MULTIMODAL CORRIDOR DEVELOPMENT AS A WAY OF SUPPORTING SUSTAINABLE MOBILITY IN ATHENS

ABSTRACT

The current paper aims at examining ways to support sustainable modes in a metropolitan environment, as a means of enhancing accessibility and social equity. The study adopts a mix-method approach consisting of field observations, literature review and secondary data analysis. Through this approach, the research develops a method *for reconceptualising urban car traffic arterials and provide a coherent plan for transforming them into multimodal corridors*. The multimodal corridors are proposed based on their position in the street network, their connectivity properties, their urban characteristics, the existence of major public transport routes or dedicated cycling routes and their current street classification. Furthermore, the paper suggests design methods referring to each corridor category under the principles of sustainable mobility (e.g. cross-sections). The study area is the metropolitan area of Athens (AMA) in Greece. The implementation of the proposed interventions is expected to generate significant positive impacts such as the promotion of active modes and public transport, unification of the urban fabric, accessibility improvements, environmental protection and urban liveability benefits. The creation of multimodal corridors constitutes an alternative planning tool which prioritises walking, cycling and public transport. The method developed in this case study could be applied to other study areas with similar characteristics and may be a prototypical “roadmap” for policy-makers, planners and local communities, aiming to transform car-dominated corridors to multimodal ones.

Keywords:

Multimodal corridors, sustainable mobility, integrated transport planning

1. INTRODUCTION

In the era of climate change, rapid urbanisation and social inequalities, cities face serious challenges which question their capacity to be genuinely efficient and sustainable (Jabareen, 2006). Several of these issues are to a large degree a by-product of the car-oriented approach that influenced, mainly after 1950s, urban and transport planning process (Marshall, 2005; Banister, 2005). This is because transport enables, dictates and shapes urban spatial development and city prosperity (Knowles et al., 2020). Urban systems dependent on car traffic are typically associated with inaccessible public spaces, unattractive street environment, intense traffic congestion levels, road accidents, and severances to the urban fabric, as well as health hazards etc. (Godschalk, 2004; Seto et al., 2007; Urban and Maca, 2013;). For these reasons, cities should adopt innovative, efficient and inclusive strategies in order improve urban environment conditions (Aleta et al., 2017).

Among the various concepts that have emerged during the last decades concerning cities and transport, one of the most significant is Sustainable Mobility (Banister, 2008). This concept envisions a system that meets contemporary road user needs via promoting public transport, walking, cycling, introducing innovative ways of transport (e.g. micromobility and shared transport modes) and restricting car usage and ownership (Nikitas, 2018; Bakogiannis et al., 2020). Sustainable mobility looks to create a new ethos in transport provision (Nikitas et al., 2019) strengthening social equity, economic efficiency, environmental protection (Gudmundsson, 2004) and contributing positively to communities and their built environments (Attard & Shiftan, 2015). Establishing a culture of sustainable mobility in cities is a challenging task requiring a paradigm shift (Sdoukopoulos et al., 2019) that should be based on the adoption and implementation of an integrated and multimodal urban and transport planning approach (Bakogiannis et al., 2016). A critical component in this approach is street functional classification (Huang et al., 2016), which organises the various transport modes and specifies the role of the network routes (Dong et al. 2013; Stamatiadis et al., 2017). Classification systems that promote sustainable mobility should be multimodal and therefore limit the existing car-dominance (Carroll and Yamamoto, 2015; McAndrews et al., 2017). These alternative classification systems propose the formulation of urban corridors (mainly on arterial roads) which promote multimodal mobility, accommodating the movement of sustainable modes in particular (Curtis and Tiwari, 2008; McAndrews and Marshall, 2018)

The present research is aimed at developing and applying a method for reconceptualising car-centric arterial routes and transforming them into multimodal corridors that can actively promote sustainable mobility for a metropolitan environment. These corridors, which have citywide range, are proposed based on a new integrated street functionality classification. This classification takes into consideration both the urban and traffic dimension of the city, actively prioritising the sustainable modes of transport. The proposed method is applied to the metropolitan area of Athens, i.e. Athens Metropolitan Area (AMA), which belongs to the region of Attica. Athens is the capital of Greece and the largest urban agglomeration in the country with a population of approximately 4 million residents.

The main research objectives underpinning the present paper are:

1) The selection of the criteria that will help the reconceptualisation nature of the study;
2) The determination of the multimodal corridors that are most suitable for case of Athens;
3) The configuration of some methodological and analytical principles that will help this classification to be applicable and generalisable to urban contexts beyond Athens.

Henceforth, the paper consists of sections meaning to introduce our concept of street classification, describe our methodological considerations and tools, present our analysis, discuss our key findings, acknowledge the study limitations and provide conclusions and policy recommendations.

2. REVIEWING STREET CLASSIFICATION AND MULTIMODAL CORRIDORS

Street functional classification determines the way by which the street network is divided into classes, depending on the function they serve (Marshall, 2004). Specifically, street classification illustrates the role of each street in the entire transport network (FHWA, 2013). According to the conventional approach, street groups are defined mainly by the degree to which they promote circulation versus local access (Tumlin, 2012). In this context, the main street categories that occur are arterials, collectors or distributors and local roads (Levinson and Krizek, 2008; Institute of Transportation Engineers, 2016). For the case of Greece, the national road guidelines suggest four main road categories namely: motorways, arterials, collectors and local roads (Ministry of Environment, Regional Planning and Public Works, 2001). It should be noted that the rationale behind this traditional classification approach is basically the accommodation of car movement (Jones and Boujenko, 2009). Therefore, car-centric roads are placed at the top and are prioritised while roads designed to facilitate sustainable modes are placed at the bottom of the hierarchy ranking (Marshall, 2005).

Marshall (2004) notes that this approach has shaped hostile urban areas with intense traffic congestion, high levels of road accidents and difficult to access (if not a car user) spaces. More specifically, street classification systems dictated by this rationale, invest on road users' segregation, and therefore lead to the exclusion of cyclists and pedestrians from streets. In addition, major automobile corridors create severe barriers that fragment the urban fabric and discourage active ways of movement (Hur and Morrow-Jones, 2008). Liu et al. (2017) mention that this the existing street classification system has neglected the social dimension of streets and has also undermined the role of the sustainable modes. Also, this system largely ignores the land use activity surrounding the transport spine, yet on many roads retail and commercial activity forms a central feature of the corridor (Curtis & Tiwari, 2008). As a result, this classification does accommodate the ideal scenario where car movement and human activities co-exist harmoniously (Svennson, 2004). This is a significant problem, as cities need spaces that are both livable and useful for transportation (Cherry et al., 2006).

