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Combining centrality and mobility towards human-oriented cities

Development of an integrated methodology for analysis, evaluation, and planning

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ABSTRACT

This paper adopts an alternative rationale where analysis and planning are treated as a unified process, proposing an integrated evidence-based planning method towards sustainable mobility and human-oriented urban space. Specifically, centrality (active and network) and infrastructure (pedestrian streetscape characteristics and transport network) are combined in a GIS environment, aiming to identify both existing and emerging centralities and utilise them as human-oriented nodes of sustainable mobility.

The proposed methodological process consists of two levels (municipality and local/neighbourhood) where each level has three stages: A. Mapping, B. Assessment C. Planning. Firstly, regarding the municipal level and especially the urban dimension, the established local centres are identified, evaluated in terms of vitality and then, their pattern is re-organised towards an efficient coverage of the study area (emerging centres are utilised). Afterwards, concerning the transport dimension, the existing ways of connection between the above centres are examined (public transport, walking and cycling), evaluated in terms of multimodality and then re-organised. Secondly, when it comes to the local/neighbourhood level, emphasis is now given to the area within these centres. Specifically, with regard to the urban dimension; the characteristics of urban centres are recorded, evaluated based on vitality criteria and then planning interventions are suggested. Next, reflecting the transport dimension, the pedestrian infrastructure is mapped thoroughly, evaluated based on walkability criteria, and then planning interventions are also proposed. The results signify the need for improvements both at macro and micro scale. Therefore, this paper could function as a compact strategy, capable of upgrading typical planning practices.

KEYWORDS

evidence-based planning, space syntax, integrated urban-trasport planning, urban form, road network hierarchy

1 INTRODUCTION

Cities are complex entities influenced by multiple factors that are encountered in the urban realm (Gallegos, 2017). Urban and transport dimension could be considered as two of the most significant elements of modern cities, shaping and transforming urban environments intensively (Tsigdinos, et al., 2022). In this context, these two elements should be treated as a unified process (Hull, 2005); however, traditional planning schemes acted as if urban and transport perspective are independent notions, if not conflicting. Consequently, urban formations experienced many serious problems such as unattractive public spaces, mobility inequalities, urban sprawl, low residential density suburbs, increase in average travel distances, inadequate public transport service, intense traffic congestion, road accidents and major severances to the urban fabric (Nieuwenhuijsen & Khreis, 2016). These circumstances highlight strikingly that cities are not places for people but (merely) places with people (Gehl, 2010). Hence, there is an inescapable need for developing the appropriate strategies that will improve the urban life conditions with special focus on active mobility, accessible, inclusive and people-centric public spaces.

In this context, the present research aims to develop an evidence-based planning methodology that combines spatial and functional centrality as well as sustainable mobility infrastructure to construct a coherent planning strategy associated with two spatial scales (city and neighborhood). At the same time this method considers equally both urban and transport dimension towards climate-resilient, functional, accessible and people-centric cities. The proposed planning method works on two distinct spatial levels (city/municipality and neighbourhood/local) and each level has three steps: A. Mapping, B. Assessment C. Planning (MAP). At the city-level, a planning strategy for the (re-)organization of the centrality pattern and their multimodal connections is employed, while at the neighbourhood-level the vitality and walkability characteristics of the centres are mapped and assessed to develop specific guidelines for needed urban and transport interventions within the identified centres.

The paper is structured in five main sections as if follows. In the second section, the relevant literature review is presented. Afterwards, the methodological framework followed in this paper, as well as the datasets and software used are described in the third section. The next section contains the results of the methodological framework, as implemented for the study area (i.e., Alimos Municipality in Athens, Greece). In the last sections, the findings and the limitations of this research are critically examined as well as, some thoughts regarding further research in this (particularly) broad field of urban and transport studies.

2 LITERATURE REVIEW

The rationale behind urban and transport planning, mainly after the middle of the 20th century, was undoubtedly a car-centric attempt, striving to encourage auto-mobility and thus cultivating a "motorized" mobility culture (Mattioli, et al., 2020). Many authors, however, indicate the serious issues that have emerged since the dominance of automobiles in the public space (e.g., Geurs and van Wee, 2006). Consequently, cities have now started to tackle or mitigate these problems, regardless if they are global like climate change and resilience issues, or local like insufficient open space to build space ratio or low road safety levels (Kinigadner, et al., 2020).

As an answer to this "city crisis", which pertains both environment and society, a new perspective has emerged; the notion of unified urban and transport planning approach. This notion consolidates urban and transport dimensions along with their interactions, aiming to formulate an integrated strategy capable of dealing with the complex reality of urban environments (Anciaes & Jones, 2020). Within the "bounds" of this approach, one can find the quest for sustainable mobility and sustainable form. The former emphasizes active travel, namely walking, cycling/micro-mobility and public transport (Banister, 2008). In addition, it introduces new technologies to enhance sustainable mobility to adapt to the needs of societies (Hickman, et al., 2013). The latter, which is also related to transportation issues (Rode et al., 2006), entails a valiant re-organization of the urban pattern, towards human-scale conditions (Gehl, 2010). In this context, centers and the notion of centralities (local, citywide or metropolitan) is an important parameter in this challenging "equation". According to Bielik et al. (2018), these central cores can be facilitators of walk-attractiveness and thus human presence. For this reason, it is important to reduce the number of motor vehicles within these areas and to provide space for active mobility, strengthening social cohesion and improving the quality of life.

Many researchers (e.g., Waitt et al., 2019) acknowledge the importance of walk-access in urban centers. Interesting real-life paradigms that transform urban space to human-oriented entity, are the wide pedestrianization of central areas (Soni and Soni, 2016) or the transit-oriented development form proposing walkable clusters of approx. 10-minutes walking radius (National Academies of Sciences, Engineering, and Medicine, 2004). According to Alexander et al. (1977, p. 168-173) people are attracted to places with the proper walking infrastructure that enables them to stroll, meet and communicate. Notwithstanding, Alexander et al. (1977, p. 164) also note that human presence is a crucial factor for increasing human flows. Hence, centers experiencing already high human flows, attract even more pedestrians (Alexander, et al., 1977, p. 164).

But what are actually these centers? Legeby et al. (2017) stress that in essence these areas are considered as "places of concentrated of non-residential activities". Therefore, this definition in the urban design field, differs significantly from other definitions used in mathematics or physics that perceive centers just as a geometric characteristic. The success of a center, ensuring its vitality, lies on the diversity of activities and users encountered there (Jacobs, 1961, pp. 143-

147). Functional characteristics such as retail, commercial and public services as well as community and open public spaces are necessary for a city/town center, signifying its existing conditions (Thurstain-Goodwin & Unwin, 2000). There are various geographical and configurational approaches for identifying centrality clusters (e.g. Hillier, et al., 1993; Hillier 1999; Yang, et al., 2015; Scoppa & Peponis, 2015; Liu & Wang, 2016; Taubenböck et al., 2017; Mariani et al., 2018; Li et al., 2019; Yu et al., 2021) but what is really interesting is that in the last few years there are increasingly more methodological attempts that combine these concepts to identify urban centres and sub-centres (Zhong, et al., 2015; Shen & Karimi, 2017; Li, et al., 2018, Paraskevopoulos & Photis, 2020; Wei et al., 2020; Geddes, 2022; Paraskevopoulos et al., 2022).

Taking a deeper look into the subject, it should be noted that fundamental centrality concept derives by the inherit ability of network to shape human movement and activity or as mentioned by Hillier et al. (1993, p. 32), *"the proportion of urban pedestrian movement determined by the grid configuration itself"*. A great tool for measuring centrality is Space Syntax Analysis. It is a set of techniques, employing topological, geometric and metric distances, used to quantify the way that urban environments work and consequently analyze and predict human movement and thereupon economic activity (van Nes and Yamu, 2021; Yamu et al., 2021). Many scientific papers have highlighted the positive correlation between centrality and economic activity (e.g., Porta, et al., 2012) or human movement (Hillier et al., 1993).

Finally, when it comes to the sustainable mobility and form, another issue should be also considered. The way that these centers are connected with each other; meaning the spatial pattern and transport modes that should be incorporated. Therefore, a new road network hierarchy should prevail. This crucial tool is a fundamental element of the unified urban and transport planning approach (Huang et al., 2016), and presents the role of each road or street in the entire urban road network (Ribeiro, 2012). Conventional approaches in transport planning either neglected the importance of hierarchy for a road network or favored a car-oriented rationale that ultimately resulted in several serious problems and deficiencies for the urban environment (La Plante and McCann, 2011). However, roads are multimodal and vivid places (Tumlin, 2012), and as a response, new approaches emerged, giving priority to sustainable modes (Tsigdinos and Vlastos, 2021). Notable examples are the transit-oriented hierarchy scheme proposed by Marshall (2006), the three-dimension classification system based on Hierarchy, Activities and Mode suggested by Liu et al. (2017), the remaking of the neighborhoods, which are destined to function an urban nucleus (Mehaffy et al., 2010) and the link-place approach encountered in numerous studies (e.g., Jones, 2016).

