Finding Centrality: Developing GIS-Based Analytical Tools for Active and Human-Oriented Centres

Yannis Paraskevopoulos(✉) and Yorgos N. Photis

National Technical University of Athens,
Heroon Polytechneiou 9, Athens 15780, Greece
parask.yannis@gmail.com

Abstract. Integrated urban-transport planning should exploit not only conventional methodologies, which are crucial for identifying the already established local centres of the city (***places with people***), but also multi-dimensional methodologies for identifying the vibrant places of the city that can facilitate the centrality needs of citizens and provide access to urban vitality, functionality, and liveability (***places for people***). In this article, we conceptualise and quantitatively define these two types of centres, as ***Active Centres (AC)*** and ***Human-oriented Centres (HoC)***, respectively. Accordingly, two distinct methodological tools (available as python scripts and ArcGIS toolboxes in a public repository) are introduced for identifying **Active** (*where-it-is*) and ***Human-oriented*** (*where-it-should be)* centres. Active Centres are identified based on the functional density of the study area, while Human-oriented centres are found based on the density and diversity of typological criteria, considered essential for liveable centres. To this end, the aim of this work is two-fold. On the one hand, to formulate a comprehensive methodology for identifying different types of centrality and on the other to develop a GIS-based analytical toolkit which can assist evidence-based planning and support decision making towards sustainable urban form, active mobility, and human-scale public places. The proposed methodology and tools have been implemented and evaluated while effectively identifying the Active and Human-oriented Centres of an Athenian suburb, Greece.

Keywords: Centrality · Urban centres · Space syntax · Spatial analysis · Urban planning

1 Introduction

City constitutes the place where all kinds and classes of people are mixed so as to produce a common, though constantly changing and ephemeral life, forcing this heterogeneous ensemble to interact [1]. The essential feature of urbanity is, therefore, concentration and co-existence [2] and the local centres that emerge in a city are at the core of this process. These "*activity nodes*" [3, p. 166] beyond their role in city's functionality, act as 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*

© Springer Nature Switzerland AG 2020
O. Gervasi et al. (Eds.): ICCSA 2020, LNCS 12255, pp. 577–592, 2020.
https://doi.org/10.1007/978-3-030-58820-5_43

seen (…), the place where people with a shared way of life gather together to rub shoulders and confirm their communities" (p. 169). Therefore, a centre in order to be meaningfully successful should be functional for its residents but also vibrant, attractive and accessible for all its users. It should promote active street life, animation in the street, dense and diverse human activity and movement -especially walking- and in summary to create what Jacobs [4] called "*intricate sidewalk ballet*" (p. 50) of people walking around neighbourhoods, at different times for different purposes.

There are numerous theoretical approaches framing the notion and the different aspects of centrality [3–5]. However, relevant analytical methods describe and define a city's centrality by focusing on the distribution and density of limited urban features such as population groups, jobs and retail activity [6]. Despite their strength in locating established local centres, these conventional approaches fail to explore and reveal the complex nature of centrality as a phenomenon. The main reason for that is because functional, vibrant and accessible centres cannot be captured through a limited number of the urban environment's characteristics.

In this paper, we conceptualize these two types of centres, as **Active** and **Human-oriented**, develop detailed methodologies for exploring them and provide GIS-based analytical tools to identify them. Therefore, the research questions of this paper are the following:

RQ1. How to quantitatively define and evaluate the magnitude of the Active Centres of a city?
RQ2. How to quantitatively define and evaluate the completeness of the Human-oriented Centres of a city?
RQ3. Can we develop semi-automated GIS-based analytical tools which can support the identification of these two types of centres?

In order to address these questions, we set a two-fold focus. First, to introduce methodologies for identifying Active Centres (AC) and Human-oriented Centres (HoC) and subsequently, to develop GIS-based analytical tools for implementing these methodologies. Supplemental material (python scripts and ArcGIS Pro toolboxes) has been made available in a public repository[1], along with all maps and figures of this article[2].

2 Background and Conceptual Framework

2.1 Theoretical Background and Relevant Work

Centrality clusters can be understood as descriptions of phenomena or as abstractions or symbols for a certain function in a larger context (the neighbourhood or the city or the region) The concept of 'centre' within architecture and urban design is rather different from its more precise definition within physics: it is ambiguous; both in a

[1] https://doi.org/10.6084/m9.figshare.11973951.v1, https://doi.org/10.6084/m9.figshare.11973933.v1, https://doi.org/10.6084/m9.figshare.11974059.v1, https://doi.org/10.6084/m9.figshare.11973996.v1.