Streets serve many more functions, than their primary transport role, and they should be multimodal and vivid places (Tumlin, 2012). In general, streets should not only be linear passages, but they may also work as places for cultural interactions, political expression and socialisation (Sadik-Khan 2017). Street corridors should also function as neighborhood cultural assets and social activity spaces (Bosselmann, et al., 1999; Loukaitou-Sideris, 2002; McAndrews et al., 2006; McAndrews & Marcus, 2014). As movement and access do not always conflict, it is time to balance these functions along the major arterials that are the lifeblood of many urban areas (Curtis, 2006; McAndrews & Marshall, 2018). Hence, a new classification planning approach promoting sustainable modes should be the next priority of cities (Rychlewski, 2016). In a classification system like this, it would be possible to transform street space from a mere traffic conductor to capacitors of interactions and exchanges where different speeds and modes co-exist (Marshall, 2005).

Under the aforementioned circumstances, it is suggested that arterial routes, within main urban cores, should be gradually transformed into multimodal–activity corridors, which promote inclusive mobility and limit car-dominance (Noland et al, 2015; Svennson, 2004; McAndrews et al., 2017; McAndrews & Marshall, 2018). Multimodal corridors are major transport facilities which accommodate auto, bus, bicycle and pedestrian travel (AC Transit, 2018). Also, the multimodal corridor (MC) concept signifies the concentration of denser, more varied land uses along redesigned arterial thoroughfares (Curtis & Tiwari, 2008). This may pose considerable promise in improving sustainability for cities seeking to reduce urban sprawl and provide for transport choice in proximity to activities (Adams, 2009; Biddulph, 2012). Furthermore, multimodal corridors are a key strategy in spatial policy in cities (Davison, 2006; Ruming, 2014) for improving liveability, as they integrate land use and transportation (Moore et al., 2007) and accessibility for all users (Williams and Seggerman, 2014; Florida Department of Transportation, 2016), thus reducing social and spatial inequalities (Kompil et al., 2019).

Notable research has been conducted, indicating the need of reconceptualising large urban streets (i.e. arterials) as places for walking, shopping, and socialising along with their car-movement function (Hess, 2009). An enabling element of these concepts is the rationale that corridor development will catalyse a redistribution of travel patterns, with more localised daily trips, and greater share of longer trips made on public transport (McLeod and Curtis, 2019). Also, numerous scientific papers and technical guidelines adopted a matrix-based approach of classification which takes into consideration both "Link" and "Place" functions (e.g. Svennson, 2004; Department for Transport, 2007; Jones et al., 2008, Ribeiro, 2012, Transport for London, 2019), that tend to promote multimodal travel. Furthermore, Curtis and Tiwari (2008) developed a management tool designed to guide the transition of appropriate urban arterials to activity corridors in Greater Perth Area (Australia). This tool was based on the "Network City" metropolitan planning strategy (WAPC, 2004) which formulated activity corridors in Perth and Peel regions. It is striking that the MC concept has found renewed interest and practical application in several metropolitan and regional plans, such as the "boulevardisation" project for Helsinki (City of Helskini, 2017) or the case of Cape Town, which through its activity corridor approach, aimed to address the economic and social issues of impoverished townships by developing a well-integrated transport system and a comprehensive land use structure (Watson, 2002).

The implementation of multimodal corridors is a complex task that demands flexible, robust and innovative solutions (McAndrews & Marshall, 2018). Existing research identifies several ways in which arterials can differ from one another in their street design and traffic management (Marshall & McAndrews, 2017), social and economic activity (Mejias & Deakin, 2005), land use mix (Urban Land Institute, 2016), presence of multimodal transportation amenities (Cherry et al., 2006), and urban design

(Macdonald, 2007; Gillem, 2008).There are no fixed solutions though, that could be applied anywhere without adjustment. However, there are some considerable projects that deal with the design of these corridors, composing valuable tools (e.g. Institute of Transportation Engineers, 2006; Institute of Transportation Engineers, 2010; Grand Boulevard Task Force, 2010; DRPT, 2013; Duckworth-Smith, 2013; FHWA, 2016; AC Transit, 2018).

In this research, we intend to combine different methods and tools that have been reported in the relevant literature in a unique way custom-tailored to the Greek context in order to compose an Athenian multimodal corridor network that could help crafting pathways to a just and sustainable mobility future.

3. PLANNING MULTIMODAL CORRIDORS: METHOD EXPLAINED

The paper uses a mixed method governed by a case study approach; this is a research recipe similar or comparable at least with other notable works in the field of transport (e.g.. Attard and Ison, 2015; Bakogiannis et al., 2014; Shokoohi and Nikitas, 2017; Roukouni et al, 2012). More specifically, our approach consists of three components. The first one refers to a thorough examination of the literature (thematic literature review) regarding street classification and multimodal corridor planning, the second was the use of secondary data including road widths and speed limits, while the third one refers to field observations set to identify the existing situation and understand better the needs of a metropolitan road environment. Through using and combining these three distinct but complementary methods, we developed a data analysis approach, which consists of three main steps: i) the first step concerns the analysis of the existing situation (urban and transport features) aiming at the identification of potential opportunities and challenges in the study area; ii) the second step refers to the formulation of the multimodal corridors (utilising the existing routes in order to limit possible costs) and iii) the final step defines the various design characteristics of the corridors (e.g. cross-sections).

