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Research Article

Exploring the active and network centralities in Metropolitan Athens: The organic vs. the planned form.

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Keywords

*urban form,
space syntax,
road network hierarchy,
institutional spatial planning
framework,
Metropolitan Athens,
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Abstract

The social, historical and spatial processes that shape the centrality pattern of a city have always been at the core of urban studies that explore the interplay between network configuration, human activities and the planned/formal form of the city. However, there is far limited research dealing with historic metropolitan areas, and exploring these links under a quantitative geospatial approach. In this article, we aim to address this gap by the exploring the different centrality aspects of Metropolitan Athens and more specifically by (a) providing a reproducible methodology for identifying active and network centralities, as defined by land-use pattern and space syntax respectively, (b) exploring the geospatial signature of the planned and organic form of Metropolitan Athens as framed by its institutional spatial framework as well as its active and network centrality, respectively, (c) investigating the role of network centrality, in shaping the existing active centrality pattern. The research results highlighted that the organic patterns are similar with the planned ones, mainly in the central and western part of the study area, whereas in the rest parts considerable differences are encountered. Notably, a study, in a metropolitan area with such extent and diverse characteristics (e.g., urban morphology, land uses), is currently missing from relevant literature. Hence, this work could shed light on urban development issues, revealing meaningful insights on how similar metropolitan cities in the Mediterranean region are assembled. Last, it could function as a valuable input for future planning suggestions.

Highlights:

- Providing a reproducible methodology for identifying active and network centralities
- Relation between planned and organic centrality patterns of Metropolitan Athens
- Investigating the role of network centrality, in shaping active centralities
- Results showed considerable disparities between organic and planned centrality patterns
- Results highlighted a direct positive correspondence between active and network centrality



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1. INTRODUCTION

The decades following the Second World War, the socioeconomic conditions and the technological development, led contemporary cities to transform into large metropolitan regions, with low population density and car-dependent suburbs (Buliung, 2011). As a result, the form of the historic city setting has radically changed; new urban centres and sub-centres have emerged, creating a wide network, which gradually absorbed the functions encountered in traditional and historic centres. In this context, quantitative GIS-based approaches are essential for reading and planning the contemporary European city characterised by diffused urban form (Serra, 2013; Berghauser Pont et al., 2019; Atakara & Allahmoradi, 2021). Furthermore, Space Syntax and its definition of centrality is crucial to understand the spatiotemporal evolution of a city González, 2017 since it provides a spatial theory of society (or a social theory of space) (Karimi, 2018).

Centrality theory represents “spontaneous” and “organic urban evolution” (Jacobs, 1961; Jacobs, 1993; Hillier, 2003; Porta, et al., 2009). According to Hillier (2003), centrality is defined as “city creating process” that follows the principles of “natural movement” (Hillier, et al., 1993, p. 32) as well as “movement economy” (Hillier, 1996/2007, pp. 125-127). More specifically, it claims that cities could be studied as self-organising spatial systems, transforming from mere buildings and infrastructure to vivid entities via the interaction of spatial configuration (network) and functional mix (land-use distribution). This process shapes the local centres of a city –or “activity nodes” according to Alexander (Alexander, et al., 1977, p. 166)- which function as the meeting points for citizens, where practices of encounter and exchange (economic, social etc.) take place, where “you can go to see people, and to be seen (...), the place where people with a shared way of life gather together to rub shoulders and confirm their communities” (p. 169). In this paper, we explore these two different aspects of centrality: active centrality and network centrality. Active centrality refers to functional pattern of the city (Batty et al., 1997) meaning the density of non-residential uses while network centrality (also known as configurational centrality) refers to the space syntax definition of centrality originally conceptualised by Bill Hillier, Julien Hanson in the Bartlett School of Architecture in UCL (Hillier & Hanson, 1984; Hillier, et al., 1987; Hillier, 1999).

In this context, we set three objectives for this article. Firstly, to provide a compact reproducible methodology for identifying active and network centralities. Secondly, to explore the geospatial signature of Metropolitan Athens centrality pattern as defined by the active and network centralities of Metropolitan Athens, as well as by the institutional spatial planning framework (i.e., the planned form of the city in terms of centres and road network hierarchy) and thirdly to investigate the role of spatial configuration, as quantified by space syntax measure of angular choice, in shaping the existing active centrality pattern.

The remainder of the papers is as follows; the second section includes the methodological process, the third section focuses on the results of the study, the fourth discusses these results and mentions limitations and suggestions for the future and the final section draws the conclusion of the paper by underlining the value of this research.

2. BACKGROUND

Centrality clusters can be interpreted as actual descriptions or symbols for a specific function in a wider context (i.e., the neighbourhood or the city or the region). The idea of ‘centre’ has a different meaning in the fields of architecture and urban design compared to physics, since it is characterised by ambiguity; both symbolically and in that it shall be viewed as a centre with reference to the urban surroundings (Allen, 1999). What is more, centralities can be also found in other networks such as the urban road network that mainly addresses the movement of peoples and goods (Zhang et al., 2011). The notion of this road network centrality can be reflected in the concept of road network hierarchy or street classification that plays a key role for the urban environment and its efficiency (Friedrich, 2017). Therefore, research initiatives

trying to explore and scrutinise the multifaceted urban form, should also take into account this crucial element (de Martinis et al., 2014), with the aim to identify formal and organic centrality perspectives. After all, urban and transport dimensions are now examined under a common framework, thus ensuring the integrity of urban space (Miller, 2018).