3 DATASETS AND METHODS

3.1 Datasets and Software

This paper incorporates quantitative research on spatio-functional centrality and sustainable mobility, and thus relevant datasets are utilized to this end. Initially, when it comes to the mapping (M), assessing (A) and planning (P) of the urban centres (i.e., the urban dimension) the data are all secondary. More specifically, urban blocks and cartographic backgrounds data are derived from the Hellenic Statistical Authority (ELSTAT). Additionally, data regarding land-uses were provided and collected by 'Polis L.P' via on-site investigations in 2011. Whereas, the existing (planned/formal) street network classification was found in the published General Urban Plan of Alimos Municipality.

The data used for mapping (M), assessing (A) and planning (P) the new connection pattern are also entirely secondary and mainly derived from the Municipality of Alimos that developed its first Sustainable Urban Mobility Plan (SUMP), which is a plan aiming to promote sustainable mobility at a municipal scale, in 2019. More specifically, the dataset used, includes various data such as a) the emerging and established centres (this is the only exception coming from the first stage of this study), b) the road network of Alimos, c) the public transport routes both road and rail-based (bus, trolley, tram), d) the cycling infrastructure, e) the designed speed limits, and f) the overall sidewalk width. However, it should be noted that all these secondary data could be obtained through other ways as well, either free via open source platforms or via on-site observations.

Moving to the microscale data which concern the walkability measurement within the identified centres (emerging or established), it should be mentioned that they basically come from on-site observations and also from the SUMP of Alimos Municipality. Precisely, the primary data obtained from on-site observations are a) the number of curb-ramps per segment and b) the existence of tactile paving in the sidewalk. Regarding, the secondary data acquired from the SUMP, these are a) the overall sidewalk width, b) the pavement width and c) the road direction (one-directional or bi-directional).

Finally, the software used for this paper is documented as follow: ArcGIS Pro 2.4.3; DepthmapX 0.30, DepthmapXnet 0.35, Qgis 2.16.3, Space Syntax Toolkit (Qgis plugin), and MS Excel 2013.

3.2 Methodology & Methods

This study expanding on the work of Paraskevopoulos and Tsigdinos (2022); Paraskevopoulos, et al (2019) and Tsigdinos, et al. (2018) introduces an evidence-based planning method, contemplating holistically urban and transport dimension, while employing a multilevel analysis (macro and micro scale). Precisely, land uses/points of interest and infrastructure (streetscape and transport network characteristics) experience a combinatorial analysis in a GIS environment, with the aim to identify centralities in the study area (existing and emerging) and to utilize them as human-oriented nodes of sustainable mobility.

The methodological process followed, is depicted in Figure 1. It is evident that it works on two distinct levels (city and neighbourhood) where each level has three steps: A. Mapping, B. Assessment C. Planning. At the city-level, a planning strategy for the (re-)organization of the centrality pattern and their multimodal connections is presented, while at the neighbourhood-level the vitality and walkability characteristics of the centers are mapped and assessed to develop specific guidelines for potential urban and transport interventions within these centers.

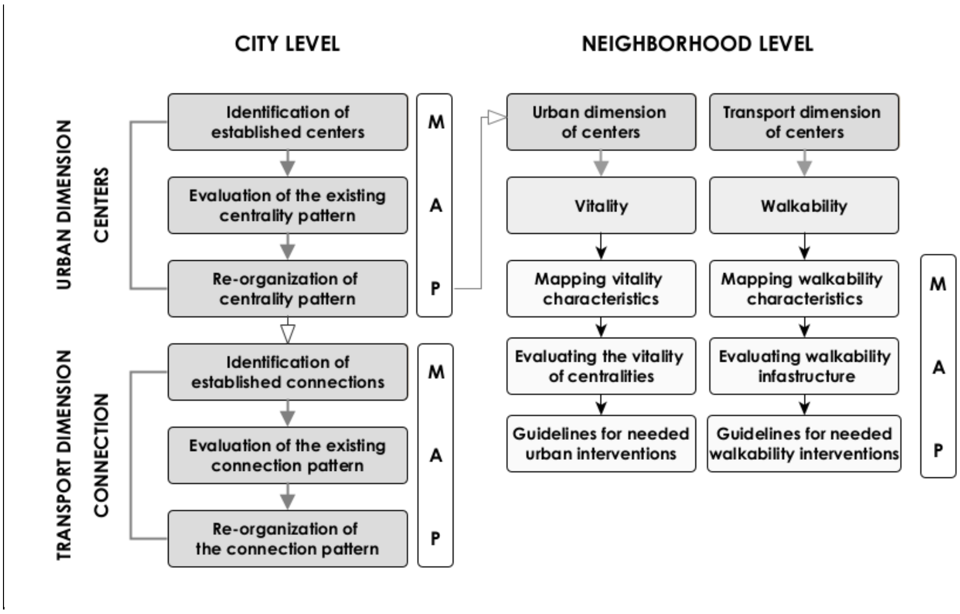

Figure 1: Methodological framework

A. Planning Strategy at City level

A.1 Urban Dimension at City Level

Firstly, regarding the city-level and especially the urban dimension, three tasks will be implemented. The **1st Task** refers to **the identification of the existing centres of the study area**, i.e., to explore the distribution of the existing centrality clusters of the study area. In the **2nd Task** the existing centrality pattern is evaluated, meaning whether the 10-min walkshed area generated by this pattern can serve the whole study area. The 3rd **Task** refers to the re-organization of centrality pattern (if needed), specifically there is an attempt to identify potential/emergent centers that could be added to the existing pattern in order to serve entire study area.

For the **1st** and **3rd Task** we build on the method of Paraskevopoulos & Photis (2020) to identify not only existing, but also emerging/potential, Active and Human-Oriented 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)[1] of the non-residential uses is utilized for a radius and cell size suitable for center analysis, but also representative of the study area[2]. Regarding Human-Oriented Centres, these clusters are defined as the central places that are suitable to facilitate the *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 interaction and urban vibrancy (Jacobs, 1961, pp. 143-147; Hillier, et al., 1993). Therefore, to quantitatively define Human-Oriented Centres, five typological criteria are employed. In this context, a Kernel-estimated density in the study area that derives from three different vitality components (Functional Centrality, Network Centrality, and Accessible Centrality) is then utilized. '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*" (Hillier, et al., 1993), 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 places of human co-existence and interaction.

Table 1: The components, criteria, and thresholds forming Human-Oriented Centres

Vitality Component	Criterion	Criterion Threshold (*Kernel Density*≥)
Accessible Centrality	**POPoAC**: Public open places of accessible co-existence	Mean + 1×STD
Functional Centrality	**PoERE**: Places of everyday retail and entertainment	Mean + 1×STD
	PoCA: Places of communal activities (incl. governmental/municipal/ social services)	Mean + 1×STD
	PoW: Places of Work	Mean + 1×STD
Network Centrality	**PoNIC**: Places of network-driven intrinsic co-presence (i.e. local angular choice)	Mean + 1×STD

[1] The KDE estimates the density within a range (bandwidth) of each observation to represent the value at the centre of the window. Within the bandwidth, the KDE weighs nearby objects more than far ones based on a kernel function. The KDE generates a density of the events (discrete points) as a continuous field (e.g., raster). By using the density (or average attributes) of nearby objects to represent the property at the middle location, the KDE captures the very essence of location: it is not the place itself but rather its surroundings that make it special and explains its setting (Wang, et al., 2011).

2 KDE radius represents Centrality Radius and is set as 3 Typical Street Segments of the study area (~ 250 m) while KDE cell size represents the Minimum Centrality Size and therefore is set as 2 Typical Urban Blocks of the study area (~13500 sq.m) (Paraskevopoulos & Photis, 2020)

To sum up, for identifying the existing and the potential/emerging centres we propose a **Centrality Grade** that describes the significance/magnitude of Active and Human-Oriented Centres based on their non-residential density and number of criteria, respectively. The proposed centrality grade is presented on the table above:

Table 2: Conceptual explanation of Centrality Grade for Active and Human-Oriented Centres

Centrality Grade	**Description**	**Active Centres Threshold (Kernel Density≥)**	**Human-Oriented Centres Threshold (Number of criteria≥)**
A	Metropolitan	MEAN+8×STD	5/5
B	City/Inter-municipal	MEAN+4×STD	4/5
C	Local/Municipal	MEAN+2×STD	3/5
D	Neighbourhood	MEAN+1×STD	2/5
E	Potential/Emerging	MEAN	1/5
F	No Centre	<MEAN	<1/5

For the **2nd Task**, i.e., the evaluation of the centrality pattern, the 10-minutes walkshed areas are estimated as generated by the existing centers. To this end, we use the catchment analyzer of space syntax toolkit (QGIS 2.16.3) and specifically the 600-meters catchment area is calculated. Through this method, it is possible to evaluate the sufficiency of existing centrality pattern to serve the study area. In case that this pattern is deemed insufficient the potential/emerging centers that are outside of the calculated walkshed area, are now included in the reorganized centrality pattern of the study area, and then the algorithm is applied again.