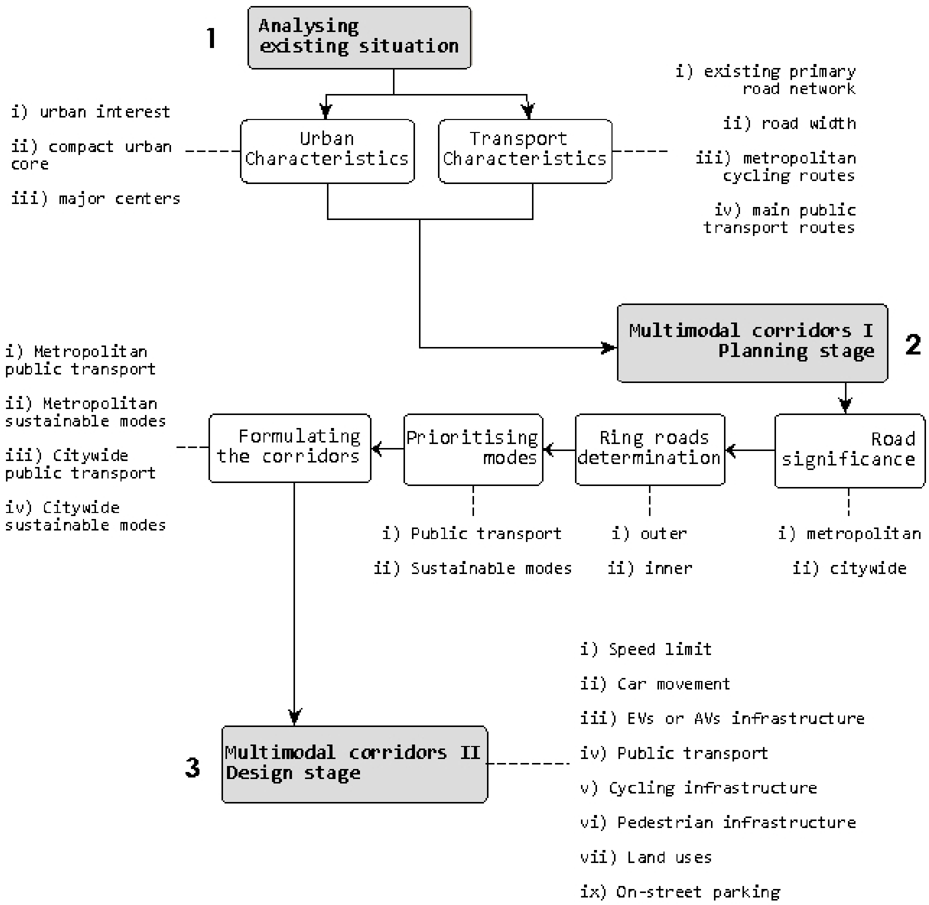

Figure 1: Flow chart of the adopted analytical method

3.1 Analysing existing situation

The first step consists of two parts that are equal in terms of importance. The first part concerns: i) the urban characteristics of the existing main road network consisting of motorways and primary arterials; ii) the identification of the compact urban core of the study area; and iii) the recognition of the major urban centres. If we focus on each feature, we should address the following: i) the urban characteristics indicate the urban interest of each segment. Specifically, they represent the mix of land uses, the functional density (land use per 100meters) and the existence of points of interest such as architectural monuments, squares, archaeological sites, etc. in a given road edge. An edge with high land use mix and significant functional density (Shannon index >=0,5 and density>= 5 land uses per 100 meters respectively) and at least one notable point of interest, is considered as "High interest", otherwise as "Low Interest"; ii) the compact urban core consists of municipalities with residential density exceeding the threshold of 200 residents per hectare; iii) the major urban centres and their classification are derived from formal regional planning documents.

The second part investigates characteristics related to transport and mobility: i) existing main network, ii) main public transport routes, iii) metropolitan cycling routes and iv) road width. In a more detailed view, we should point out the following: i) the main network of a metropolitan city is derived from formal urban or transport planning documents. Usually it is composed by motorways and primary arterials; ii) the main public transport routes including major bus lines and tramway lines that accommodate metropolitan or intermunicipal trips; iii) the metropolitan cycling network is retrieved from formal urban or transport planning documents and consists of either already constructed or planned routes; iv) the total width of a road segment (sidewalk, pavement, parking, median, etc.) is calculated from on-site observations.

3.2. Multimodal corridors I: Planning

The research used a qualitative approach for developing the method to determine the multimodal corridors. More specifically, the construction of the proposed method is mainly based on an extensive literature review analysis regarding street classification and multimodal corridors with respect to approaches enhancing sustainable mobility. The method adopts a bi-dimensional approach (dimension one-significance and dimension two-mode priority) in order to formulate a multimodal corridors classification system.

General features of the method for classification

The method is composed by four steps. The first defines the multimodal corridors and their significance, the second determines the ring roads that divide the study area, the third assigns mode priority in every corridor and the fourth is the mapping of the corridors' network. Next, we describe the criteria used in each step.

1) Multimodal corridors and their significance

The first step concerns the selection of multimodal network segments and their significance that represents the first dimension of the classification matrix (Figure 2). Taking into account the strong relation between urban and transport planning (Milakis et al., 2008), we decided to adjust the significance categories with the size of the study area. Since we deal with the main urban core of a metropolitan area, we selected to divide road significance into two categories. The first category is Metropolitan and the second is Citywide. The criteria used for choosing the routes (group of road edges) are the following:

a) Connectivity: Based on the assumption that the importance of a network segment depends on the importance of the places which are connected by this segment (Friedrich, 2017) we introduce this criterion to examine the significance of the connection between two places

b) Sustainability potentials indicator: It is an indicator depicting the potential for sustainable transport modes. The formula is the following:

$SPI=a*UI+b*TW+c*PT+d*CL$ (1)

Where:

SPI is the sustainability potentials indicator (values 0 to 4),

a, b, c and d are coefficients depicting when a factor is considered (value=1) or not (value=0)

UI is the urban interest (value = 0 when urban interest is high and value =1 when urban interest is low)

TW is the total width of a road segment (value = 0 when road with is lower than 25m and value =1 otherwise)

PT is the existence of main public transport line (value = 0 when public transport line is absent and value =1 otherwise)

CL is the existence of metropolitan cycling route (value = 0 when cycling route is absent and value =1 otherwise)

c) Shortest path algorithm: this criterion contains the application of "v.net.allpairs" tool in the software GRASS GIS which generates the shortest path between all pairs of nodes in a given network (urban centres within the main urban core in particular). This algorithm connects two centres with one route, thus increasing the robustness of the proposed strategic network. It is worth noting that this algorithm uses as cost the sustainability potentials indicator (SPI), which is different in each alternative. Thus, when a street has high value of this indicator, then this segment has higher possibilities of being chosen.

