made landfills), shifts of ground mass began to be seen fairly frequently, and in 2000, in the zone of Calhabé (Lourenço & Lemos, 2001; Lemos & Ferreira, 2004; Quinta-Ferreira, 2007), as well as in the southern part of the city (Dimuccio et al., 2006), they gained significance due to the impact they had on the life of the residents.

This brief analysis intends to show that, not only the direct relationship between the endogenous factors —the morphological system— and the urban design of the city of Coimbra developed in a fully balanced manner over the course of many centuries, but also how this phehomenon, with the introduction of changes in that balance and, consequently, the different relationships of cause/effect between these endogenous factors and other physical supports (as seen in the second half of the last century), ruptures will become increasingly common. For this reason, this whole relationship should be taken as an important element in a "map of constraints and easements" for the various land use plans. It seems quite evident that, in many cases, the starting point for many of these constraints is related to the morphological system and, therefore, the choice was made to initially analyse individual factors, their relationship with the growth phase of the city in the second half of the last century being undertaken in the second stage.

Nevertheless, it must be pointed out that, in terms of the "map of constraints and easements for planning" (which are mandatory for Portuguese municipal master plans), these factors of the morphological system only very recently began to weigh on the legislation (Cordeiro, 2017). For this reason, their systematisation and direct, active integration in these maps of planning constraints should always be viewed holistically[17], something that began to be employed, although only partially, when one considers that some of these factors are integrated in various planning instruments, the National Ecological Reserve and the Municipal Ecological Structure (Cordeiro et al., 2012).

Concluding Remarks

When associated with human settlements, land-use planning requires an interdisciplinary analysis of the various elements that make up the territory, and it is essential to take into account both physical and human aspects in a rational management of the resources, in order to avoid conflicts, thereby enabling sustainability in the constructed space.

It is well known —especially when territories with a strong regulatory component are analysed, as in the case of the European Union countries that the significance and valuation of the physical and biological systems under the framework of the complex systems are directly related to that territorial reality.

The analysis of the physical supports, and in this particular case those of the morphological system —geomorphology/geology/lithology/tectonics, as well as those associated with them, such as the declivitys, the exposures of the slopes, and even the materials of alteration or the soils— were described and interpreted from an interdisciplinary point of view and with analyses different from those carried out in the disciplinary (or even multidisciplinary) approaches. Taking the historical evolution of the city of Coimbra as an example, we took as crucial pieces its urban settlements, which developed in very different historic (and technological) contexts during their long relationship with the morphological system, making it possible to map out and realign some of the analyses of the city territory carried out previously. In reality, physical geography conditioned the development of Coimbra's urban design over the time. In harmony during a millennium, but in disruption due to the existent real estate pressures during the last six decades.

Undeniably, the endogenous factors are integrally associated not only with the direct limitations, but also with the risk-related limitations (cindynics science) and environmental factors, fields that should be included upstream in urban design and which take on added prominence within the framework of the various planning instruments, which is further reinforced with the implementation of the Urban Agenda for the EU (European Union, 2016).

The individualisation of the endogenous factors —as units of a complex system of a city with over a thousand years of history, with urban functions that have varied over the time— was assumed herein within the context of the physical supports in land-use planning and urbanism as an element of systematisation, and while understood as a multidisciplinary starting point, its objective is a final interdisciplinary analysis resulting from the assumption of a holistic vision intended for the sustainable urbanism required in this beginning of the 21st century.

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1 However, and as mentioned by Malekpour et al. (2015), only much later are environmental issues fully introduced in planning areas, in particular in the context of strategic planning development associated with environmental impact issues.

2 The need to prepare a holistic approach for this matter is mirrored in different papers published on other factors —exogenous, environmental and cindynics (Cordeiro, 2005; Cordeiro et al., 2012; Cordeiro & Guimarães, 2013; Cordeiro, 2017)— so the very short-term purpose is to carry out an integrated analysis of these factors, including an overview of such factors, the links between them and their impact on urban design.

3 Many of the bibliographical references herein are papers presented at a meeting held in 1996 on the geography(ies) of the city of Coimbra, which addressed two major topics – "The territories of the city" and "What shall we do with the city?", topics that from the start reflected the gap existing between the different areas related to the reading of the territory and urban planning. Multidisciplinary analysis is reflected in a very precise manner in these texts published in 1999, which is why their analysis includes referencing them as the starting points for the "units", in the attempt to conduct a multidisciplinary study, the goal of this paper, which is intended as an interdisciplinary overview.