A.2 Transport Dimension at City Level

As it was described earlier, the second stage, refers to the transport dimension of the city level giving particular emphasis on the connection routes between each center. More specifically, it involves the mapping (M), assessment (A) and planning (P) processes in terms of multimodality. The notion of multimodality, used in this research, signifies the potential of a given network or road infrastructure to accommodate more than one transport modes (McAndrews and Marshall, 2018). For instance, a route that may have separate lanes for cycling, cars and public transportation, as well as wide sidewalk, would be reasonably considered as a multimodal corridor (Curtis and Tiwari, 2008) or a complete street (McCann, 2013), depending on its context and role. Therefore, this stage should incorporate the proper features and utilize the essential data, in order to obtain a trustworthy demonstration of the multimodality status and then transform it into better conditions.

In this context, this stage consists of 3 main steps, i.e., M, A, P, following a sequential order, where the output of one step is the input of the other. Beginning with the mapping of these connections (M), it should be mentioned that the required data are a) the centroids of the central areas and b) the road network of the study area. With these two elements, network analysis in a GIS environment is applied (similar analysis has been implemented in other works like Tsigdinos and Vlastos, 2021 or Tsigdinos et al., 2021). Precisely, the study employs an algorithm calculating the shortest path between all pairs of nodes in the given road network, thus identifying the main connections between the centers.

Table 3: Conceptual explanation of qualitative evaluation score concerning each characteristic

Public transport Type		**Walking Sidewalk width**		**Cycling Infrastructure**	
Value	***Score***	***Value***	***Score***	***Value***	***Score***
Rail-based	A	SW>=1,5m	A	Exclusive	A
Bus/Trolley	B	SW>0 AND SW<1,5m	B	Low speeds/Share	B
None	C	None	C	None	C

Table 4: Conceptual explanation of overall qualitative evaluation score for any possible combination

Public transport Score	**Walking Score**	**Cycling Score**	**Overall Score**
A	A	A	Multimodal (Pro)
B	A	A	Multimodal (Pro)
B	A	B	Multimodal (Pro)
A	B	A	Multimodal (Basic)
A	B	B	Multimodal (Basic)
B	B	B	Multimodal (Basic)
B	B	C	Public Transport Ordinary
B	C	B	Public Transport Ordinary
B	C	C	Public Transport Ordinary
C	A	A	Active (Pro)
C	A	B	Active (Pro)
C	B	A	Active (Basic)
C	B	B	Active (Basic)
C	A	C	Active Ordinary
C	B	C	Active Ordinary
C	C	A	Active Ordinary
C	C	B	Active Ordinary
C	C	C	Non suitable

Afterwards, we proceed to the assessment of these routes in terms of multimodality, i.e., the existence of public transport lines (bus or rail-based) and active mobility infrastructure (walking or cycling). For this purpose, a checklist containing the possible values is developed. The following tables illustrate a qualitative evaluation score concerning each characteristic and an overall qualitative evaluation score for any possible combination, respectively.

Next, these routes are assigned their significance according to the current road network hierarchy system. To be more specific, in case a route belongs to arterial roads or collectors, it is characterized as “Main Route”, else as “Local Route”.

The final step contains the re-definition of the connection pattern aspiring to enhance multimodality in all basic routes. The criteria for developing the new system are a) the connectivity, i.e., the significance of centers that will be connected and b) the previous assessment indicators, meaning a) multimodality status and b) road significance. The next table displays in full detail the new multimodality status which should be implemented in these connection routes. It should be noted that this table is divided into two parts. The first one refers to the corridors that are characterized as “Main Routes” and the second as "Local Routes”.

Table 5a: Conceptual explanation of the proposed multimodality status in Main Routes

Main routes		
Origin center	***Destination center***	***New category***
	B	Multimodal (Pro)-rail based
B	C	Multimodal (Pro)-bus enhanced
	D-E	Multimodal (Pro)-bus enhanced
C	C	Multimodal (Pro)-bus enhanced
	D-E	Multimodal (Pro)-bus simple
D-E	D-E	Multimodal (Pro)-bus simple

Table 5b: Conceptual explanation of the proposed multimodality status in Local Routes

Local routes			
Origin center	***Destination center***	***New category*** ***If route=ML***	***If route =/ ML***
	B	Multimodal (Pro)-bus enhanced	Multimodal (Pro)-bus simple
B	C	Multimodal (Pro)-bus enhanced	Multimodal (Pro)-bus simple
	D-E	Multimodal (Pro)-bus simple	Multimodal (Pro)-bus mini-bus
C	C	Multimodal (Pro)-bus mini-bus	Activity pro-enhanced

	D-E	Multimodal (Pro)-bus mini-bus	Activity pro-enhanced
D-E	D-E	Multimodal (Pro)-bus mini-bus	Activity pro-simple

It also is necessary to highlight that if a route has a higher multimodality status compared to the proposed one, then this existing status should be preserved, since it would be a meager decision to downgrade the overall quality of the multimodal status of the area. Finally, each new category has a different meaning; for instance, multimodal corridors which are nominated as rail-based, accommodate the movement of Tram lines, those ones that are characterized as bus corridors differentiate the quality of their services depending on the frequency and the type of vehicles passing by (e.g. Bus Rapid Transit, Conventional or Electric Simple Bus, and mini-bus) and those ones referring to activity corridors are differing based on the quality of interventions destined to pedestrians, cyclists and micromobility (e.g. wider sidewalk, exclusive cycling infrastructure, etc.).

B. Planning Strategy at Neighbourhood level

B.1 Urban Dimension at Neighbourhood Level

Apart from the city level, this paper deals with the micro-scale of neighborhood-level as well. Firstly, regarding urban dimension, the characteristics of centers are mapped and evaluated based on vitality components derived by the definition of human-oriented centrality (Paraskevopoulos & Photis, 2020). As mentioned previously, the combination of spatio-functional urban elements described by the vitality components of Human-Oriented Centres are essential for defining the meaningful centres of a city. Urban features such as pubic open spaces, commercial activities and network centrality have been highlighted as fundamental to vibrant centrality clusters (Jacobs, 1961, pp. 143-147; Hillier, 1999; Pinto & Brandão, 2015). 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 (Vaughan, et al., 2010). All these features are mapped though the Vitality Components of Human-Oriented Centres (Accessible Centrality, Functional Centrality and Network Centrality), and therefore are used to evaluate the urban dimension at neighbourhood level. What is more, we utilise the vitality components, with the aim to construct planning guidelines for the potential urban interventions within the centres, as can be seen in the following table:

Table 6: Planning guidelines for fostering vitality

Which Vitality Component is missing?	Planning Guidelines
Accessible Centrality	# Accessible centrality (AC), refers to the Open Public Spaces with free access which are very important since they can function as *Landmarks* (as defined by Lynch), and therefore as references to the whole city. # When missing, AC is the 1st Priority, because it can be directly created by the city authorities and has high impact on the livability and vibrancy of the centres # Have to be inclusive, modular, aesthetically pleasing # Indicative Measures: parks, squares, playgrounds, open-air courts, pocket parks, superblocks, shared streets, cyclovias/open streets, play streets, parklets, pedestrianisations
Functional Centrality	# 'Functional Centrality' (FC) refers to the different urban functions (commercial activities, public services, places of work etc.) and to what degree they are found in the central areas of the city # Intensification of diverse commercial and communal activities. Emphasis on small-scale establishments with respect to the local scale in order to ensure the vitality and viability of local businesses and more importantly to provide job opportunities for the city's population # Indicative Measures: pop-up markets, creation (or upgrade) of social services, ephemeral and or permanent cultural activities/festivals/street events, changes in the general land use plan,
Network Centrality	# Network Centrality' (NC) quantifies "natural movement" (Hillier, et al., 1993), as the intrinsic property of urban grid itself to form human activity and to unearth "natural" centralities. # Intensification of connections at local scale to promote walkable routes # Indicative measures: Utilisation of informal public space paths (to be included in the network), removal of human movement barriers like walls in public spaces or fenced parcels, alteration of the urban network structure where the proper space is available

B.2 Transport Dimension at Neighbourhood Level

The fourth stage is related to the transport dimension of the neighborhood level focusing on the walkability assessment within the central areas (established or emerging). Similarly with the previous stages, this one is adopting the process MAP as well, defining 3 discrete steps (following a sequential order) that result in suggestions for improving walkability conditions. The first step involves the mapping of the basic features such as a) overall sidewalk width, b) tactile paving, c) curb ramps, d) road pavement width and e) road direction (one-directional or bi-directional).