2) Ring roads determination

The second step determines ring roads (outer and inner-central) for the study area by considering three criteria which are the following:

a) Significance: This is the significance that was determined in the previous step

b) Geometry: This criterion concerns the geometrical structure of segments, examining if they are radial or circumferential to the metropolitan centre of the city

c) Location: We examine the location of a road segment in regards with the main urban core and the basic metropolitan centre

The process for formulating ring roads is the following: The central-inner ring road is composed by circumferential routes that have metropolitan significance and they have the greatest proximity to the central area of the city. This ring road protects the commercial and historic centre. The outer ring road is formulated either by regional roads or metropolitan circumferential routes and its main objective is to accommodate the diversion of regional through traffic.

3) Modes priority

This step refers to the second dimension of the classification matrix and divides road segments into different categories depending on the modes they prioritise (see Figure 3). Hence, in case of prioritising only conventional transport and mainly car, there is one category on the matrix, in case of prioritising either car or public transport, there are two categories, and in the last case of giving priority to either conventional or public transport or innovative sustainable modes, there are three categories. The criteria used for assigning priority are the presented below:

a) Significance: This is the significance that was determined in the previous step

b) Location: We examine the location of a road segment in regards with the ring road zones that were defined in step 2.

4) Final classification

The final categories occur from the bi-dimensional matrix. Therefore, the maximum number of categories should be four categories (2*2). We should note though that it is possible to determine even empty cells, when it comes to risky combinations.

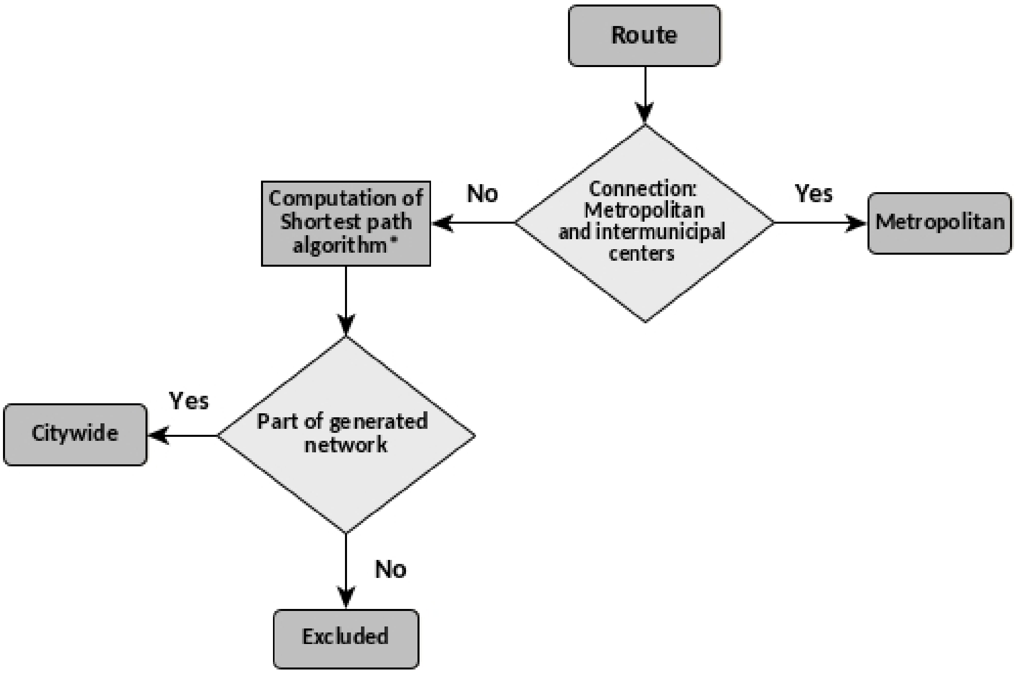

Figure 2: Flow chart of the method for selecting routes and their significance

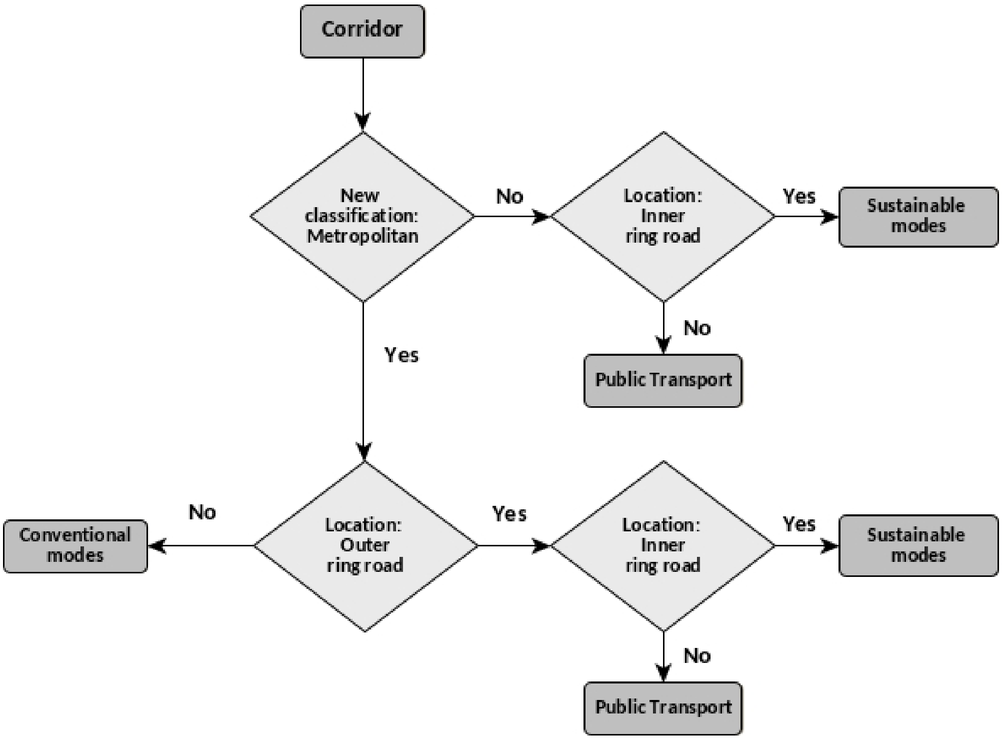

Figure 3: Flow chart of the method assigning mode priority

3.3. Multimodal corridors II: Design

This step refers to the specification of corridors' characteristics, in order to bridge the gap between the planning and implementation stages, and therefore completes the process of making multimodal corridors. Specifically, this step presents example cross-sections for each corridor category as well as design features (e.g. suggested land uses, modes' infrastructure, etc.) for each individual corridor. The cross-sections are based on the Greek guidelines (Ministry of Environment, Regional Planning and Public Works, 2001) while the selection of the design features was based on various sources (e.g. FHWA, 2016; AC Transit, 2018). It is noted that the design features' proposals are indicative, thus representing some particular dynamics (promote multimodality, traffic safety, etc.).