[2] https://doi.org/10.6084/m9.figshare.11973642.v1.

symbolic sense and in that it should be perceived as a centre in terms of their urban surroundings [7]. Consequently, centrality and the local centres that emerge in a city have been researched by numerous approaches, both theoretical and analytical. The former frame the notion of centrality and the different aspects of a vibrant and liveable centre while the latter mostly quantify centrality based on individual urban characteristics.

However, the majority of the analytical approaches identifying urban centres derive from a geographical or configurational perspective, and exploit limited, if not just one, dimensions of urbanity. To this end, geographical approaches generally utilise functional pattern, population density and job density (e.g. [8, 9]) whereas, configurational research focuses mostly on network centrality, as conceptualised by Space Syntax [10], in order to predict human activity in urban space and verify the emergence of centrality clusters (e.g. [11–13]). Hence, most empirical studies of the urban structure and consequently the developed methodologies suffer from the limitation of focusing on single attributes when quantifying centrality. What is more, the available geoprocessing tools for analysing urban centres, are either geographical (e.g. Metropolitan Form Analysis Toolbox for ArcGIS [9]) or configurational (e.g. Space Syntax Toolkit [14] and Place Syntax Tool [15] for QGis/MapInfo), and in either case uni-dimensional. In addition, these GIS-based analytical tools despite their success in identifying the existing centrality pattern of a city, meaning the already established local centres, fail to quantify the various urban elements that contribute to liveable, vibrant and functional central areas.

On the other hand, theoretical approaches put forward a combination of spatio-functional urban elements for defining the meaningful centres of the city [3–5]. Meaning the public places that are integrated in city's everyday life and can facilitate citizens' centrality needs. In particular, urban features such as pubic open spaces, commercial activities and network centrality have been highlighted as fundamental to vibrant centrality clusters [4, 12, 16, 17]. Moreover, activities beyond retail, such as places of work, education, public/municipal services etc., have been singled out as unique sources of urban viability and functionality [3, 6]. Evidently, such multidimensional approaches have not been significantly researched under a quantitative scope. Lately, there has been an increasing interest in terms of studies, research and publications towards the identification of urban centres as multi-dimensional phenomena [18–20] none of which is combined with GIS-based analytical tools and/or toolkits.

2.2 Conceptual Framework

As presented in previous sections of this work, local centres that emerge in a city constitute one of its most elemental component and therefore should be at the epicentre of any planning process [16]. To this end, we argue that any integrated urban planning strategy should take into account both the already established local centres of the city (*places-with-people*), and the centres of the city that have the ability to facilitate everyday practices of human co-existence, (*places-for-people*). Accordingly, we provide conceptual and quantitative definitions of the former as '*Active Centres*' (AC) a term derived from the work of Vaughan et al. [6] and the latter as '*Human-oriented Centres*' (HoC) based on the work of Jacobs and Gehl [4, 5].

Active Centres (AC)

AC refer to the already established urban centres with dense people's presence, the existing pattern of centrality regardless of any additional criteria towards urban vitality, functionality and liveability. Founded on the relevant approach introduced by Vaughan et al. [6] we define AC as the places of the cities with significant functional density. Meaning the density of non-residential uses, which corresponds with a variety of human activities and therefore attract dense people's presence [8, 18, 19, 21] (Fig. 1).



Fig. 1. Conceptualization of Active Centres (AC)

The critical advantage of the proposed approach, is that it builds upon the latest relevant research [19, 20] which challenges the retail-centric view for identifying centrality clusters and proposes that the sources of centrality are embedded in the diverse socio-economic and cultural activities that take place beyond the high street's shopping hub. Namely, the utilisation of functional density constitutes the suitable proxy for identifying the AC of the city, since it encompasses this wide variety of activities. It should be noted that in this paper, the term 'non-residential uses' includes any and all build-use/land-use that is not a residence, that attract/generate human activity.

Human-oriented Centres (HoC)

We define HoC as the central places of the city that are suitable to facilitate meaningful centrality (*where-it-should be*). As places integrated in the everyday life of citizens that satisfy their *centrality needs* for entertainment, communal activities, work etc.; as 'human nodes' where practices of co-existence can manifest without any restrictions in access and finally as places where the physical form of the city and network centrality, in particular, can provide the opportunity of human encounter and urban vibrancy [4, 11]. In other words, we define this type of centrality as 'Human-Oriented' and 'Human-oriented Centres' as places for people, *and* as places with people [5]. Therefore, in order to define HoC, we utilise five typological criteria that derive from three different components of centrality (Functional Centrality, Network Centrality, and Accessible Centrality).