Afterwards (in step 2), a combinatorial assessment of the pedestrian infrastructure is performed found in Paraskevopoulos et al., 2020), with the aim to obtain a view on walkability potentials. The criteria used are classified into three categories, demonstrating how the accessible network changes, when physical difficulties/barriers regarding walking increase. Precisely, the first category requires the overall sidewalk width to be at least 1,5m (min sidewalk width ≥ 1,5 m), as the minimum requirement for convenient movement of one person per direction. As a result, this category is destined mainly for able-bodied pedestrians. The next category requires a) the total width to be at least 1,5m, (min sidewalk width ≥ 1,5 m) b) the existence of tactile paving and c) the presence of two curb ramps per section. Last, the third category maintains the criteria of tactile paving existence and curb ramps existence, while increasing the minimum overall sidewalk width required from 1,5 to 2,1m (min sidewalk width ≥ 2,1 m), which in accordance with the Greek planning legislation (Ministry of Environment, Regional Planning and Public Works, 1996) representes the minimum sidewalk width for the convenient accommodation of any person and the installation of streetscape features (e.g. streetlamps, trees, etc).

Finally, step 3 contains the planning procedure which intends to make the roads within the central areas accessible to all regardless of their capabilities (method based on similar research by Tsigdinos et al., 2019). For this purpose, overall sidewalk width, road pavement width and road directions are utilized. The comparison between supply (existing infrastructure) and demand (standards for pedestrian needs), leads to the identification of the proper transformations. These transformations may vary; for example, they could be solutions such as a) driveway decrease (space available for car movement), b) one or two parking rows decrease and c) radical road change including shared space or pedestrianization. The application of these solutions depends on how far is the existing infrastructure conditions from the standards of making the sidewalk or the "room" for pedestrians accessible.

4 RESULTS

The developed methodology is tested for Alimos Municipality, a southern coastal residential suburb of Athens, located 8 km south of central Athens. Alimos, is inhabited by 41720 people (according to 2011 census) in its approx. 6 km^2 area. The spatial organisation of the city of Alimos is separated in two main districts. The southwest district known as "Lower Alimos" which was the historic city of Alimos and it was first urbanised; and the northeast district known as "Upper Alimos" which was later inhabited (and even later urbanised).

In the next figure (Figure 2), we can see the implementation of the first methodological task, and specifically the identified established and emerging centralities and their correspondent 10-minutes' walkshed areas. As shown in Figure 2, the existing centralities are located in two main clusters, with the exception of the centrality in Pani Hill.

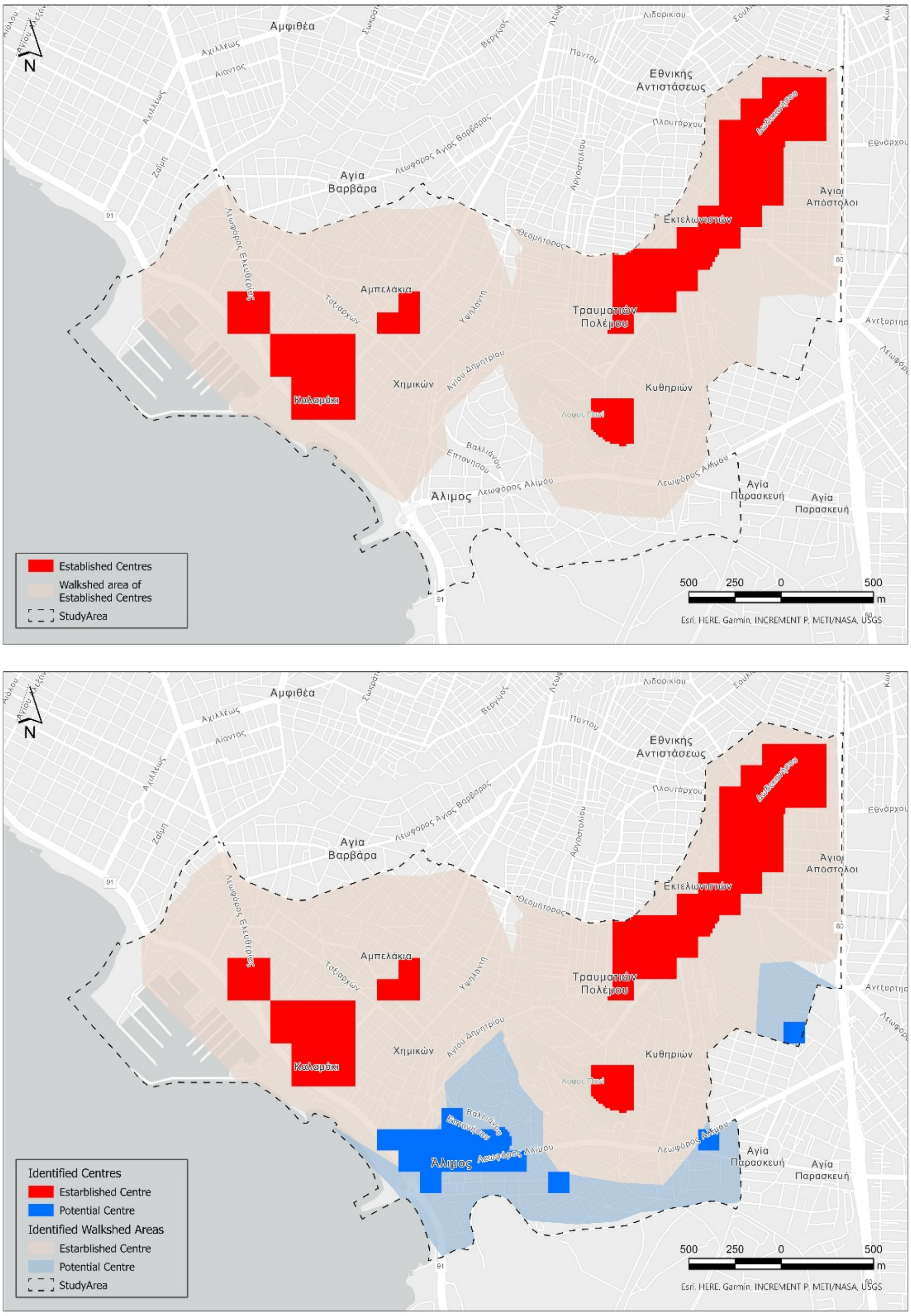

Figure 2: Existing Centralities and their walkshed (Above) & Existing and Emerging Centralities and their walkshed (Below)

In the southwest district of "Lower Alimos", three centrality clusters are identified, i.e. the traditional centre of Alimos and two satellite centralities are identified, while in the more recent northeast district of "Upper Alimos" an extensive continuous centrality emerges following an important arterial road of the city. However, the crucial finding here is that the existing centrality structure cannot facilitate the whole municipality by walking, and therefore is deemed non-sustainable leading to car-dependent mobility. To this end, we explore additional potential centrality clusters to be added towards a walk-accessible centrality pattern (see Figure 2, bellow) The new centrality pattern improves substantially the pedestrian accessibility of the study area, since the 10-minutes walkshed area increases and almost service the entirety of Alimos, leaving only a limited part of the city not accessible by 10-minutes walking.

Subsequently, regarding the transport dimension at city-level, the connection pattern is mapped and evaluated. According to the shortest path analysis, the routes (found in figure 3) connecting the existing and potential centres spread throughout the area, presenting a length of 19351,23 m. Additionally, the greatest proportion of these routes belong to the Main Road Network of the study area (approx. 67,60%). In terms of network structure, the routes' network forms a continuous entity with no unconnected vertices, which means that there is no vertex connecting two nodes that both have order (degree) equal to 1 (Rodrigue, 2020). What is more, these routes seem to have quite a potential to form an intelligible network that will be easily understood by any kind of possible user.