4. MAKING THE CORRIDORS HAPPEN: APPLICATION OF THE METHOD TO ATHENS

4.1. Description of the study area

Our study area is the main urban core of Metropolitan Athens (AMA) and covers 37 municipalities, including Athens and Piraeus, with a total geographic area equal to 366,02 km^2 (9,9% of Attica region). AMA has 2970820 residents (ELSTAT, 2011), which corresponds to approximately 27% of Greece's population. According to the Regional Plan of Attica (Ministry of Environment & Climate Change & ORSA, 2011), AMA's major central areas are grouped into two categories (metropolitan and intermunicipal) (Figure 4). The study area is a region with diverse urban, social and environmental characteristics, strong metropolitan or intermunicipal centres, and great strengths but at the same time serious deficiencies.

The main network of the city is car-oriented meaning that the space provided for car movement (driving lanes, medians, parking spots, etc.) is considerably larger compared to the space destined for sustainable modes (sidewalks, pedestrian zones, cycling and bus lanes, etc.). Subsequently, significant traffic flows pass through intermunicipal and metropolitan centres, creating unfavourable conditions for pedestrians, cyclists and vulnerable social groups. This traffic congestion overload is also due to the absence of efficient ring road zones. At the same time, the role of sustainable transport modes such as walking, cycling and public transport is neglected, since neither motorways or primary arterials give priority to any of these alternative modes. The percentage of the main network in the entire road network of the city is around 9,8% (motorways are 22,0% and primary arterials are 78,0%), verifying that a substantial number of roads are devoted in facilitating motor vehicles movement.

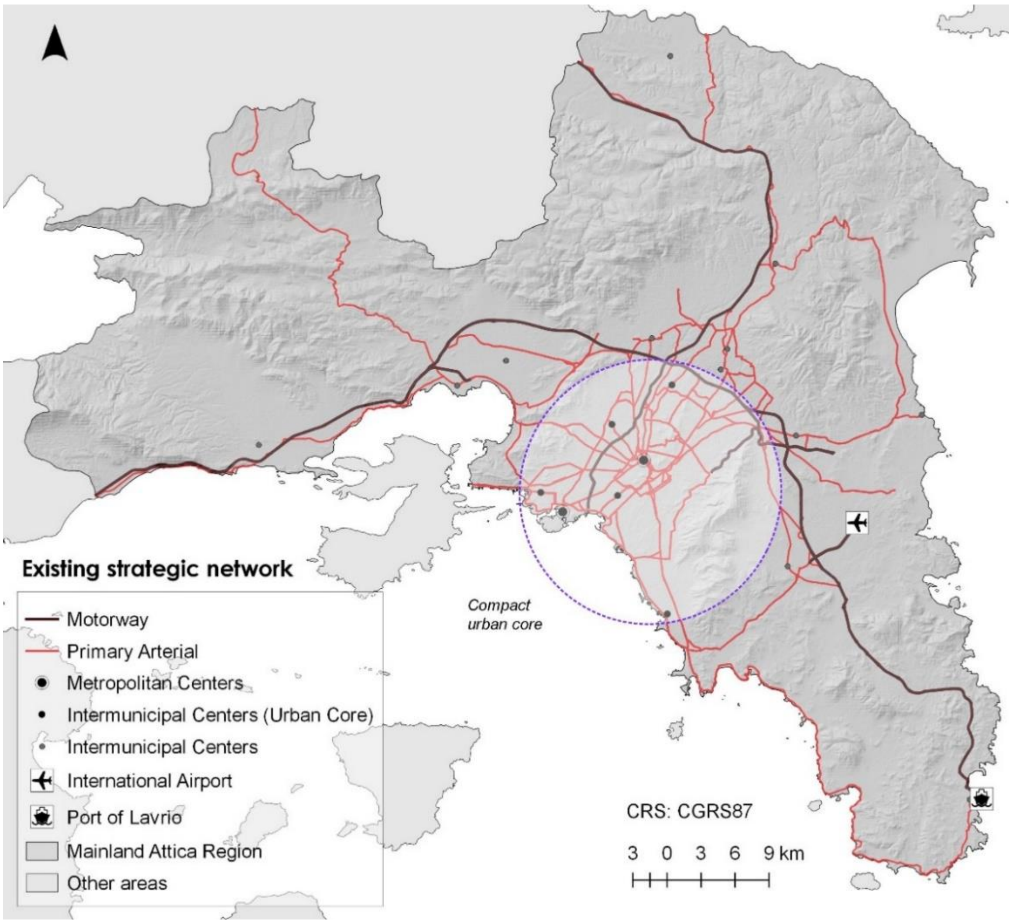

Figure 4: Current strategic road network and main urban centres

As a result, the current conditions in AMA do not favour multimodal corridors. Hence, major changes are needed to enhance sustainable and socially inclusive mobility for all and to improve the quality of urban environment. In the next steps, we present our results.

4.2. Formulation of multimodal corridors

This paper proposes several multimodal corridors via establishing a new street classification system of metropolitan and citywide importance (*Figure 5*). This new classification re-addresses the priority of the transport modes, composing an entirely different road network system. It should be mentioned that this new network consists of 74 corridors of various lengths.