We introduce these three centrality components to create a more comprehensive understanding of the needs that a HoC should facilitate. 'Functional Centrality' refers to the different urban functions (commercial activities, public services, places of work

etc.) and to what degree they are facilitated by the central areas of the city. 'Network Centrality' quantifies "*natural movement*" [11], as the intrinsic property of urban grid itself to form human activity and to unearth "*natural*" centralities. 'Accessible Centrality' refers to a fundamental element of human-oriented centralities, which is the meaningful open access to the places of human co-existence and interaction. Consequently, the proposed centrality criteria are defined as follows (Fig. 2):

1. '*Public open places of accessible co-existence (POPoAC)'* criterion refer to the Public Open Spaces of the city, formal and informal, which contribute to liveable and sustainable centralities as they provide a public meeting place with social meaning and open access.
2. '*Places of everyday retail and entertainment (PoERE)'* criterion refer to commercial activities such as markets, cafes, entertainment and other activities that facilitate the citizens' everyday needs for retail and recreation.
3. *'Places of communal activities (PoCA)'* criterion refer to the wide spectrum of activities beyond commercial that facilitate the everyday needs of residents, such as education, health facilities, religion, and municipal/public services. Their presence is essential for the '*place identity'* of a centre, especially a local one, and is what makes a city functional, competent and self-sufficient.

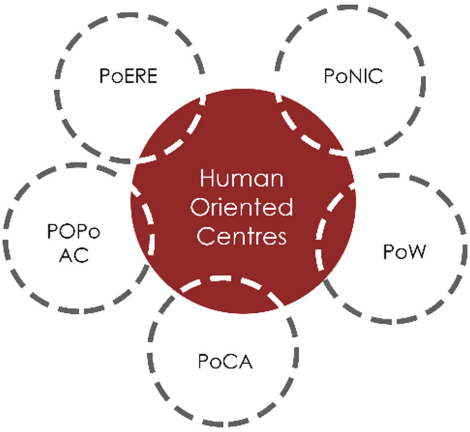


Fig. 2. Conceptualization of Human-oriented Centres (HoC)

4. *'Places of work (PoW)'* criterion refer to the urban functions providing jobs to citizens such as professional workshops, offices etc. These functions contribute to local economy not only as places of work but also as nodes of human activity creating movement at overlapping scales [6]

5. *'Places of network-driven intrinsic co-presence (PoNIC)'* criterion is essential for a human-scale centre as it refers to the ability of the urban grid to shape human activity and attract dense pedestrian movement. Specifically, we utilise the space syntax measure of local angular betweenness (also known as angular choice)[3] with a walkable radius (i.e. 600 m) which is found to be instrumental in detecting major pedestrian through-movement paths in a city [22].

3 Methodology and Methods

In order to provide the conceptual and analytical tools for identifying different typologies of urban centres, namely, AC and HoC, spatial analysis and geoprocessing tools are utilised and corresponding methodological workflows are developed. Kernel Density Estimation (KDE) is used for the elemental task of measuring the density of the features of interest for each methodology (land-use for AC and typological criteria for HoC). KDE uses the density within a range (window) of each observation to represent the value at the centre of the window [23, pp. 68–71]. KDE is not only a widely adopted tool for calculating the density of events, but is also considered ideal in a substantial amount of relevant research, regarding the identification and analysis of centrality clusters [8, 9, 24] since it has the comparative advantage of estimating the density of nearby objects to represent the property at the middle location. In this respect, KDE captures the very essence of location as reflected by densities of nearby Features of Interest. Ultimately, such an approach stresses the notion that it is not the place itself, in terms of X, Y coordinates that make it central and explain its setting but rather its surroundings [24]. Hence, KDE is not only utilized in order to for the analysis to be performed at a unified spatial reference unit level but also a prerequisite of accurately capturing the true dimensions and geographical extent of centres.

In such a framework, the radius and cell size of KDE, effectively signify the anticipated radius and (minimum) size of the identified centre, respectively, and thus shall be representative of the study area. Therefore, Centrality Cell size and Centrality radius are automatically estimated inside the developed tools as relative measures, representative of the study area. Specifically, based on the statistics of the study area's street segments, its average street-length is automatically calculated (*Mean_Street_Length*) and subsequently the Centrality Radius is automatically set as three typical street segments. Respectively, the minimum (accepted) cluster size is automatically set as two typical urban blocks, after has been automatically estimated (*Mean_Block_Area*).

[3] **Angular Betweenness** (also known as Angular choice) is calculated by counting the number of times each street segment falls on the 'shortest path' (in terms of angular deviation) between all pairs of segments within a selected distance (termed 'radius') [22].