According to the evaluation process, some very interesting results occurred. Firstly, the majority of the routes (83,34%) has a public transport line passing by. Precisely, 6,35% of the routes has a rail-based transport line and 76,99 has at least one bus line (metropolitan or municipal significance). Therefore, public transport can be considered as a strong point for the study area. On the other hand, active mobility is at stake, since cycling infrastructure is found be at an inadequate level in the area. More specifically, there is only a low percentage of cycling lanes or tracks in the routes, meaning that there is still work to do in case of accommodating cyclists or micro-mobility. Fortunately, walking level is much better, as the 67,30% of the overall routes' length has a sidewalk width equal to or exceeding 1,5m, which means that pedestrian movement is facilitated relatively well.
Moving to the combinatorial evaluation, the results concerning the existing condition in terms of multimodality are the following:

Table 7: Existing multimodality condition

Category	Length	Percentage
AC basic	1746.97	9.03%
AC ordinary	653.14	3.38%
AC pro	824.07	4.26%
ML basic	1061.69	5.49%
ML pro	4298.44	22.21%
PT ordinary	10766.92	55.64%
Grand Total	*19351.23*	*100%*

It is clear that ordinary public transport routes prevail, however, there is a substantial proportion of Multimodal corridors (22,21%), meaning that there is a significant potential for the future. On the other hand, the rest categories display low percentages and especially ordinary Active Corridors that comprise only the 3,38% of the routes. The next figure shows the evaluation of the routes depicted on a map along with the centers.

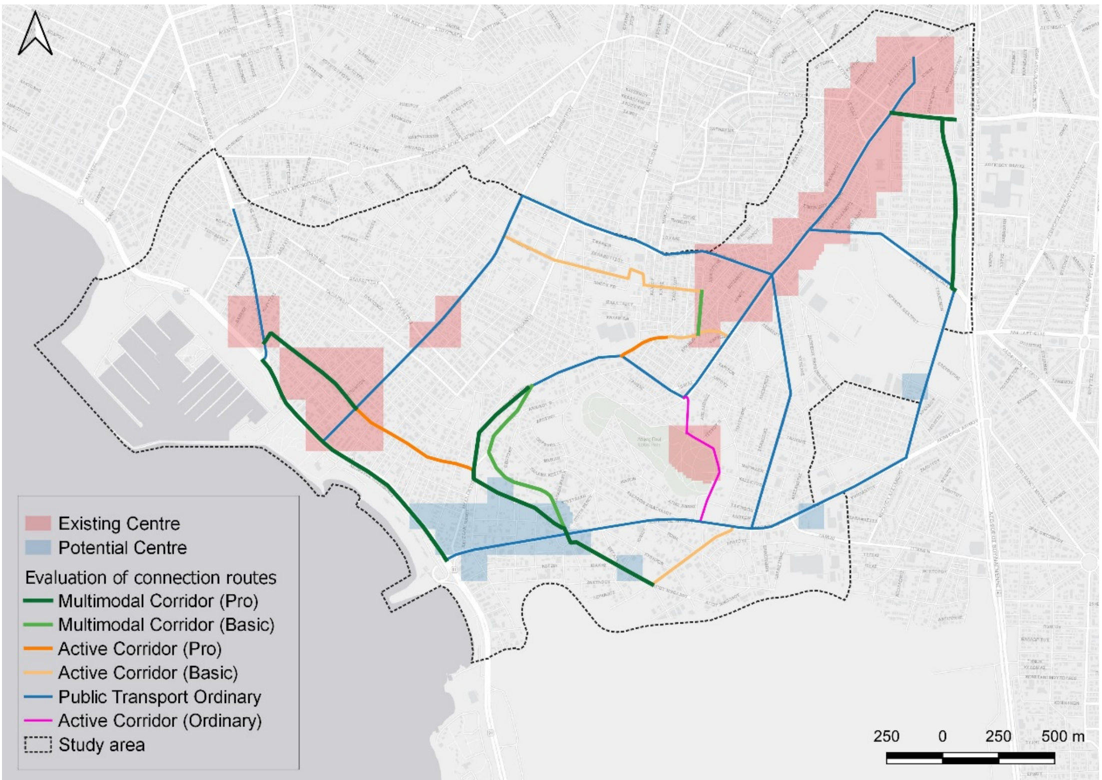

Figure 3: Evaluation of connection routes

It is clearly observed that the most complete streets in terms of multimodality can be found at the edges of the study area, but mostly at the seafront. On the other hand, activity corridors are located mainly within the study area in residential areas. Finally, ordinary public transport corridors seem to have a dispersed pattern, connecting many centres of the area, either existing or potential.

The final step of this stage regards the planning procedure. After the implementation of the suggested method, we concluded into a new route classification system that connects the centres in a sustainable and to be more exact, in a multimodal way. The results are illustrated in the next table:

Table 8: Statistics of the new route classification system

Street type	Length	Percentage
AC pro-enhanced	1115.62	5.77%
AC pro-simple	1694.02	8.75%
ML pro-bus enhanced	5938.82	30.69%
ML pro-bus simple	6477.81	33.47%
ML pro-mini bus	2896.65	14.97%
ML pro-rail based	1228.31	6.35%
Grand Total	*19351.23*	*100.00%*

The above figure illustrates in a discrete way the suggested route classification system, a different one, if it is taken into account that it has (actually) respected the urban dimension, meaning the centrality pattern. The new categories fostering multimodality are found throughout the entire study area. More specifically, the Multimodal corridors giving emphasis on rail-based public transport are located at the seafront and when it comes to buses, it can be seen that they connect a substantial number of centres. Tellingly, the enhanced bus services can be found at the western and central part of the study area. Regarding the activity corridors which prioritise cycling and walking, it should be noted that they are found mainly in the inner part of the study area, functioning more as a supplementary street network.

Finally, focusing on the neighborhood level and specifically its urban dimension, we utilize the components of Human-Oriented centralities, to propose specific planning interventions towards walk-attractive, livable centrality clusters. The results of mapping and evaluating the vitality characteristics of the study area can be found in figure 4, and the typology of needed planning interventions in figure 5:

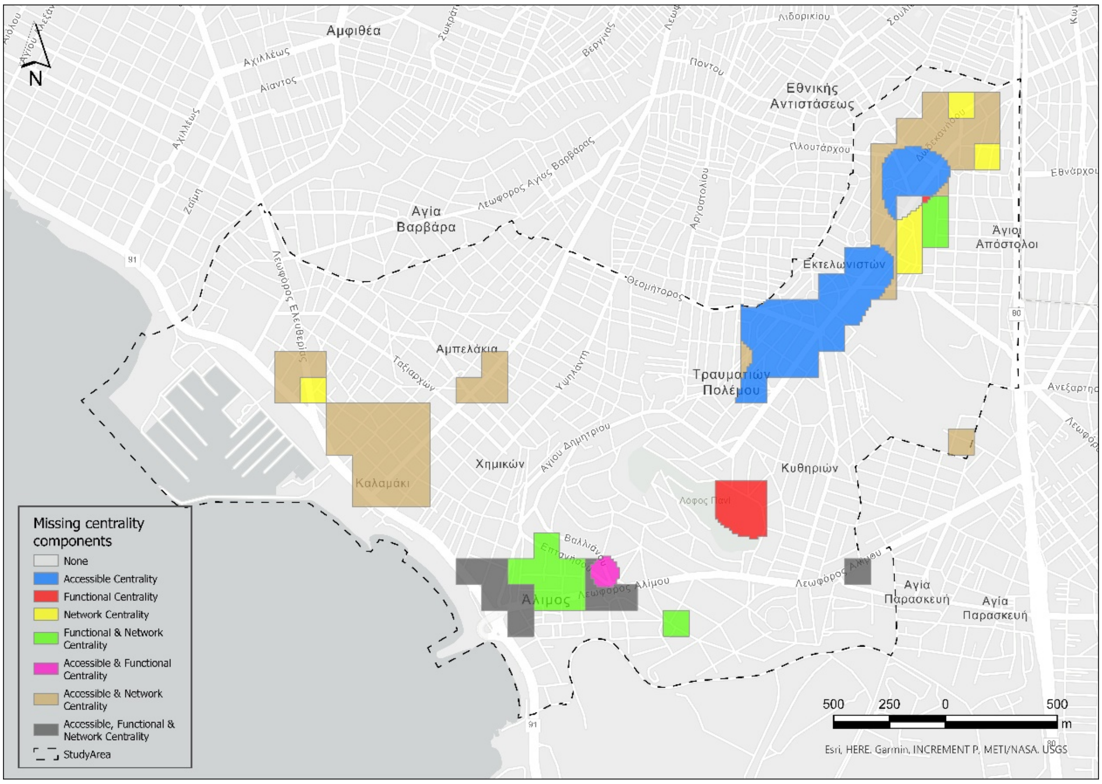

Figure 4: Evaluation of centrality components

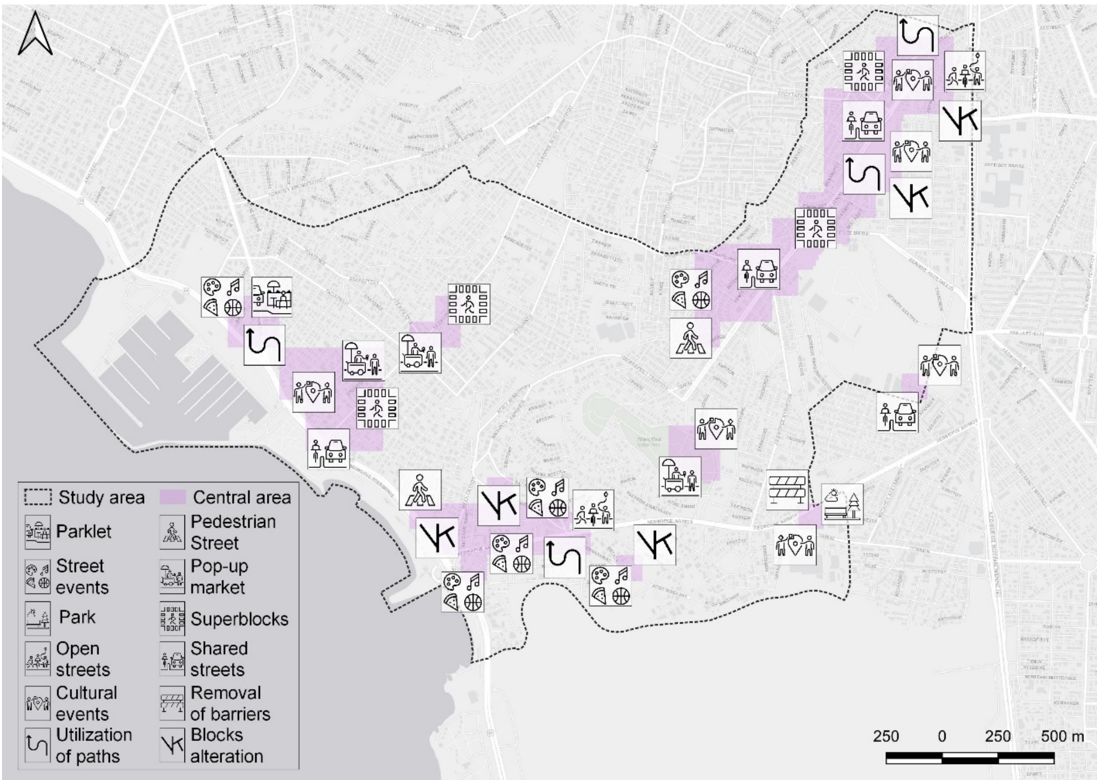

Figure 5: Typology of prioritised planning interventions

In figure 4 the vitality aspects of the study area are mapped to evaluate the existing and emerging centralities of the study area. As can be seen from the evaluation of vitality characteristics of the re-organised centrality pattern, in most of the cases, at least two (out of three) vitality components are missing, with the notable exception of the centrality clusters of upper Alimos where only accessible centrality is missing (depicted with blue) and the centrality cluster in Pani Hill where only Functional Centrality is missing (depicted with red).Specifically, the centrality clusters of ‘Lower Alimos’ were evaluated less favorably the centrality clusters in ‘Upper Alimos’, since ‘Upper Alimos’ is a later developed district with dense and diverse land-uses and substantial network centrality. Furthermore, in figure 5, we implement a typology of interventions based on the missing centrality components mapped in figure 4. For each centre a planning intervention is prioritized as dictated by the vitality characteristics of each identified centre. Cultural events, street events, and pop-up markets are employed in fifteen cases to intensify functional centrality while shared streets, open streets, superblocks, pedestrian streets, parks and parklets are proposed in seventeen cases to facilitate accessible centrality. Also, in ten cases we propose removal of barriers, blocks alteration and utilization of paths to enhance network centrality.

Regarding transport dimension at neighborhood level, we examine the existing accessibility infrastructures for all users. The width of the sidewalks and the infrastructure for mobility impaired people such as the existence of curb ramps and tactile pavement (guidance path surface for blind people) recorded via Street View and On-site observations.

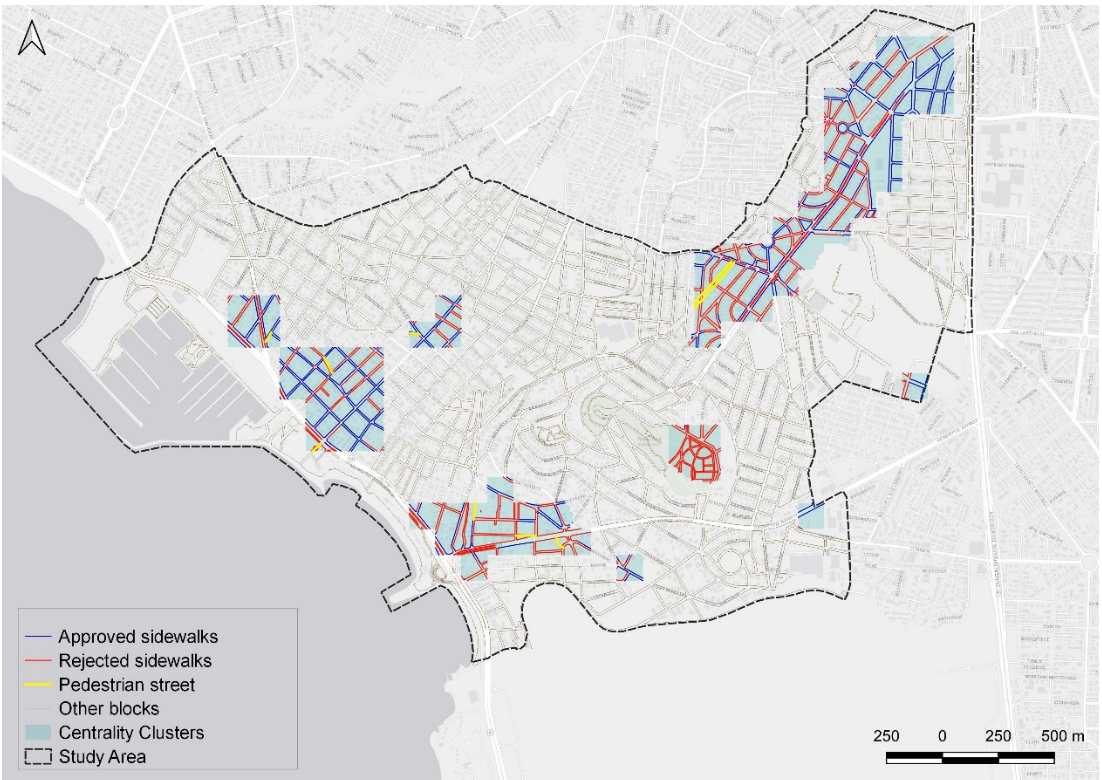

Figure 6: Evaluation of basic pedestrian infrastructure: Sidewalk width > 1.5m

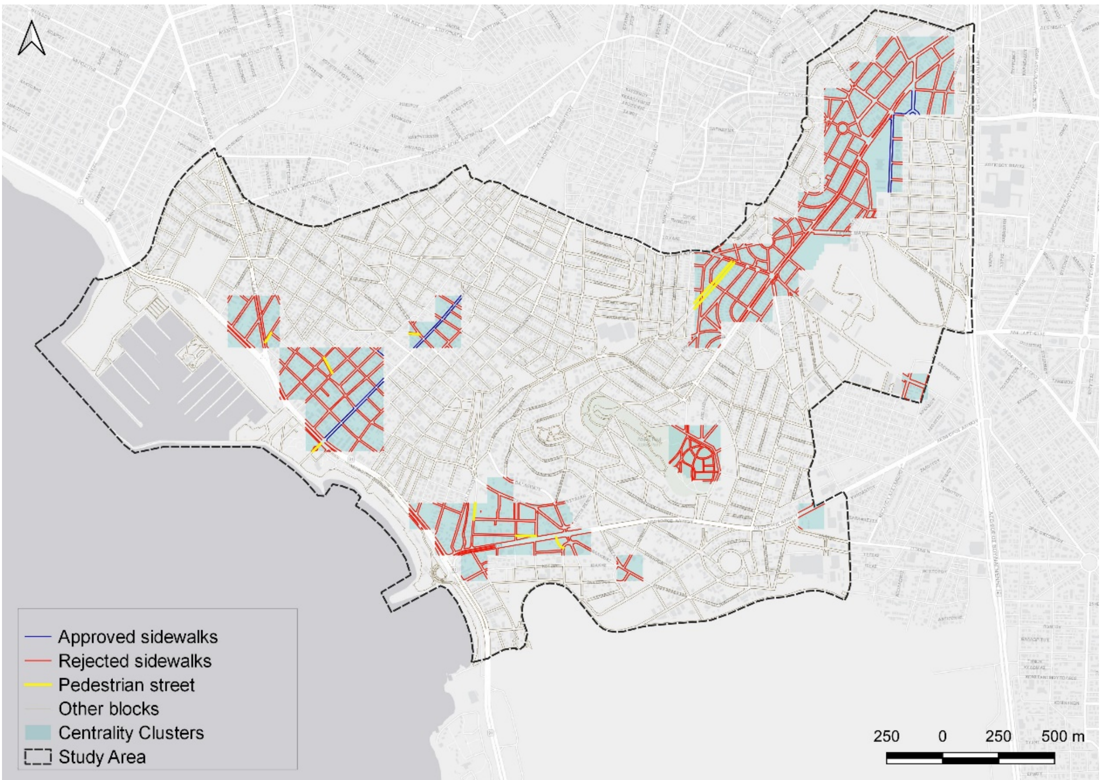

Figure 7: Evaluation of basic pedestrian infrastructure: Sidewalk width > 1.5m, 2 curbs ramps & Presence of tactile pavement