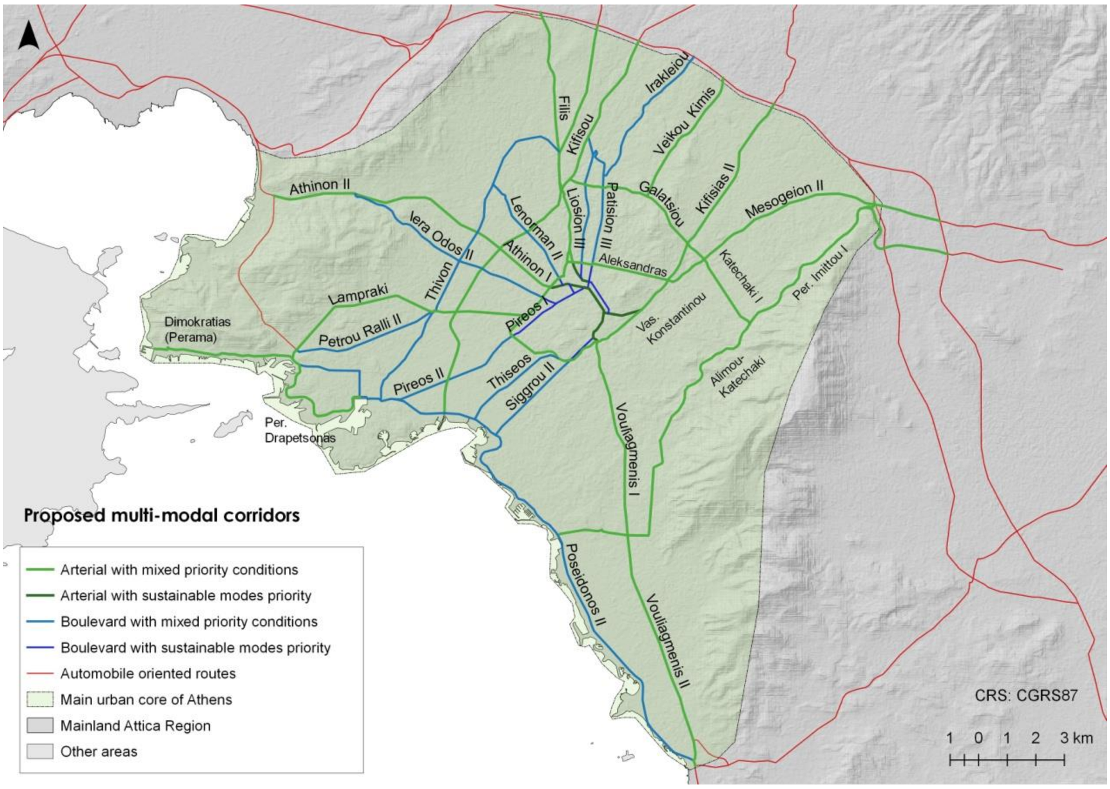

Figure 5: Proposed multimodal corridors - zooming into the corridors

Each road segment or route was evaluated one by one in order to identify its role in the multimodal network. The results are the following: 63% metropolitan and 37 % citywide. Focusing on each category separately, we should note that: a) concerning the metropolitan network 96% brings public transport to the forefront and the rest 4% prioritises sustainable modes (cycling, walking, micromobility, etc.), and b) regarding the citywide network, 9,3% supports sustainable modes and 90,7% favours public transport. Furthermore, the overall length of the proposed multimodal corridors is 237,5 km (28,81% of the main network in Attica Region in general), and its designation signifies that the existing car-oriented streets has been reduced by 35,9%. In this research, we define as car-oriented streets the segments where the available space for other modes is limited (e.g. narrow sidewalks, absent of cycle lanes, no bus or tram lines, illegal on-street parking, etc.) or there is a lack of the appropriate measures that ensure prioritisation of collective transport, for instance no signal priority for buses or trams.

Moreover, the creation of these corridors reduces frictions points by 86%. A friction point is a central urban area of metropolitan or intermunicipal significance, where movement and access functions confront. In other words, these areas have notable vitality and intense pedestrian flows due to the activities and land uses; but at the same time, they are penetrated by major arterials. Therefore, the reduction of these areas means that we protect these centralities by diverging the through traffic or by changing the hierarchy of the roads passing by. All of the aforementioned features are summarised in the next table:

Table 1: General features of the multimodal corridors network

Roads dedicated to public transport	237,5 km

Length of corridors/Length of main network in Attica Region	28,81%
Length of corridors/Length of total road network in Attica Region	3,09%
Car oriented streets reduction	35,9%
Friction points reduction	86%
Exclusively sustainable corridors	6,01%

According to our approach, the multimodal corridors are classified into four (4) categories which are presented at the next table:

Table 2: Categories of multimodal corridors (source; authors' own elaboration)

<table>
<tr><th colspan="2">Category</th><th rowspan="2">Type Code</th><th rowspan="2">Presence of modes (hierarchy)</th><th rowspan="2">Desirable Characteristics</th></tr>
<tr><th>Significance</th><th>Priority</th></tr>
<tr><td rowspan="2">Metropolitan</td><td>Public transport</td><td>MP</td><td>1) Public transport
2) Conventional automobiles and motorcycles
- Conventional freight vehicles
3) Bicycle
- Micromobility
4) Pedestrians</td><td>• Speed: up to 60-70km/h,
• Car movement: Signalized junctions, 2 lanes for car circulation per direction
• Public transport: Tram or BRT,
• Cycling infrastructure: Separate,
• Pedestrian infrastructure: Adequate or moderate,
• Land uses: Zoned or mixed (pedestrian friendly)
• On-street parking: Restricted</td></tr>
<tr><td>Sustainable modes</td><td>MS</td><td>1) Bicycle
- Micromobility
2) Pedestrian
3) Public transport
4) EVs and AVs
- Alternative freight vehicles
5) Car and conventional automobiles and motorcycles</td><td>• Speed: up to 40-50km/h,
• Car movement: Signalized junctions, 1-2 lanes for car circulation per direction,
• EV or AV (Shared) infrastructure: Separate,
• Public transport: Tram or BRT,
• Cycling infrastructure: Separate or roadway,
• Pedestrian infrastructure: Moderate or enhanced
• Land uses: Mixed (pedestrian friendly)
• On-street parking: Restricted</td></tr>
<tr><td>Citywide</td><td>Public transport</td><td>CP</td><td>1) Public transport
2) Bicycle
- Micromobility
- Pedestrian
3) EVs and AVs
- Alternative freight vehicles
4) Car and conventional automobiles and motorcycles</td><td>• Speed: up to 50-60km/h, (mainly 50km/h)
• Car movement: Signalized junctions, 1-2 lanes for car circulation per direction
• EV or AV (Shared) infrastructure: Separate,
• Public transport: Streetcar or bus (high frequency),
• Cycling infrastructure: Separate or roadway,
• Pedestrian infrastructure: Enhanced,
• Land uses: Mixed (pedestrian friendly)
• On-street parking: Mainly restricted</td></tr>
</table>