Table 1. Calculation of representative values for the various centre characteristics

Centre attribute	Representative value	Calculation
Centrality radius	3 typical street segments	3 × Mean_Street_Length
Centrality (min) size	2 typical urban block	2 × Mean_Block_Area

Table 1 depicts the study case-specific characteristics that are automatically calculated based on the urban blocks and the street segments of the study area.

3.1 Identifying Active Centres (AC)

This section describes the methodology for identifying the AC of a study area and their magnitude. The next figure (Fig. 3) demonstrates the 4-step methodological framework for constructing this workflow. The first step refers to the automatic calculation of the study area-specific Centrality radius and Centrality (min) size, as extensively explained in the previous section. The second-step concerns the estimation of non-residential density with the previously calculated radius and size which are representative for the study area. Subsequently, the cut-off Active Centrality Thresholds are automatically calculated based on the density statistics of the study area in order to single out the AC and their different magnitude (see Table 2). Finally, the delineation of the AC is implemented by reclassifying the *Functional Density Raster* (created in step-2) based on the *Active Centrality Thresholds* (estimated in step-3).

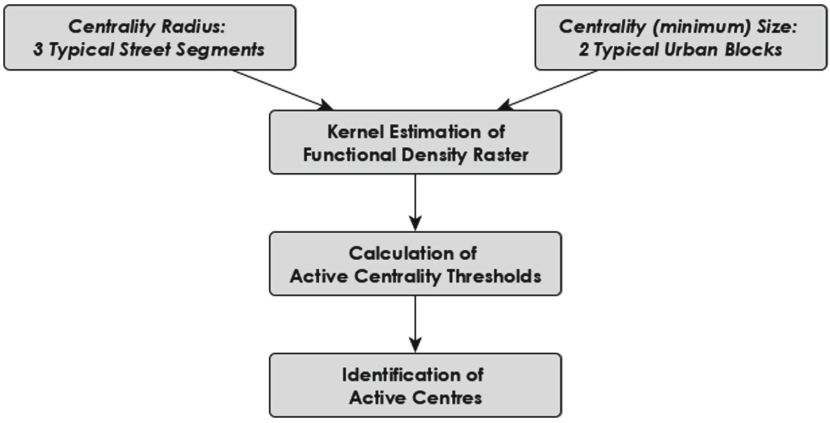


Fig. 3. Methodological steps for identifying AC and their magnitude

Table 2. Thresholds for identifying active centres and evaluating their magnitude

Centrality magnitude	Active centrality threshold (Functional_Density>)
Neighborhood centre	MEAN + 1 × STD
In-between centre	MEAN + 2 × STD
City centre	MEAN + 4 × STD

The only initial prerequisite data for implementing this methodology are the Features of Interest (Non-residential Uses) as lines or points; the Study Area as a single polygon feature; the Urban Blocks as polygons feature and the Street Segments as lines feature.

3.2 Identifying Human-Oriented Centres (HoC)

One of the primary objectives of this paper is to propose a method for identifying HoC, as places with people, *and* places for people. The proposed methodological framework for identifying HoC can be seen in the following figure (Fig. 4).