It should be noted that there are various approaches capable of investigating the character and hierarchical organisation of urban centres and streets (e.g., Luo et al., 2015; Ye et al., 2015); however, this research work emphasises on the pertinent geographical and configurational ones. Geographical methods generally put forward functional pattern, population density and job density (e.g. McDonald, 1987; Giuliano & Small, 1991; Batty, et al., 1997; Agarwal, et al., 2012; Liu & Wang, 2016; Taubenböck et al., 2017; Mariani et al., 2018; Li et al., 2019; Yu et al., 2021). Whereas, configurational research focuses mostly on the structural properties of spatial configurations (street network) and network centrality (as defined by Space Syntax) to create suggestions for (potential) urban centres and road network hierarchy (e.g., Hillier, et al., 1993; Hillier 1999; Yang, et al., 2015; Strano et al., 2012; Scoppa & Peponis, 2015; Marshall, 2016; Marshall et al., 2018). Notably, the last few years there are increasingly more research outputs utilising a combinatorial centrality approach utilising geographical and configurational approaches to identify urban centres (Zhong, et al., 2015; Shen & Karimi, 2017; Li, et al., 2018, Paraskevopoulos & Photis, 2020; Wei et al., 2020; Geddes, 2022). An important research development, since acknowledging different aspects of centrality are essential for constructing an up-to-date integrated urban-transport planning towards people-centric and climate-resilient urban centres and urban public space, in general (Anas et al., 1998; Zhong, et al., 2015; Shen & Karimi, 2017). Additionally, lately there are also several relevant research attempts (e.g., Tsigdinos et al. 2020; Stamatiadis et al. 2017; Tsigdinos, et al, 2019; Paraskevopoulos et al, 2020; Paraskevopoulos & Tsigdinos, 2022) utilising multiple centrality aspects to construct evidence-based planning which also take into account the vision of each city (for example, sustainable or car-oriented), thus formulating planning concepts close to the human scale, but also efficient.

Another important centrality aspect is the *formal/planned* centrality shaped by the law-designated institutional spatial planning framework, which attempts to designate specific areas and networks in the city as “central”. Focusing on the Greek case, since we are exploring the centralities of Metropolitan Athens, Greek constitution recognises that planning is a state responsibility (Christofilopoulos, 2002) and the wide spectrum of planning-related laws, rules and regulations of the Greek state shape its institutional spatial planning framework. However, we will focus on the regulatory (law-designated) plans regarding centrality clusters and road network and more specifically on the “General Urban Plans” (as defined by the laws 1337/1983 and updated by the laws 2508/1997 and 4819/2021). ‘General Urban Plan (GUP)’ is a normative study conducted by Municipalities of Greece (and ratified by law) that defines the location, size, and boundaries of all areas dedicated for urban development, and the zoning regulations for the urban and suburban areas of the Municipalities, including the significance and magnitude of centres and street network (Potsiou & Mueller, 2008). More specifically, General Urban Plans, define the various urban centres as well as the significance of street network superficially by designating the permitted -but not the desired- functions without a compact vision for the city (Aravanitnos, 2007). It is extremely interesting that from the absence of planning legislation that characterised urban development of Metropolitan Athens in the first post-war years (after 1920’s), we have now moved to a condition where human activity is heavily “organised” by a regulatory framework that defines “permissible” uses without dealing with the essential function of these central areas (i.e. human-scale public open spaces, walkability, connection with public transport, protection from high-speed vehicular mobility) (Triantis, 2017).

Lastly, two valuable tools for exploring centrality in this research are Space Syntax and Kernel Density Estimation. Firstly, Space Syntax is both a theoretical and a methodological tool that quantifies geometry and topology of street networks to measure the implicit property of urban grid to shape human activity (Hillier & Hanson, 1984; Hillier, et al., 1987). Notably, Space Syntax has been qualified as an important asset for analysing centrality by various

relevant studies that prove the strong correlation among network centrality, human movement and economic activities (e.g., Hillier, 1999; Porta, et al., 2009; 2012; Scoppa & Peponis, 2015; Omer & Kaplan, 2017; Serra & Hillier, 2019).

On the other hand, Kernel Density Estimation (KDE) method incorporates the density within a specified range (window) of each observation to display the value at the centre of the window. Within this window, the method “*weighs nearby objects more than distant objects, based on a kernel function*” (O’Sullivan & Unwin, 2010, pp. 68-71). Apparently, KDE is not solely a well-known method for calculating the density of events, but it is also employed in several studies related to the recognition of centrality clusters (e.g., Borruso & Porceddu, 2009; (Redfearn, 2007; Sevtsuk & Amindarbari, 2012; Porta, et al., 2009, Porta, et al., 2012; Andrakakou & Keßler, 2022; Paraskevopoulos & Photis, 2022, Bartzokas-Tsiompras et al. 2021). In general, the Kernel Density Estimation method is rather beneficial for this type of research, since it apprehends the very essence of location indicated by densities of neighbouring Features of Interest. This rationale underscores that emphasis should not be given on the place itself, but on the contrary on its surroundings (Porta, et al., 2009). Utilising KDE in this research is not only a means for analysing all available data under a common perspective, but also a prerequisite for truly understanding the essence of centralities in the study area.

3. ANALYSIS APPROACH

3.1 Study Area and Data Sources

The study area is the Metropolitan Athens, also known as Athens Urban Area (AUA), which is formulated by two prefectures or regional units of the Attica region, belonging to the NUTS-3 group of Eurostat. More specifically, these prefectures are Greater Athens and Greater Piraeus that consist of several municipalities (Local administrative units of Eurostat) as well. To be more precise, the study area includes 40 municipalities, 35 of which belong to the Greater Athens region, and the rest to the Greater Piraeus. It should be also noted that AUA is somehow similar to Functional Urban Area (defined by OECD), but these two areas do not coincide geographically. With a continuous built-up area spanning over 412 km² and a population of 3,090,508 residents according to the latest census conducted by Hellenic Statistical Authority (ELSTAT) referring to the year 2011, metropolitan Athens or AUA is the largest urban conglomeration in Greece (Maloutas et al., 2020) and one of the most populated urban areas in Europe (Salvati et al., 2016). In general, it is considered as a large geographical region with prominent historical importance and diverse social, morphological and functional dynamics (Tzortzi and Ioannou, 2020).