	Sustainable modes	CS	1) Bicycle - Micromobility - Pedestrian 3) Public transport - EVs and AVs - Alternative freight vehicles 4) Car and conventional automobiles and motorcycles	• Speed: up to 40-50km/h, (mainly 30km/h) • Car movement: Signalized or non-signalized junctions, 1 lane for car circulation per direction • EV or AV (Shared) infrastructure: Separate or roadway, • Public transport: Streetcar or bus (high frequency)-mixed lanes with cycling and taxi, • Cycling infrastructure: Separate or roadway, • Pedestrian infrastructure: Enhanced (more crosswalks), • Land uses: Human-oriented (urban identity), • On-street parking: Mainly restricted

4.3 Design features

In an attempt to bridge the gap between planning and implementation stages, we created several example cross-sections, which illustrate a desirable designation for each multimodal corridor category. These cross-sections are aimed at accommodating every possible transport mode according to the category they belong to. It is clear that the level of modes' mix intensifies when we shift from automobile to sustainable modes priority. Finally, we should note that the widths of each feature are correspondent to Greek Planning Guidelines (Ministry of Environment, Regional Planning and Public Works, 2001). It should be noted that the indicative flows are measured using people per hour, and not vehicles per hour. This alternative decision is based on the rationale of promoting a human-oriented mobility, thus not reproducing the existing car-oriented approach which measures the efficiency of streets according to the passing vehicles. The example cross-sections are presented in the following pictures:

The next cross-section (MP) can accommodate approx. 44000 people per hour per direction.

Figure 6: Proposed cross section for an arterial with public transport priority-MP (Example Width: 32m) | Image source; authors' own elaboration on Streetmix online software tool)

The next cross-section (MS) can accommodate approx. 54000-55000 people per hour per direction.

Figure 7: Proposed cross section for an arterial with sustainable modes priority-MS (Example Width: 30m) | Image source; authors' own elaboration on Streetmix online software tool)

The next cross-section (CP) can accommodate approx. 54000-56000 people per hour per direction.

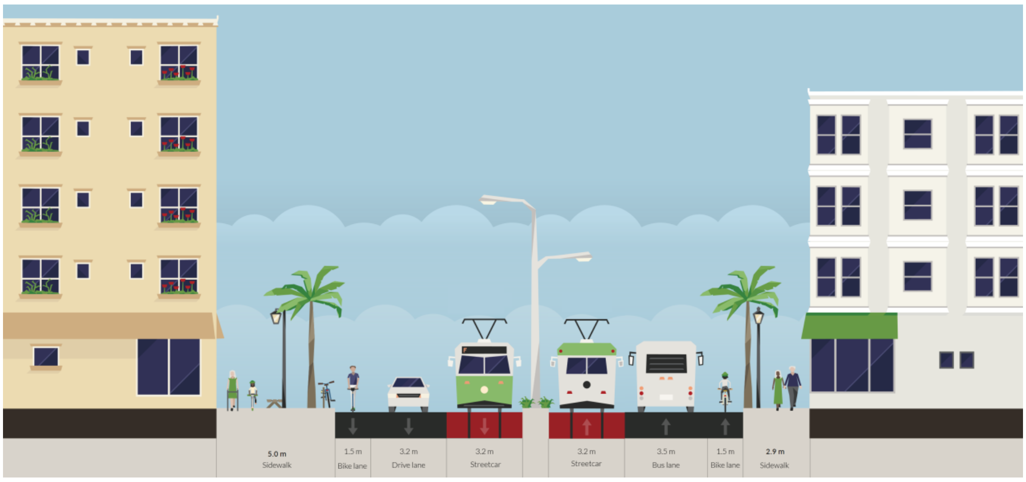

Figure 8: Proposed cross section for a boulevard with public transport priority-CM (Example Width: 25m) | Image source; authors' own elaboration on Streetmix online software tool)

The following cross-section (CS) can accommodate approx. 47000-58000 people per hour per direction.

Figure 9: Proposed cross section for a boulevard with sustainable modes priority-CS (Width: 24m) | Image source; authors' own elaboration on Streetmix online software tool)

4.4 Proposed Corridors' characteristics

In this context, we present a detailed table with the proposed features of each corridor. These features are: i) Street Type (MP, MS, CP or CS according to Table 1), ii) Length, iii) Location (Central, Central/Suburban or Suburban), iv) Street Width, v) Speed limit, vi) Public Transport Modes (BRT, Tram, Streetcar or Bus), vii-viii) Pedestrian and Cycling Infrastructure (Adequate, Moderate or Enhanced, and Separate or Roadway, respectively) as well as ix) Type of adjacent Land Uses (Zoning or Mixed).

Table 3: Proposed corridors' characteristics

Name	Type	Length (m)	Location	Width (m)	Speed (km/h)	Public Transport	Pedestrian	Cycling	Land Uses
Acharnon I	CS	539,99	Central	20	30	Bus	Enhanced	Roadway	Mixed
Acharnon II	CP	4519,45	Central	28	50	Bus	Enhanced	Roadway	Mixed
Achilleos	MS	1254,98	Central	26	40	Tram	Enhanced	Roadway	Mixed
Agxialou	CP	2149,08	Central/Suburban	11	40	Bus	Moderate	Roadway	Mixed
Aigaleo	CP	910,04	Central/Suburban	10	40	Bus	Moderate	Roadway	Mixed
Akadimias	CS	1354,72	Central	23	40	Streetcar	Enhanced	Roadway	Mixed
Akti Kondili	CP	318,67	Central	32	50	Streetcar	Enhanced	Separate	Mixed
Aleksandras	MP	2702,21	Central	36	50	BRT	Enhanced	Separate	Mixed
Alexioupoleos	MP	1660,37	Suburban	24	40	BRT	Enhanced	Separate	Mixed
Alimou	MP	1578,73	Suburban	24	60	BRT	Moderate	Separate	Mixed
Alimou-Katechaki	MP	5426,39	Suburban	24	70	BRT	Adequate	Separate	Zoning
Amalias	MS	1211,84	Central	40	30	Tram	Enhanced	Roadway	Mixed
Argiroupoleos	MP	3530,86	Suburban	26	60	BRT	Adequate	Separate	Zoning
Athinon I	MP	2226,11	Central	47	60	Tram	Adequate	Separate	Mixed
Athinon II	MP	8593,49	Suburban	44	70	Tram	Adequate	Separate	Zoning
Deligiorgi	CS	364,94	Central	10	30	Bus	Enhanced	Roadway	Mixed
Diligianni	MP	725,88	Central	35	50	BRT	Enhanced	Separate	Mixed
Dimokratias I (Agioi Anargiroi)	MP	1337,08	Suburban	23	50	BRT	Adequate	Separate	Zoning
Dimokratias I (Perama)	MP	323,21	Suburban	39	70	BRT	Adequate	Separate	Zoning
Dimokratias II (Agioi Anargiroi)	MP	4727,59	Suburban	22	50	BRT	Moderate	Separate	Mixed
Dimokratias II (Perama)	MP	4999,49	Suburban	22	50	BRT	Moderate	Separate	Mixed
Domokou	MP	447,87	Central	16	50	BRT	Enhanced	Separate	Mixed
Filis	MP	5081,90	Suburban	24	60	BRT	Moderate	Separate	Zoning
Galatsiou	MP	3837,68	Central	25	40	BRT	Enhanced	Separate	Mixed
Iera Odos I	CS	520,92	Central	24	40	Streetcar	Enhanced	Roadway	Mixed
Iera Odos II	CP	7673,67	Central/Suburban	29	50	Streetcar	Moderate	Separate	Mixed
Ioulianou	MP	871,79	Central	14	40	BRT	Enhanced	Separate	Mixed
Irakleiou	CP	5438,19	Suburban	24	50	Bus	Moderate	Separate	Mixed
Kallirois	MP	1203,25	Central	48	60	BRT	Adequate	Separate	Zoning
Katechaki I	MP	2815,85	Central/Suburban	28	70	BRT	Adequate	Separate	Zoning
Katechaki II	MP	814,33	Central	20	50	BRT	Moderate	Separate	Mixed