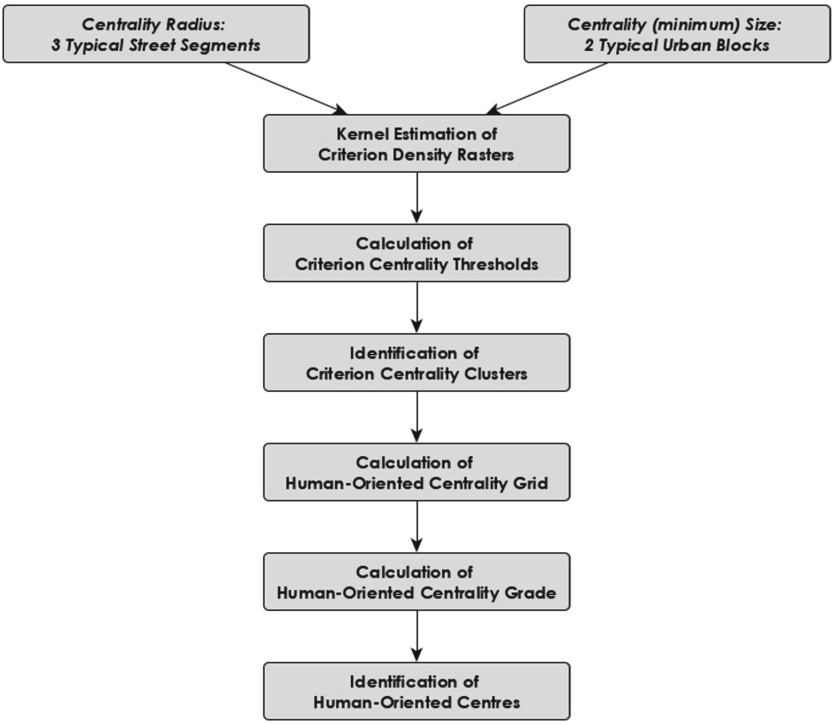


Fig. 4. Methodological steps for identifying HoC and evaluate their completeness

In order to identify and evaluate HoC, we introduce the '*Centrality Grade'* metric based on the proposed typological criteria, which have been extensively analysed in Sect. 2.2. To determine whether any of the above mentioned centrality criteria is met, firstly, its spatial density is calculated and the norm of $Density > Mean + 1STD$ is implemented as a suitable cut-off threshold, and shown in Table 3. The introduced '*Centrality Grade*' assesses both the functional and configurational/network properties of the study area, along with its accessibility, to designate areas where urban characteristics that make a place meaningfully central coexist. Its implementation results are shown in Table 4.

Ultimately to identify the HoC of the study area, a Centrality Grade cut-off threshold is set (***Centrality Grade*** $\geq$ **2/5**), meaning that if an area has two criteria or more, is deemed as 'HoC'. Subsequently, if several adjacent polygons pass the above cut-off *Centrality Grade threshold*, then these neighbouring polygons are grouped together to form joint centres, as has been also done by relevant analytical tools [9]. Then, a *Geometry cut-off threshold* is implemented ensuring that all identified HoC are larger than two urban blocks.

Table 3. The typological criteria forming the Centrality Grade

Centrality component	Centrality criterion	Criterion threshold (Kernel Density>)
Accessible centrality	1. POPoAC	Mean + 1 STD
Functional centrality	2. PoERE	Mean + 1 STD
	3. PoCA	Mean + 1 STD
	4. PoW	Mean + 1 STD
Network centrality	5. PoNIC	Mean + 1 STD

Table 4. The conceptual explanation of Centrality Grade

Centrality Grade	Description	Criteria (n/5)	Criteria (0–1)
A	Excellent	5/5	1
B	Very good	4/5	0.8
C	Good	3/5	0.6
D	Sufficient	2/5	0.4
E	Fail (some more work is required)	1/5	0.2
F	Fail (considerable further work is required)	0/5	0

The above table (Table 3 and Table 4) depict the suggested typological criteria forming the Centrality Grade and the explanation of the introduced Centrality Grade.

4 Implementation and Results

4.1 Study Area and Data Sources

Our proposed methodological approach and the developed GIS-based analytical tools were both utilized in order to define and evaluate the designed and evident based centralities of an Athenian suburb, namely, the Alimos municipality, Attika, Greece. Alimos is a coastal suburb of Athens located 8 km southeast of the Athens city centre. The municipality has an area of almost 6 km^2 and according to the 2011 census has a population of 41,720.

Data used in this research are either confidentially provided and/or commercially distributed and therefore cannot be publically shared. Data regarding Non-Residential Uses (point feature dataset) contain detailed information about all land-uses and build-uses of the study area, gathered by in-situ surveys in 2015, and are confidentially granted by an urban planning firm ('Polis L.P'). Datasets regarding urban blocks (polygon feature dataset with geometry attributes) and streets segments (line feature

dataset with geometry attributes) come from the Hellenic Statistical Authority and refer to the latest census available (2011).

However, the primary aim of this paper is to introduce reproducible GIS-based analytical tools and these have been published as python scripts and ArcGIS Pro toolboxes in a public repository under these DOIs https://doi.org/10.6084/m9.figshare.11973951.v1 and https://doi.org/10.6084/m9.figshare.11973933.v1. Finally, the software used for this paper is documented below: ArcGIS Pro 2.4.3; DepthmapX 0.30, DepthmapXnet 0.35, Space Syntax Toolkit (Qgis 2.16.3 plugin), and Microsoft Excel 2013.

4.2 Identification of Active Centres (AC)

In order to locate the AC of the study area the GIS-based analytical tools described in the previous chapter are implemented and the result can be seen in Fig. 5. The density of human activity, in the form of city's non-residential uses, is estimated with the Kernel Density Estimation (KDE) method, as described in previous Sects. 2.2 and 3.1. A semi-automated workflow is introduced for the identification of AC, consisted of two spatial models, constructed as geoprocessing tools. Thereafter, all spatial models and geoprocessing tools created for this workflow are available as ArcGIS Pro toolbox and python scripts in a public repository (https://doi.org/10.6084/m9.figshare.11973951.v1). Furthermore, due to lack of space, visualizations of all spatial models and geoprocessing tools of this workflow can be also found online (https://doi.org/10.6084/m9.figshare.11974059.v1).