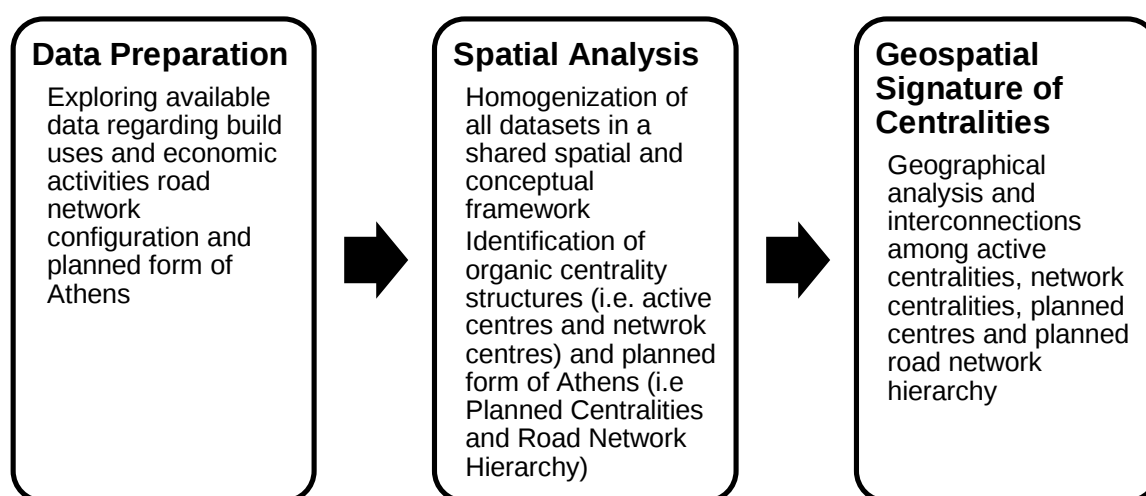
The data used in the research are secondary, coming from diverse sources. Firstly, data concerning economic activities and land uses as well as road network configuration are obtained by ELSTAT and their reference year is 2011 (latest census available). More specifically, the road centre line dataset is used for analysing the configurational form and the blocks dataset, containing detailed land uses, is used for identifying the functional form of the study area. Secondly, data referring to the institutional spatial planning framework -i.e., the planned form of the study area including street hierarchy and central areas- were collected by digitising the 49 General Urban Plans of Metropolitan Athens (obtained from the Ministry of Environment-<http://msa.ypeka.gr/>). Finally, in terms of software, QGIS 2.16.3 and PST (Place Syntax Tool, a plugin for Qgis) were used for space syntax analysis and ArcGIS 10.4 and MS Excel 2016 for geospatial and geostatistical analysis.

3.2 Methodological Framework

This work intends to thoroughly examine the spatial signature of organic and planned form of the historic Mediterranean city of Athens and more specifically the active and network centralities of the city in comparison with its planned/formal background. For this reason, a methodological framework consisting of 3-steps, has been formulated (see Figure 1).

The identification of centralities is an important part of our methodological framework. Building on the work of Paraskevopoulos & Photis (2020) and advancing the first iteration of this research (Paraskevopoulos & Photis, 2022), we propose an advanced method for identifying Active Centres. Active Centres are defined as the places of cities with significant density of non-residential uses which correspond to a variety of human activities and therefore attract dense people's presence (Vaughan, et al., 2010; Borruso & Porceddu, 2009; Li, et al., 2018; Ozbil, et al., 2011; Shen & Karimi, 2017). To quantitatively define Active Centres and their area of influence, the Kernel Density Estimation (KDE) of the non-residential uses is utilised for a radius and cell size suitable for centre analysis, but also representative of the study area. Tellingly, a critical task for recognizing the centralities via KDE method, especially in extensive urban areas, is selecting carefully the KDE's cell-size and bandwidth, since they should correspond with the (minimum) size and the magnitude of a typical centre respectively, according to the centre-identification literature and particularities of the study area. Precisely, a 300-metres bandwidth that approximates the typical size of neighbourhoods in urban design literature (e.g., Perry, 1929), and a 200-metres cell-size, representing a 40,000 m² area that corresponds with 6.5 typical blocks of the study area were selected, with the aim to identify the non-residential centralities.

Figure 1. Methodological framework



To sum up, for identifying and classifying Active Centralities, we propose a **Centrality Grade** (as explained in Table 1) that describes their significance/magnitude based on the different Kernel Density Estimation thresholds of functional density per block. To find the functional density per block for the available data for Athens Metropolitan Area we use the *Adjusted Functional Centrality Ratio (AFCR)*, introduced by Paraskevopoulos & Photis (2022) and described below:

$$AFCR_i = (\text{Ratio of Non-Residential Buildings})_i \times (\text{Average Number of Floors})_i$$

Adjusted Functional Centrality Ratio (AFCR) is a metric quantifying the relative and overall non-residential density, customised for the block-level build use data provided by the Hellenic Statistical Authority (ELSTAT).

The utilised built-environment dataset is provided by the the Hellenic Statistical Authority (ELSTAT) with the following format: For every city block it contains three fields. The first field refers to the exclusively non-residential buildings per block, the second field refers to the mixed-use buildings with non-residential being the dominant use and the third field refers to the mixed-use buildings with non-residential being the secondary use.

With the aim to identify Network Centralities, Kernel Density Estimation is applied for angular choice, for the selected local and global radii. Angular choice (also known as angular betweenness) describes the through-movement potential of the network and is calculated by counting the number of times each street segment falls on the 'shortest path' (the path of least angular deviation through the system) between all pairs of segments within a selected distance (termed 'radius') (Vaughan, 2015, p. 310). More specifically, to identify Network Centralities, a cut-off threshold is applied ($Density > Mean + 1 \text{ Standard Deviation}$), with the aim to single out the 'Network Centralities'. Furthermore, as one important objective is to reveal the various city structures arising in different spatial scales, a multi-scalar approach for classifying configurational centralities of an Urban Area, in line with Berghauser Pont, et al. works (2017; 2019), is adopted.