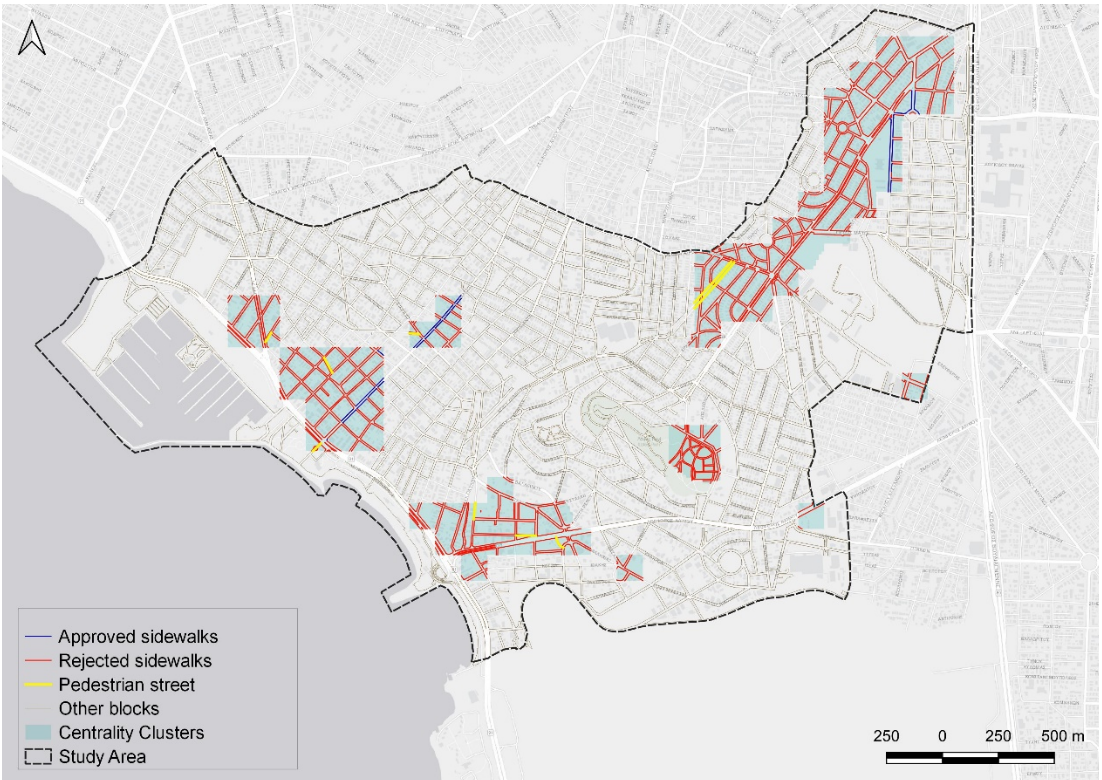

Figure 8: Evaluation of basic pedestrian infrastructure: Sidewalk width > 2.1m, 2 curbs ramps & Presence of tactile pavement

In particular, the percentage of sidewalks weighted in length that have width greater than 1.5 m is equal to 76.70% (Figure 6). This percentage, however, decreases dramatically taken into account the presence of two curb ramps and tactile pavement per block (7.89%) (Figure 7). Finally, the sidewalks that are fully accessible to all categories of users are similar to previous classification (7.40%) (Figure 8). The significant difference between the percentages of the two categories is the lack of a blind route network even on main roads. Moreover, it is important to mention that the total length of pedestrian streets amounts to 965.29 m. Their presence contributes positively to the revitalization of the centers.

After the evaluation of accessibility infrastructure, proposals were made to improve the conditions of movement within the centres. The categories of proposals are a) roadway decrease (via construction of pavements, cycleway etc.), b) one parking row decrease, c) radical change (one-way road, living street, pedestrian street etc.), d) two parking row decrease and e) no change. Their classification emerged according to the features of the road sections mentioned in the methodology.

According to Greek legislation, the required width of the sidewalk is 2.1 m and includes urban equipment (tree planting, benches, etc.), while for the free passage of pedestrians there must be a sidewalk width of at least 1.5 m. For this reason, two different approaches were created to the proposed interventions. The first is a stricter approach and requires the width of sidewalks on both sides to be equal to 2.10 as required by law. The results illustrate that the category of radical change has the greatest percentage of proposed interventions. This category even includes primary and secondary roads that need improvement.

The second approach refers to the creation of a sidewalk 2.1 on one side and 1.5 m on the other due to the lack of public space. As shown in the table below (Table 9) there is an additional category where the current situation satisfies the criteria like Iroon Matsis str. and Alimou Avenue. A common feature between the two approaches is that the category with the highest percentage is the roadway decrease increased by approximately 7.65%. In figures 9 and 10 the geography of these two approaches are depicted. Regarding the spatial and geographical subsistence, it is observed that here is no specific pattern but there is similarity in the proposed category on the main roads inside the centers.

Table 9: Percentage of interventions' length per category

	Suggestion	Length	Percentage
Sidewalk width 2.1 m (both sides)	**Roadway decrease**	6778.83	24.65%
	One parking row decrease	5230.45	19.02%
	Radical Change	13038.4	47.40%
	Two parking row decrease	2457.2	8.93%
	Grand Total	*27504.88*	*100%*
Sidewalk width 2.1 m and 1.5	**No change**	265.53	0.97%
	Roadway decrease	15140.4	55.05%
	One parking row decrease	4480.53	16.29%

Radical Change	5823.4	21.17%
Two parking row decrease	1795.0	6.53%
Grand Total	*27504.88*	*100%*