Fig. 5. Identified AC of the study area

In Fig. 5 the identified AC of Alimos are depicted. The result of the proposed workflow is successful since has recognized the central areas of Alimos as mentioned in the "Operational Program of the Municipality of Alimos 2015–2019" [25]. More specifically, it has identified as 'City Centre' the traditional costal centre in the south of Alimos while the northeast commercial centre in 'Upper Alimos' has been identified as 'In-between Centre'.

4.3 Identification of Human-oriented Centres (HoC)

The second objective of this paper is to propose a semi-automated workflow for identifying HoC and the result is shown in Fig. 7. To this end a 'Centrality Grade' is proposed based on multiple typological criteria (mapped in Fig. 6) referring to functional centrality, network centrality and accessible centrality, as analysed in the previous Sects. 2.2 and 3.2. All spatial models and geoprocessing tools created for this workflow are also available as ArcGIS Pro toolbox and python scripts under the following DOI (https://doi.org/10.6084/m9.figshare.11973933.v1) as well as their visualisations (https://doi.org/10.6084/m9.figshare.11973996.v1).



Fig. 6. The geography of the selected HoC Criteria for the study area

As can be seen on Fig. 7 five HoC of various size and 'Centrality Grade', ranging from 40286 to 502173 m^2 and from 0.4 to 0.6 grade, respectively. The traditional coastal centre of the municipality has been identified as HoC along with two other

satellite HoC, while the 'Upper Alimos' market has also been identified as an extensive HoC. Finally, an independent HoC cluster has emerged in Lofos Pani. Tellingly, the proposed workflow has successfully identified the meaningfully central areas of Alimos, by promoting areas with diverse human activity, network centrality (PoNIC) and Open Public Spaces (POPoAC) rather than exclusively retail-centric areas of intense mono-functional activity. This is why the traditional coastal centre of Alimos is graded as 'Fairly Good' (for its most part with 0.4 or 0.6, namely mean_centrality_grade = 0.47), due to its limited multifunctionality and absence of local network Centrality (PoNIC).



Fig. 7. Identified HoC for the study area

On the contrary, the more recent northeast centre of 'Upper Alimos' scores substantially higher in all of its extent and is graded as 'Good' (for its most part 0.6 or 0.8, namely mean_centrality_grade = 0.62) since it demonstrates both dense and diverse functional (PoERE, PoCE, PoW), accessible (POPoAC) and network centrality (PoNIC).

5 Conclusions

The local urban centre is the spatial setting of human interaction, co-existence and exchange (social, economic etc.) in the city and therefore authorities, experts and citizens should focus on the different types of centralities that emerge in a city. However, planning authorities have been overly focused on the established centres of the city while disregarding the centrality clusters that can function as the vibrant human nodes of the city. In this paper we presented a methodological approach along with metrics and tools for defining and measuring different types of city centralities. The introduced metrics have been developed as GIS-based analytical tools accessible and mainly addressed to non-expert users in the fields of urban planning, transportation planning, urban geography etc. We argue that our work fills and bridges this gap by incorporating the multi-dimensional definitions provided by theoretical approaches into an analytical/quantitative framework, in order to identify both the existing centrality pattern of the city (*where-it-is*) and the central areas of the city that have the potential to be functional, vibrant, accessible and liveable (*where-it-should be*).

In essence, this research explores two different types of centres: Active Centres (*places with people*) and Human-oriented Centres (*places for people*). Furthermore, we developed detailed methodologies for exploring these two types of centre, and also provide easy-to-use GIS-based analytical tools to identify them. For addressing the first question posed by this research (*RQ1. How to quantitatively define the Active Centres of a city, and evaluate their magnitude?*), a comprehensive methodology was introduced that successfully located the AC of the study area, as the centrality clusters characterised by dense human activity, and also assessed their magnitude and significance for the study area. Regarding the second question (*RQ2. How to quantitatively define Human-oriented Centres of a city, and evaluate their completeness?*), a novel methodology was proposed based on the density and diversity of selected typological criteria corresponding with the significant (co)presence of accessible public open spaces, commercial activities, communal activities, places of work and local network centrality. Finally, the third research question (*How to create semi-automated GIS-based analytical tools for identifying these two types of centres?*) was addressed by two distinct computational workflows which constitute comprehensive and easy-to-use GIS-based analytical tools/spatial models, for identifying the AC and HoC of any study area and also evaluate their magnitude and completeness, respectively.