Table 1. The developed Centrality Grade for identifying Active Centres

Centrality Grade	Description	Active Centres Threshold (Kernel Density $\geq$)
A	Metropolitan	MEAN+8 $\times$ STD
B	City/Inter-municipal	MEAN+4 $\times$ STD
C	Local/Municipal	MEAN+2 $\times$ STD
D	Neighbourhood	MEAN+1 $\times$ STD
E	Potential/Emerging	MEAN
F	No Centre	<MEAN

For Metropolitan Athens three (3) classes are selected that correspond with 'Local', 'City' and 'Metropolitan' scale, which are defined as follows (its conceptual explanation is also depicted in **Table 2**). As 'Local Network Centralities' are characterised areas with High Local Angular Choice (900m) but without substantial Global Angular Choice (15km), as 'City Network Centralities' are characterised areas which simultaneously have High Local Angular Choice (900m) and High Global Angular Choice (15km), and as 'Metropolitan Network Centralities' are characterised areas with High Global Angular Choice (15km) but without High Local Angular Choice (900m).

Table 2. The developed approach for classifying Network Centralities

	High Local Angular Choice (900m)	High Global Angular Choice (15km)
Local Network Centralities	✓	✗
City Network Centralities	✓	✓
Metropolitan Network Centralities	✗	✓

Finally, the third stage of the proposed methodology framework refers to the geographical and geostatistical signature of active and network centralities and has a dual focus: The first is to analyse the socio-economic setting in which the various centralities emerge and thus the geography of the identified centralities is examined. The second is to investigate the role of network centralities in influencing the land-use distribution, i.e., the recognised active centralities and for this reason, cross-tabulation is incorporated.

4. RESULTS

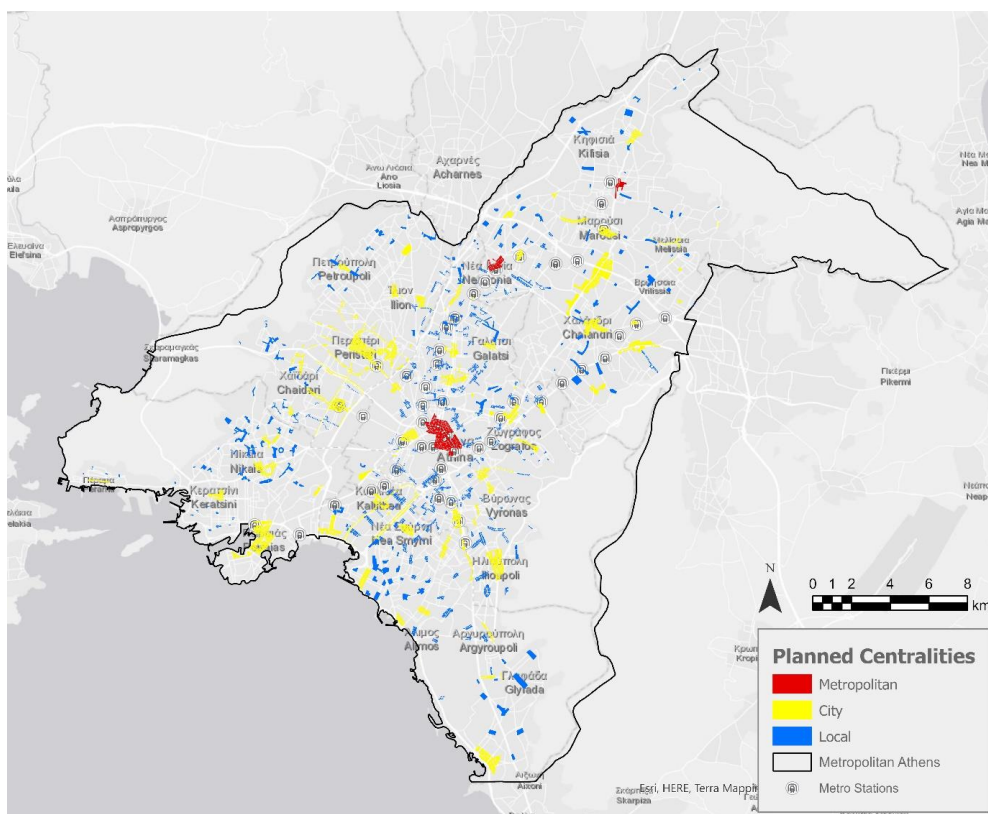
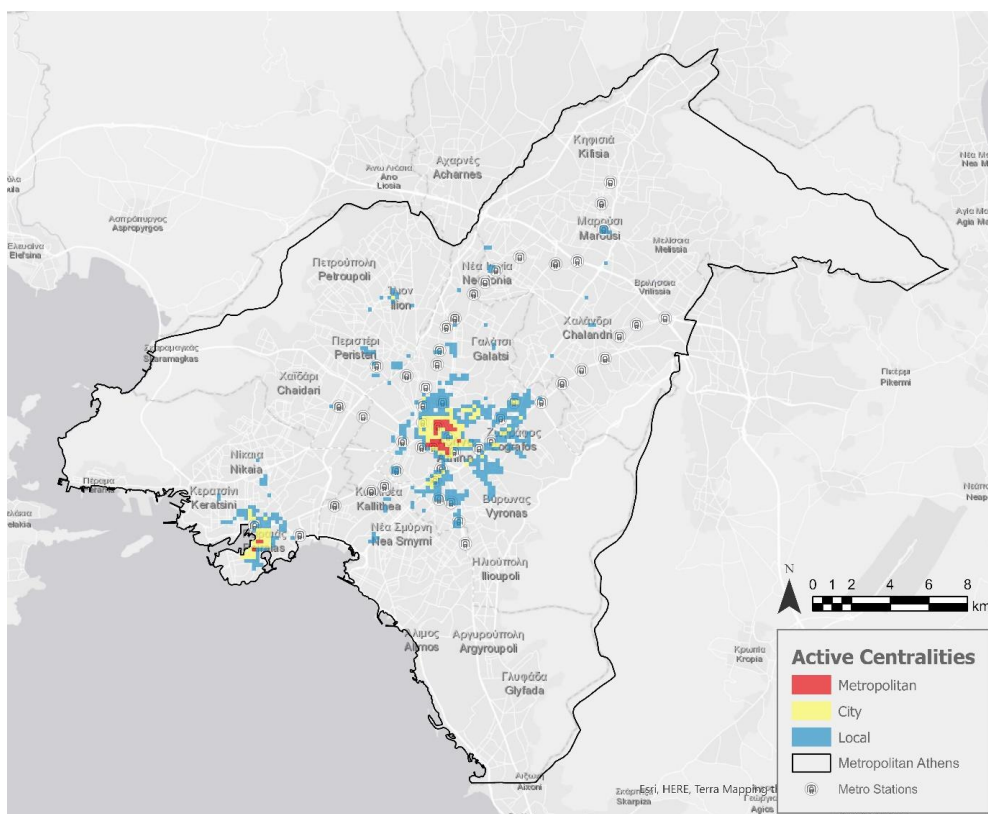
4.1 The Active Centralities of Metropolitan Athens: Planned vs. Organic centrality structures