4 In the Portuguese legal context, the development of the Municipal Master Plan (PDM) triggers the need for a key document, the "Map of easements and constraints" (the others being the "Regulations" and the "Land-use map"). Therefore, many of the factors related to land-use planning take this document as their starting point.

5 The method used to design the load capacity cartogram was based on the adjustment of soil classification, of its physical component and of the load capacity of its geological material, in order to create a hierarchical scale for the design of a geotechnical mapping. This implies adapting mapping knowledge, but applied to geological soil bases and to their building capacity, following the analysis documents by Sobreira e Souza (2012) and Dimuccio et al. (2006). Thus, we took into consideration the classification of land units and their susceptibility and aptitude assessment to categorise the geological components of the areas in question, assigning a scale from 0 to 10, based on the lower or higher susceptibility to the importance of the product between the slope and the load capacity of the morphological units.

6 Starting the second half of the last century, Alfredo Fernandes Martins masterfully demonstrated the importance of locus and position in the medieval urban design of Coimbra (Martins, 1951), reinforced by later works by Rossas (2001) and Alarcão (2008).

7 Human occupation of the hill may even date back to the times of the "Iron Age".

8 Archaeologist Jorge Alarcão mentions that the "rua das tendas" (street of tents), where the stairs of Quebra Costas are located today, would have an incline around 14º, which would make mobility along the principal "street" of the city very difficult for people and vehicles drawn by "animals" (Alarcão, 2008, p. 84).

9 A set of infrastructures was built in this space surrounding the university hill. A street was opened that was represented as being the route provding the best access to the Upper City (Costa & Fernandez, 2003). Much of the previous growth, associated with the Reform by Minister *Marques de Pombal* (second half of the 18th century), had also been marked by that same relationship with the hill, being found in peripheral spaces (among them, the Botanical Garden, the old College of Jesus (Jesuits), the *Laboratório Chimico* (Chemical Laboratory), the astronomical observatory, and the creation of the Couraças, as axes for movement between the "Alta" and the "Baixa", encircling the entire hill).

10 From about 15,000 inhabitants residing in the city in 1864, the population grew to 25,000 in 1900, and to 40,000 in 1930 (Lobo, 2000).

11 It must be pointed out that along with the preferential conditions of the endogenous factors, there were, at the same time, preferential conditions associated with the exogenous factors. The ventilation and solar exposures found in these sectors were factors of bioclimatic comfort and environmental quality that still today make these areas very interesting spaces in terms of bioclimatic comfort and quality of life.

12 Architect De Gröer, who was greatly influenced by the Athens Charter, came to Portugal in 1938, when the "New State" (dictatorial period) took on the task of developing urbanisation and public works plans for the main Portuguese cities, which in the case of the plan for Coimbra counted on the collaboration of the Portuguese architect David Moreira da Silva (Santos, 1983).

13 At the end of the first half of the 20th century, under the rule of the dictatorship, the "New State", the government decided to construct new University buildings – the Faculdades of Arts and Humanities, Medicine, Mathematics, the General Library and Archives, and later, the Physics and Chemistry Buildings (all of which today are integrated in the area classified as a Unesco Heritage Site). This building programme led to the tearing down of part of the old residential district of the upper city, which made it necessary to relocate the inhabitants. Three peripheral neighbourhoods were built for this purpose, being the largest in this sector.

14 In 2011, for the first time in history, the population of the municipality of Coimbra dropped, registering 143,396 residents within the municipal territory (5047 fewer residents).

15 The city's economic expansion during the second half of the 21st century had no relevant relation with morphological factors, even considering the main factories were built below the slope related with the muddylimestone hills and levels among the northern and southern parts of Coimbra. Its location is mainly due to the inexistence of resources and to the closeness to main roads and railways that connect Porto and Lisbon (Caetano, 1968).

16 In regard to the Municipal Land-Use Plans (PMOT) and, in particular, the Municipal Master Plans (PDM), the Legal Regime of Instruments of Territorial Management reinforces the obligation to draw up a Map of Constraints that identifies the administrative easements and public utility restrictions in force, as well as an environmental report.

17 Currently, this relationship is already being assumed as a decisive factor in sustainable urbanism, albeit only marginally employed, seeing that the analyses have been developed with preference given to the environment, in which the climate, in turn, plays the main role