Reproducibility is a key focus of this work and this is why the spatial models of this publications are available in a public repository[4] as python scripts and ArcGIS Pro toolboxes. Another, important objective of this research is the applicability of the introduced analytical tools. To this end the only initial prerequisite data for implementing the developed geoprocessing tools are the features of interest (with attributes regarding the presence of the selected typological criteria, if any) and the fundamental elements of the urban form, meaning the urban blocks and street segments (with geometry attributes). The former describes the different types of centrality in a city while the latter describe the physical form and the scale of the city, properties essential

[4] https://doi.org/10.6084/m9.figshare.11973951.v1, https://doi.org/10.6084/m9.figshare.11973933.v1.

for estimating representative and study case-specific dimensions of the centrality cluster (centre radius and minimum centre size).

The findings of this research indicate that the presented methodological frameworks and the accompanied GIS-enabled analytical tools are successful in identifying Active and Human-oriented Centres of the selected study area (Alimos, Athens, Greece). Regarding the AC-identification tool, the proposed workflow has been successful in locating the central areas of Alimos and recognizing their importance and magnitude, as described by the Operational Program of the Municipality of Alimos that was published in 2015 [25]. A significant advantage of the geoprocessing tools regarding AC-identification, is the use of Non-Residential Uses which is an excellent proxy for quantifying human activity, compared to other urban features commonly used by similar tools (e.g. job density in Metropolitan Form Analysis toolbox [9]). The methodological tool introduced for HoC-identification generates a Human-oriented Centrality Grid that describes the centrality of the entire study area and has accomplished to recognize the places with high functional diversity, network centrality and public open spaces, thus high functionality and active street life. Furthermore, it integrates a multidimensional definition of centrality not only into a methodological framework but also into a GIS-based analytical tool More specifically, the presented research and associated findings can be used as references to better understanding the dynamic phenomenon of centrality, and its different typologies. Moreover, the analytical tools presented in this paper regarding the identification and analysis of AC and HoC could be integrated into a decision-support system in order to inform evidence-based planning towards sustainable urban form, sustainable mobility, and liveable public space.

While the research detailed in this article has illustrated meaningful insights, the highly complex phenomenon of centrality and its different facets cannot be entirely analysed in one single study. The issues of human activity, movement and centrality in general, have been effectively repositioned in the age of the Fourth Industrial Revolution. Since, digital technology and especially smartphones enable a completely different definition of the urban space, and create a digital (urban) form which interconnects with the physical environment to produce an augmented network (digital and physical) with a new "*topology*" of paths, movements and activities. The integration of this conceptual element into a novel definition and metric of centrality is an interesting future work, that could substantially expand the presented research, possibly by including social media check-ins as a sixth criterion for measuring HoC. Furthermore, in-situ surveys (interviews and/or questionnaires) could substantially benefit this research by providing insight about public perceptions and desires towards shared public space and local centres. Regarding the more technical part, future work should ensure the development of the introduced computational workflows into fully automated GIS-based analytical tools. Another limitation of the introduced analytical tools is that are compatible with a commercial GIS software (ArcGIS Pro 2.4.3) and future work should ensure the construction of an equivalent open-source workflow, namely developing an GIS-based analytical tool for Active and Human-oriented Centres in an open-source environment (e.g. as a Qgis plugin). Finally, it should be abundantly clear that the introduced analytical tools are not so much constructed as "*global*" geoprocessing tools for identifying centralities, rather than the semi-automated, reproducible

tools for identifying and evaluating centres (Active and Human-oriented) as defined in this article. Therefore, the developed spatial models cannot fully adapt to a different centrality approach (e.g. with fewer criteria or with a different format), but this could be an interesting future advancement of this work.

Acknowledgements. This paper constitutes the latest findings of research conducted at the National Technical University of Athens since 2018 [26, 27] and the authors would like to thank Dr. Maria Pigaki for her contribution to the early stages of this project.