Metropolitan Athens as a historic Mediterranean city has seen enormous transformations over the ages. It combines the historic city built on the site of Ancient Athens, which retains to this day its timeless character, and the contemporary city, built after the founding of the Greek state. The diverse urban patterns of Athens are the result of the different development processes of the city during the 19th and the 20th century. These processes are associated with important historical circumstances -such as the 1923 population exchange between Greece and Turkey after WWI and the urban expansion of Athens occurred after Greek Civil War (1949) to provide housing and anonymity to rural populations from the countryside moving to industrialised Athens- (Vitopoulou & Yiannakou, 2020) as well as the implemented socio-demographic and economic development choices of the country -i.e., the middle-class suburbanization of Metropolitan Athens during the 1980's and 1990's and until the economic crisis of early 2010's (Maloutas, 2000; Maloutas and Spyrellis, 2020).

What is more, in recent decades an extensive spatial planning legislative framework has been established that designates areas with permitted land-uses, and it outlines the objectives of formal planning that de facto shapes the “formal form” of Metropolitan Athens. The consideration of the ever-evolving phenomenon of centrality and its different typologies lies at the root of this paper, and hence, the analysis of the “*planned form*” stemming from the Greek zoning plans is rather crucial to comprehend the constitutional context from which these typologies have arisen.

The following map (Figure 2) depicts the areas characterised as centres by the Greek Urban Planning Legislation. As can be seen in Figure 2, ‘Metropolitan Centres’, has been designated only in the centre of Athens Municipality and in the suburban municipalities of Kifisia and Nea Ionia, while no such centrality has been designated in other important municipalities of Athens, with Piraeus being the most prominent absence. The lack of ‘Metropolitan Centralities’ designated by the institutional spatial planning framework, show emphatically the *planned* car-dependent form of Metropolitan Athens, since there is no way to address the centrality needs of such extensive area by sustainable mobility (by walking, by cycling, by public transport) with only proposing three metropolitan centres.

In Figure 3 the functional form of Metropolitan Athens is outlined by the active centralities of the study area, as defined by our methodology. As expected, the historic centres of Athens and to a much lesser extent Piraeus have been identified as ‘Metropolitan Active Centralities’, but there is no other area identified as ‘Metropolitan’. On the other hand, there is a significant number of ‘City Active Centralities’, especially around the Athens and Piraeus ‘Metropolitan Active Centre’. Furthermore, there is a great number of -limited in extent- ‘Local Active Centralities’ dispersed mostly in the eastern and northern part of Metropolitan Athens, and in most cases located near metro stations. Apart from the metro-influenced ‘Local Active Centralities’, “independent” ‘Local Active Centralities’ are also encountered, building somehow “autonomous clusters”. Finally, ‘Local Centres’ are found throughout Metropolitan Athens and function as municipality centres for the inner/bedroom Athenian suburbs. Nevertheless, it is striking that there are a lot of municipalities without ‘Local Active Centre’, or any centrality for that matter, especially in the southern suburbs.

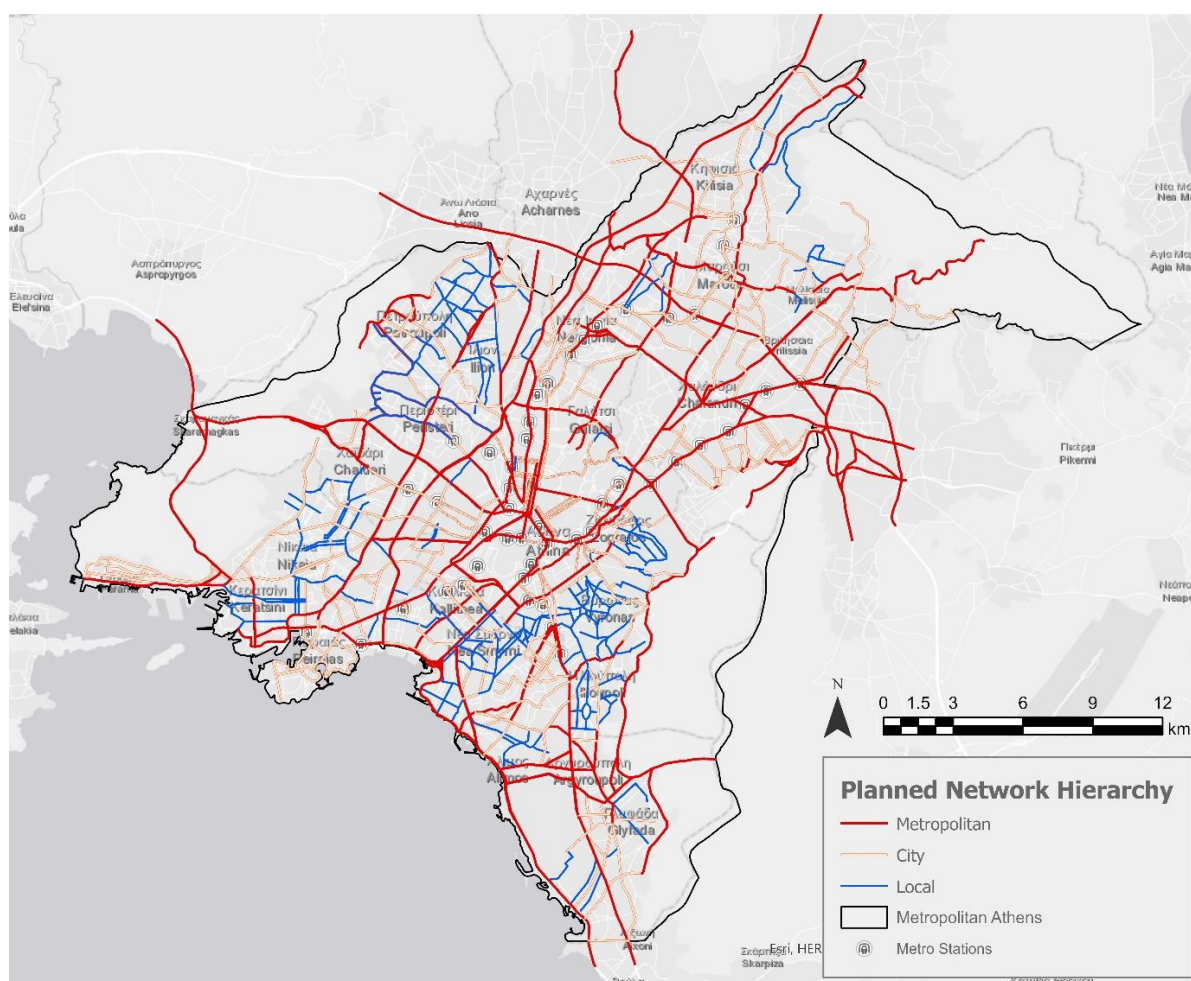
Figure 2. Planned Centralities, the centres of General Urban Plans of Metropolitan Athens**Figure 3.** The Active Centralities of Metropolitan Athens