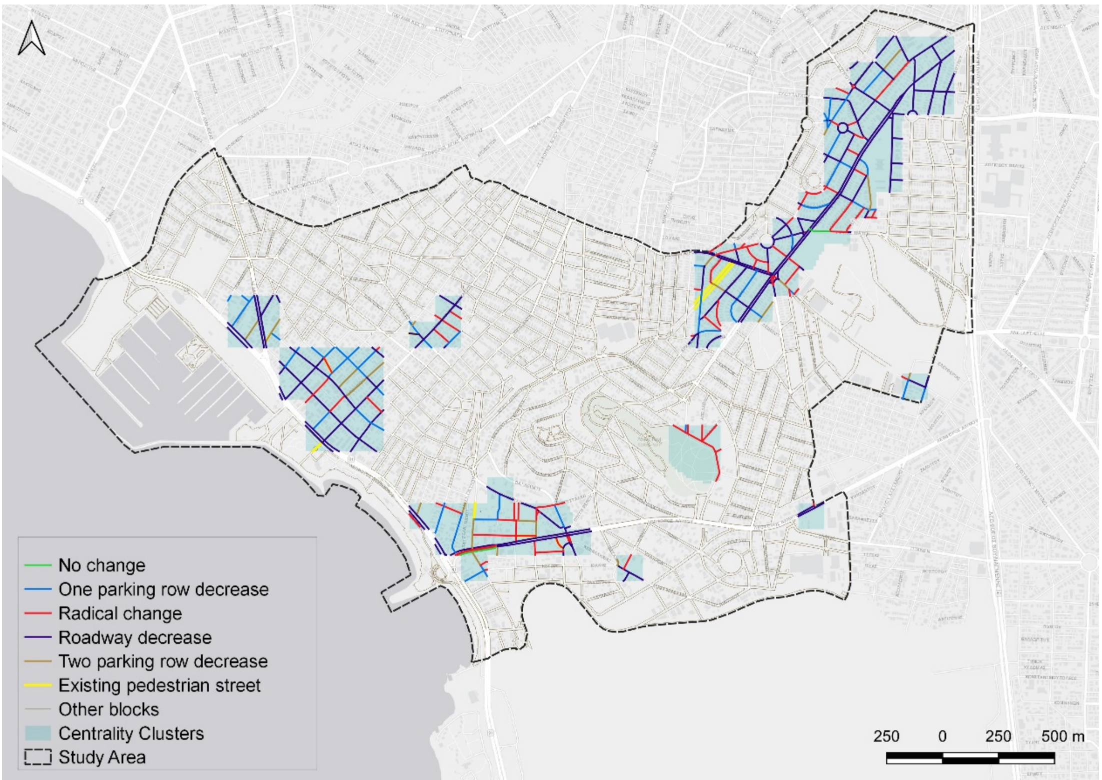

Figure 9: Pedestrian suggestion with pavement width 2.1m on both sides

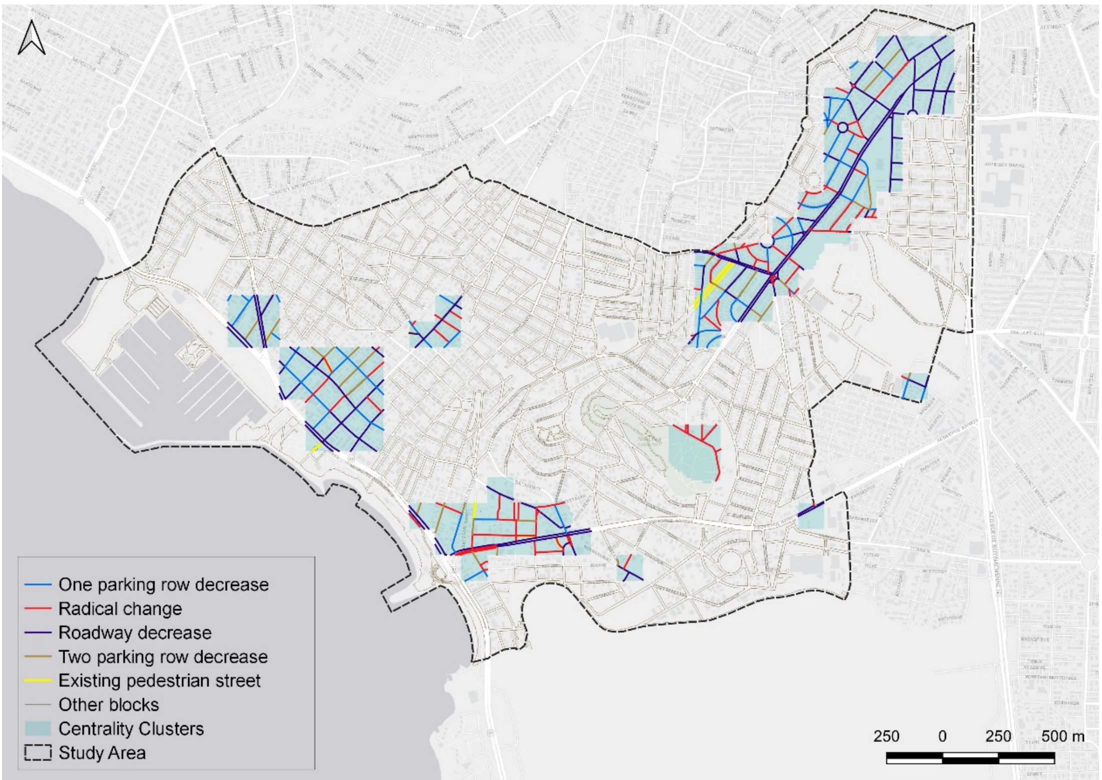

Figure 10: Pedestrian suggestion with pavement width 2.1 m. and 1.5 m in the opposite sidewalks

5 CONCLUSIONS

This paper aspired to develop an integrated method for mapping, assessing and planning central areas and their connections into multiple spatial levels. To this end, the methodology framework introduced was formulated accordingly in order to identify a) existing and emerging centralities and their walkshed area, b) transform the existing car-oriented road network hierarchy and c) renegotiate vitality and walkability issues in a microscale level. This combinatorial multilevel perspective is gaining ground in the corpus of literature, since there is a substantial number of other similar studies addressing the issue of a unified approach towards spatial planning (e.g. Hull, 2005; Cervero 2013; Koohsari et al., 2019).

Probably the most important finding of this research is the methodological framework which is significantly advanced since its first introduction (Paraskevopoulos & Tsigdinos, 2022) is generally successful in identifying established and emerging centralities, evaluating the vitality and walkability of the centres and proposing a strategy prioritizing urban planning and transportation planning interventions. This can be understood by the wakshed or catchment area analysis that confirms the adequate allocation of the new centrality pattern. Catchment areas are considered as an effective tool for spatial planning as discussed in Vale et al. (2016) and Dony et al. (2015). What is more, the utilization of multiple methods, techniques and data makes the proposed methodological framework a compelling integrated approach for active mobility strategy which is line with other comparable studies like Koszowski et al. (2018) and Appolloni et al. (2019). Focusing on the study area, it is quite revealing the fact that an upper middle-class suburban area has significant problems when it comes to sustainable urban form and active mobility since the existing centrality pattern still preserves a car-centric development. This is line with the findings of similar research attempts such as Cervero (1989; 2013). Additionally, there is a considerable proportion of the study area that is not supported by the 10-minutes walkshed areas of the existing centrality pattern. Nevertheless, an emerging walk-attractive centrality network underlies and if enchased, the suburban form of such cities can be significantly more sustainable (see more in Paraskevopoulos and Photis, 2020).

With regards to the connection pattern, the evaluation analysis proved that the routes connecting the identified centres spread throughout the study area, meaning that the connectivity is at an adequate level. The value of connectivity in such studies is also highlighted in the works of Baby Daniel et al. (2019) as well as Knight and Marshall (2015). Furthermore, in terms of mutlimodality the study area has appreciable potentials for accommodating a multimodal transport system, since practically the ¼ of the routes are already Multimodal corridors. Also, there is a great share of routes that have public transport lines passing by, signifying an increased potential for a complete multimodal corridor system. Assessing corridors in terms of mutlimodality has been based on similar studies (like Litman, 2015; Hui et al., 2018). Finally, the planning method adopts a unified view combining both urban and transport dimension for constructing the hierarchy of these routes and their transformation into mutlimodal corridors (see

Tsigdinos et al., 2021). It is very interesting that now the study area has a coherent system capable of serving all the centers efficiently. An important aspect -and innovative characteristic- of this research is the inclusion of micro-scale in the methodological framework. The results of the methodology at neighbourhood-level, demonstrate the importance of urban and transport dimension since the results are corresponding with relevant research (Palaiologou, et al., 2020; Paraskevopoulos, et al., 2020; Tsigdinos, et al., 2019).

The present research incorporates an explicit methodological framework that could function as a decision support tool for stakeholders and policy-makers and could be applied to other cities with similar characteristics. Subsequently, the rationale described could influence the formal transport and urban planning procedures, especially in countries with limited planning tradition towards a unified approach. Therefore, the main contribution of this study is not only related to research interests, but it also signifies an immediate potential for practical applications. However, the topic employed in this paper is full of complexity, since it comprises only a small part of a broad research field. Hence, it is suggested that new studies going beyond the scope of this one or improving some possible limitations, should emerge in the near future. In this context, further research could adopt new approaches related to centre identification, thus achieving a better understanding of the various components that affect centrality. As a result, comparative studies evaluating these different approaches could be an engaging example for new research opportunities. Through this procedure, there can be new directions regarding centrality identification. For example, a city could integrate a combinatorial approach to identify its centrality pattern and not focus only on a one-dimensional method. To be more specific, a potential improvement would be the integration of additional spatial morphology metrics such as the implementation of weighted space syntax analysis. Another take concerning centralities, could be the enrichment of the methodological procedure either by inserting more vitality score criteria (road environment features, etc.) or by changing the radius of the walkshed area (e.g. reduction to 300m). The improvement of our approach and the acquiring of a flexibility perpesctive by adapting to various circumstances may imrpove the given results in the future. Moving to the connection pattern, new studies should utilise more criteria for the assessment of the mulimodality status (e.g. urban identity of the routes, centrality and other network indices, etc.), so that the new hierarchy will be fairly comprehensive and well-articulated. Moreover, new research attempts could implement the directions of the planning suggestions (e.g. multimodal bus corridors with simple service) in the selected corridors, incorporating accurate street space allocation. When it comes to the microscale level, future research can employ more detailed urban planning interventions, exceeding the ones that were presented in this study. For instance, a coherent strategy about "greening" or expanding public spaces network coud be applied, in coordinance with the city level directions. Regardimg the accessibility perpsective, new similar papers should integrate cyclability and more walkability indices apart from the available space and some streetscape features that are illustrated here. Finally, the exploitation of more data (pedestrian or vehicle flows, users' perception, etc.), the utilization of more evidence-based tools and the integration of different evaluation methods would be a substantial contribution of the proposed strategy. Undoubtedly, the elaboration of more research papers and projects about centrality pattern, sustainable urban form and inclusive mobility issues in the near future can be a gamechanger towards sustainable and accessible cities.

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