References

1. Harvey, D.: Rebel Cities: From the Right to the City to the Urban Revolution, 1st edn. Verso, London (2012)
2. Lefebvre, H.: The Right to the City. In: Kofman, E., Lebas, E. (eds.) Writings on Cities, pp. 63–182. Blackwell, Oxford (1968, 1996)
3. Alexander, C., Ishikawa, S., Silverstein, M.: A Pattern Language: Towns, Buildings, Construction. Oxford University Press, Oxford (1977)
4. Jacobs, J.: The Death and Life of Great American Cities. Random House, New York (1961)
5. Gehl, J.: Cities for People. Island Press, London (2010)
6. Vaughan, L., Jones, C.E., Griffiths, S., Haklay, M.: The spatial signature of suburban town centres. J. Space Syntax **1**(1), 77–91 (2010)
7. Allen, S.: Points + Lines: Diagrams and Projects for the City. Princeton Architectural Press, New York (1999)
8. Borruso, G., Porceddu, A.: A tale of two cities: density analysis of CBD on two midsize urban areas in northeastern Italy. In: Murgante, B., Borruso, G., Lapucci, A. (eds.) Geocomputation and Urban Planning. SCI, vol. 176, pp. 37–56. Springer, Heidelberg (2009). https://doi.org/10.1007/978-3-540-89930-3_3
9. Sevtsuk, A., Amindarbari, R.: Measuring growth and change in metropolitan form: progress report on urban form and land use measures. City Form Lab, Singapore (2012)
10. Hillier, B., Hanson, J.: The Social Logic of Space. Cambridge University Press, Cambridge (1984)
11. Hillier, B., Penn, A., Hanson, J., Grajewski, T., Xu, J.: Natural movement: or configuration and attraction in urban pedestrian movement. Environ. Plan. B: Plan. Des. **20**(1), 29–66 (1993)
12. Hillier, B.: Centrality as a process: accounting for attraction inequalities in deformed grids. Urban Des. Int. **4**, 107–127 (1999). https://doi.org/10.1057/udi.1999.19
13. Yang, T., Li, M., Shen, Z.: Between morphology and function: how syntactic centers of the Beijing city are defined. J. Urban Manag. **4**, 125–134 (2015)
14. Gil, J., Varoudis, T., Karimi, K., Penn, A.: The space syntax toolkit: integrating depthmapX and exploratory spatial analysis workflows in QGIS. In: Karimi, K., Vaughan, L., Sailer, K., Palaiologou, G., Bolton, T. (eds.) Proceedings of the 10th International Space Syntax Symposium (SSS 2010). Space Syntax Laboratory, The Bartlett School of Architecture, UCL, London (2015)
15. Ståhle, A., Marcus, L., Karlström, A.: Place syntax: geographic accessibility with axial lines in GIS. In: Van Nes, A. (ed.) Proceedings of the 5th Space Syntax Symposium, Amsterdam, Netherlands. Techne Press, TU Delft (2005)
16. Whyte, W.: City: Rediscovering the Center. University of Pennsylvania Press, Philadelpheia (1988)

17. Pinto, A.J., Brandão, A.L.: A multi-scale approach of public space networks in the scattered city. Urban Des. Int. **20**(3), 175–194 (2015). https://doi.org/10.1057/udi.2015.4
18. Shen, Y., Karimi, K.: Urban evolution as a spatio-functional interaction process: the case of central Shanghai. J. Urban Des. **23**(1), 42–70 (2017)
19. Li, J., Long, Y., Dang, A.: Live-Work-Play Centers of Chinese cities: identification and temporal evolution with emerging data. Comput. Environ. Urban Syst. (2018)
20. Zhong, C., Schlapfer, M.M., Muller Arisona, S., Batty, M., Ratti, C., Schmitt, G.: Revealing centrality in the spatial structure of cities from human activity patterns. Urban Stud. **54**(2), 437–455 (2015)
21. Ozbil, A., Peponis, J., Stone, B.: Understanding the link between street connectivity, land use and pedestrian flows. Urban Des. Int. **2**(16), 125–141 (2011). https://doi.org/10.1057/udi.2011.2
22. Al_Sayed, K., Turner, A., Hillier, B., Iida, S., Penn, A.: Space Syntax Methodology, 4th edn. Bartlett School of Architecture, UCL, London (2014)
23. O'Sullivan, D., Unwin, D.: Geographic Information Analysis, 2nd edn. Wiley, Hoboken (2010)
24. Porta, S., Latora, V., Wang, F.: Street centrality and densities of retail and services in Bologna, Italy. Environ. Plan. B **36**, 450–465 (2009)
25. Alimos Municipality: Strategic Planning: Operational Program of the Municipality of Alimos 2015–2019. Alimos Municipality, Alimos (2015)
26. Paraskevopoulos, Y., Pigaki, M.: Combinatorial syntactic analysis of suburban centralities: application of methodology framework for identification, typological analysis and evaluation of activity centres in Alimos, Attica, Greece. In: Proceedings of the 11th ICHGS, Athens, Greece. Govostis Publishers (2018)
27. Paraskevopoulos, Y., Photis, Y.N.: A methodological framework for identifying and evaluating centralities with space syntax and land-use pattern analysis in a GIS environment. In: Charalambous, N., Cömert, N.Z., Hoşkara, Ş. (eds.) Proceedings of CyNUM 2018. Urban Morphology in South-Eastern Mediterranean Cities: Challenges and Opportunities, Nicosia, Cyprus, CyNUM 2018, pp. 36–45 (2018)