As shown in Figure 2 and Figure 3 the zoning restrictions definitively cannot contain active centrality since only a fraction of Active Centres abide by the zoning laws and there is a significant difference between the typologies of planned and active centralities. The geography of active and planned centrality structures illustrates that the institutional spatial planning framework was not able to impose the realisation of certain types of active centralities.

4.1 The Network Centralities of Metropolitan Athens: Planned vs. organic network types

The following map illustrates planned network hierarchy as it is defined by the Greek institutional spatial planning framework. In other words, it depicts a “desired” condition, meaning to accompany the previously described urban centralities.

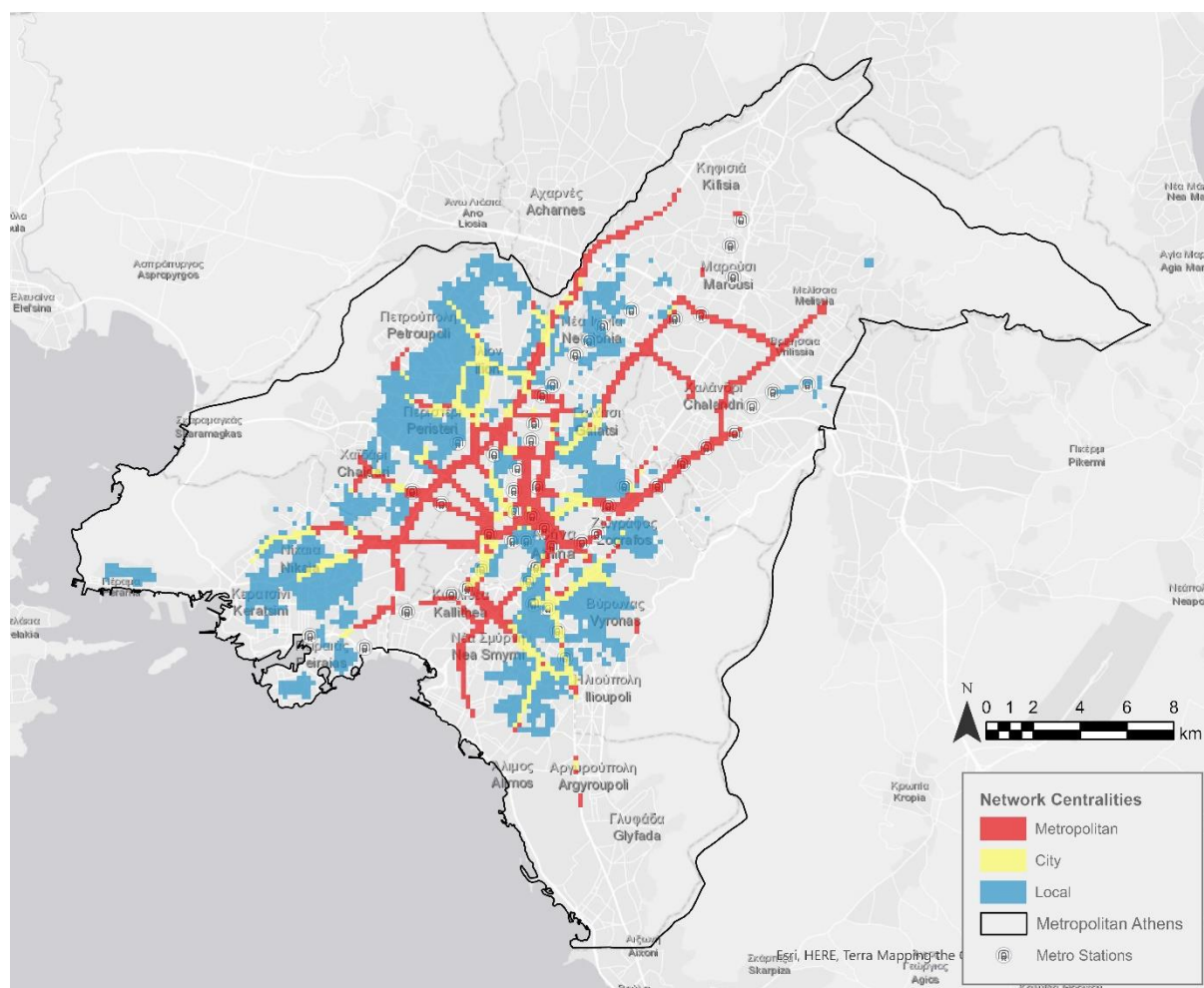
Figure 4. Planned network hierarchy, the road network hierarchy of General Urban Plans



As it can be seen, planned network hierarchy formulates a wide network, which cannot sustain a transparent picture, signifying low levels of readability. The roads belonging to the group with metropolitan significance do not appear to have an intelligible structure, while their arteriability, i.e., their topology property to form a contiguous network (see more in Marshall, 2005) is not so high as well. In this group, one can encounter very emblematic arterial roads of Metropolitan Athens like Panepistimiou Ave., Attiki Odos, Poseidonos, etc. Moving to the other categories, roads characterised as “city significance” have an intermediate role of connecting metropolitan and local road networks, while the latter illustrates a limited role

attempting to distribute traffic movement within municipalities. In general, the form of planned network hierarchy is somehow “chaotic”, encompassing many radial routes (especially arterials) that pass through several central areas, thus creating great conflicts between movement and access functions, since this planned hierarchy is mainly car-oriented (see the national guidelines concerning hierarchy in Ministry of Environment, Regional Planning and Public Works, 2001). On the other hand, the configurational form of Metropolitan Athens concerning the road network hierarchy, appears to have a different viewpoint on classifying streets. Outlined by angular choice (betweenness), the following maps resemble the organic conditions encountered in Metropolitan Athens.

Figure 5. The Network Centralities of Metropolitan Athens



In general, through comparing the above maps, one can figure out an implying relation between these two approaches. This is more evident in the central and western part of Athens. More specifically, all roads that are identified as metropolitan according to their configurational properties, are also characterised as the same significance level by formal planning. Moreover, there is an actual similarity between local roads as well. However, city-significant streets tend to differentiate considerably. However, in the rest parts of Metropolitan Athens, two different images emerge. On the one hand, planned hierarchy seems to be abundant, and on the other, organic conditions are found to be insufficient in terms of covering the entire area of Metropolitan Athens.

4.3 Relation between the active and network centralities of Metropolitan Athens

Among the objectives of this work, one particularly important is to examine the role of spatial configuration, as quantified by space syntax analyses of angular choice, in influencing the current land-use distribution. Notwithstanding, as expressed previously, regulations incorporated by the top-down zoning plans of the study area's municipalities, aim to limit the movement-generated form of active centrality. Consequently, this is the main reason why this paper firstly examines the role of zoning plans in relation to the functional centralities. In the following tables (Tables 3 and 4) the relationship between 'Law-Characterised' and Active Centralities is displayed.

In the following table 3, the relation between the different types of active and network centralities is detailed. Results appear to be, to some extent, illegible, because a great share of the study area cannot be characterised as *central* in any way.

Table 3. Relation among typologies of 'Network Centralities' and 'Active Centralities'

	Network Metropolitan Centrality	Network City Centrality	Network Local Centrality	Network Non_Centre	Total
Active Metropolitan Centrality	46.76%	36.01%	3.54%	13.68%	100.00%
Active City Centrality	28.41%	17.78%	17.18%	36.63%	100.00%
Active Local Centrality	23.38%	29.90%	16.83%	29.89%	100.00%
Active Non_Centre	5.19%	11.67%	2.14%	81.00%	100.00%

Table 4. Relation between 'Network Centralities' and 'Active Centralities'

	Network Centrality	Network Non_Centre	Total
Active Centrality	69.49%	30.51%	100.00%
Active Non_Centre	19.00%	81.00%	100.00%

As shown in table 4 there is a substantial link between 'Network Centralities' and 'Active Centralities'. Specifically, the relative majority of 'Metropolitan Active Centralities' (approx. 47%) have been established in relation to their 'Network' counterparts. The weaker connections, but not in any way weak per se, are detected between 'Local Active Centralities' and 'Local Network Centralities' since 'Local Active Centralities' are identified in various network scales (~23% in Metropolitan, ~30% in City and ~17% in Local). Another stimulating finding is that the vast majority (81%) of functionally non-central areas are configurationally (network-wise) non-central as well. What is more, when studying the simpler depiction of the results in Table 4, the link between 'Active' and 'Network' centralities seems a lot clearer and straightforward to say the least. Because the vast majority of identified active centralities (69.5%) have been established in areas identified as 'Network Centralities'

5. DISCUSSION

This article explores the form of the historic Mediterranean city of Athens, by comparatively exploring its organic centrality pattern (active centrality and network centrality) and its formal/planned form (formal classification of urban centres and road network) under a quantitative geospatial perspective, which is -to our knowledge- unique at the scale and characteristics of Metropolitan Athens. First and foremost, the analysis employed contributes notably to a better comprehension of the configurational form and its notable role in influencing the functional pattern of the city, as the majority of active centralities have been developed in network-wise central areas. Additionally, active centralities have been developed to a lesser extent compared to their network counterparts, since the intrinsic property of the grid to attract human movement has yet a lot of effort to unfold into active centrality in every case; however, these cases could be explained as outliers of a future centrality distribution. Another intriguing, yet expected, finding of this work, is the prevailing organic character of active centralities found in Metropolitan Athens. Notably, zoning laws cannot fully control these centralities, since only a small part of them are formally characterised as ‘centres’ by the institutional spatial framework of the study area. When it comes to the road network centralities, it should be noted that the qualitative findings of this research reveal a distinct relation between the formal road network hierarchy attributed by the municipal authorities and the organic conditions that occur from the topological structure of the network. To the best of our knowledge, previous similar literature emphasised multiple ways of analysing and interpreting urban centres and urban road networks (e.g., Zhong, et al., 2015; Shen & Karimi, 2017; Marshall, 2016; Strano et al., 2012), but it did not put efforts to compare potential “desirable” centrality patterns and road network hierarchy forms.

Focusing on the present paper’s case study, it can be seen that these two aspects of classifying the street network are quite similar, especially in the central and western part of Metropolitan Athens. More specifically, all roads with metropolitan significance which are identified as such by the space syntax measures, are also classified as metropolitan by formal planning. Furthermore, local roads seem to match adequately as well. However, in the rest parts of the city, organic conditions and formal planning differ considerably, indicating different viewpoints by these two approaches. Looking individually in each approach, formal planning generates a “confusing” image which is not easily readable by the users, having also low arteriability, whereas organic conditions create a clear hierarchy, which covers a small part of the Athenian metropolis. According to Gulgen (2014) and Marshall et al. (2018) intelligibility, arteriability and sufficient spatial coverage are critical elements for a sustainable road network hierarchy.

When looking into the active centrality pattern, one shall stress that Metropolitan Athens cannot be described as an organised polycentric metropolis, on the contrary, results imply that the study area functions as a dual-core city where the two metropolitan centres of Athens and Piraeus prevail. Noteworthy, there are also some satellite centralities with lower spatial significance around these two main centres, and beyond that, several centralities with local significance addressing daily life communal and retail needs of residents. The non-sustainable form of Metropolitan Athens is highlighted by the limited presence of ‘City Active Centre’ and ‘Local Active Centre’ in the suburbs of Metropolitan Athens. Therefore, based on the above findings a combinatorial approach should be embraced, incorporating both a “desirable” status suggested by the planned and the organic condition indicated by active centrality and network centrality. Relevant approaches can be found in other similar studies such as Tsigdinos et al. (2020); Stamatiadis et al. (2017); Tsigdinos, et al, (2019); Paraskevopoulos, et al, (2020). These works underline the meaning of evidence-based integrated approaches, which also take into account the vision of each city (for example, sustainable or car-oriented), thus formulating planning concepts close to the human scale, but also efficient.

The main novelty of this work that goes beyond the existing literature on integrated urban and transport planning can be found in the following: Firstly, this study sets out a coherent method for identifying and exploring the identity of active and network centres, which is a task

with a very limited discuss in existing literature. Especially when it comes to a historic Mediterranean Metropolitan area, relevant methods are currently not available. Furthermore, what is truly innovative is that this research compared the organic centres with the formal centralities (both active and network) in a historic Mediterranean metropolitan city using quantitative GIS-based techniques. This process is something new to relevant research (see also Paraskevopoulos & Photis, 2022; Andrakakou & Keßler, 2022; Latinopoulou, et al., 2018), since the majority of similar works in the literature adopt mainly a qualitative approach (e.g., Triantis, 2017; Vitopoulou & Yiannakou, 2020).

Although this research has revealed meaningful insights related to the study of the urban form, there are still some limitations encountered, which could be further developed in the future. First and foremost, a critical step for improving the robustness of this research, could possibly be a spatiotemporal analysis related to the actual evolution of the Metropolitan Athens form (focusing on centres and networks) by implementing the followed method using data from previous censuses (e.g., for 2001, 1991, 1981, etc.). Furthermore, the application of the proposed methodological framework in European metropolitan areas as well, could provide valuable information concerning the centralities of European cities, and how these centralities emerge in different urban environments. Incorporating urban morphology (e.g., urban density, buildings' age, and pattern of plots) as an extra element, would advance the proposed method even further, since all aspects of urban form would be then represented and analysed.

What is more, advanced spatial analysis methods for the identification and analysis of centralities (e.g., grouping analysis, clustering analysis, Principal Component Analysis - PCA, geographically weighted regression – GWR), could be a substantial improvement to this research work. Particularly, when it comes to (organic) network centralities, which in this method are considered ax-based, while in reality human activity and movement is mainly sidewalk-based and therefore block-based. In addition, the employment of multiple radii and especially middle radii between local (900 m) and global (15 km), is expected to draw a more complete picture of (organic) network centrality.

Finally, this study was mainly constrained by the data-cleaning and data-processing requirements of an extensive study area such as Athens. Initially, metropolitan Athens was selected in a quite empirical way, yet influenced by the administrative boundaries of municipalities. A different approach concerning the study area, probably based on the Urban Morphological Zones used by the European Environmental Agency (EEA), would produce better results, but it would bring about further complexity in an already lengthy and demanding data cleansing procedure. Furthermore, the addition of more detailed datasets relevant to centrality (e.g., pedestrian counts, vehicular traffic records, economic activities at build-level) would contribute to a better understanding of the centrality process in Metropolitan Athens. Another take that could possibly overcome the limitations of this study would be the extension of the 'configurational analysis area', i.e., the actual area where Space Syntax analysis is applied. This task can mitigate the "boundary effect" of the forthcoming results.

6. CONCLUSIONS

This study sets up the first attempt to comprehend and explain the urban form of Metropolitan Athens through mapping its active and network centralities, interpreting their geography and investigating the role of spatial configuration in shaping the centrality structures of the study area as a whole. For this reason, a compact and easily applicable method for recognizing active and network centralities, well-suited for metropolitan urban areas, was developed. Additionally, this paper ignites an intriguing "debate", comparing planned and organic centralities, aiming to explore their similarities and differences, thus paving the way for future development suggestions.

The research findings could be used as references contributing to the realisation of the dynamic phenomenon of centrality, both active and network, and also of the multispectral process of shaping a metropolitan Mediterranean city such as Athens. Furthermore, the

methodological process suggested in this research work related to the identification and interpretation of centralities could be incorporated into a decision support system to inform urban planning and design as well as transportation planning procedures towards sustainable urban form, sustainable mobility, and viable urban centres. More specifically, this method can provide two distinct applications; firstly, it could be employed for evaluating the compactness of the Athens form via engaging sustainable mobility service that is accommodated by the current centrality pattern. Secondly, it could be utilised in an integrated urban-transportation planning approach for designing people-centric, walk-attractive centres and streets through re-organizing central areas and road network hierarchy.

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