Kautantzoglou	MM	635,77	Central	16	40	BRT	Moderate	Separate	Mixed
Kifisias I	MM	1487,36	Central	28	40	Tram	Enhanced	Roadway	Mixed
Kifisias II	MM	5829,11	Central/Suburban	46	60	Tram	Moderate	Separate	Mixed
Kifisou	MM	15541,29	Suburban	65	70	Tram	Adequate	Separate	Zoning
Kimis	MM	2072,22	Suburban	51	60	BRT	Adequate	Separate	Zoning
Konstantinoupo-leos	MM	2737,67	Central	45	50	BRT	Adequate	Separate	Zoning
Lampraki	MM	6032,37	Suburban	30	50	BRT	Moderate	Separate	Mixed
Lenorman I	CS	276,15	Central	26	40	Streetcar	Enhanced	Separate	Mixed
Lenorman II	CP	4105,43	Central/Suburban	24	40	Streetcar	Moderate	Separate	Mixed
Liosion I	MS	961,28	Central	15	30	Bus	Enhanced	Roadway	Mixed
Liosion II	MP	457,66	Central	14	40	BRT	Enhanced	Roadway	Mixed
Liosion III	MP	2428,19	Central	24	50	BRT	Adequate	Separate	Zoning
Marathonos	MP	2403,41	Suburban	24	60	BRT	Adequate	Separate	Zoning
Mesogeion I	MP	1552,43	Central	32	50	BRT	Moderate	Separate	Mixed
Mesogeion II	MP	6662,36	Suburban	42	60	BRT	Moderate	Separate	Mixed
Mikras Asias I	CP	965,38	Central	20	50	Streetcar	Moderate	Separate	Zoning
Mikras Asias II	CP	1057,78	Central/Suburban	41	50	Tram	Moderate	Separate	Zoning
Panepistimiou	MS	1151,48	Central	30	30	Tram	Enhanced	Roadway	Mixed
Patision I	CS	835,03	Central	23	40	Streetcar	Enhanced	Roadway	Mixed
Patision II	MP	49,23	Central	30	40	Streetcar	Enhanced	Roadway	Mixed
Patision III	CP	4356,18	Central	26	40	Streetcar	Enhanced	Roadway	Mixed
Perifereiaki Drapetsonas	MP	4765,85	Suburban	28	70	BRT	Adequate	Separate	Zoning
Perifereiaki Imittou I	MP	6741,17	Suburban	45	70	BRT	Adequate	Separate	Zoning
Perifereiaki Imittou II	MP	4260,80	Suburban	30	70	BRT	Adequate	Separate	Zoning
Petrou Ralli I	MP	3254,04	Central/Suburban	30	60	BRT	Adequate	Separate	Mixed
Petrou Ralli II	CP	5068,47	Suburban	30	50	Bus	Adequate	Separate	Mixed
Pireos I	CS	3072,29	Central	24	40	Streetcar	Enhanced	Roadway	Mixed
Pireos II	CP	4828,02	Central/Suburban	23	50	Streetcar	Enhanced	Separate	Mixed
Poseidonos I	MP	185,06	Suburban	36	70	Tram	Moderate	Separate	Mixed
Poseidonos II	CP	14951,06	Suburban	40	50	Tram	Enhanced	Separate	Mixed
Poseidonos III	CP	2868,14	Suburban	80	50	Tram	Enhanced	Separate	Mixed
Siggrou I	CS	1127,88	Central	29	40	Tram	Enhanced	Separate	Mixed
Siggrou II	CP	3708,33	Central/Suburban	51	60	Tram	Enhanced	Separate	Mixed
Thiseos	CP	3822,21	Central/Suburban	34	40	BRT	Moderate	Separate	Mixed
Thivon	CP	12127,36	Suburban	23	40	BRT	Moderate	Roadway	Mixed
Tsaldari	MP	2384,55	Central	45	60	BRT	Adequate	Separate	Zoning
Vas. Sofias I	MS	1356,24	Central	28	30	Tram	Enhanced	Roadway	Mixed
Vas. Sofias II	MP	1398,14	Central	40	40	Tram	Enhanced	Separate	Mixed
Vasileos Konstantinou	MP	1937,80	Central	32	40	Tram	Enhanced	Roadway	Mixed
Veikou	MP	2978,35	Central/Suburban	58	60	BRT	Enhanced	Separate	Mixed

Vikela	MP	573,87	Central	26	50	BRT	Moderate	Separate	Mixed
Vouliagmenis I	MP	6966,21	Central/S uburban	53	50	Tram	Adequate	Separate	Mixed
Vouliagmenis II	MP	8318,09	Suburban	54	70	Tram	Adequate	Separate	Zoning

According to the above table, the corridor with the greatest length is Kifisou (15541,29m) and with the minimum is Patision II (only 49,23m, due to change of street type). Concerning other descriptive statistics of the corridors' network, we should mention that the average corridor length equals to 3208,81m, and 37,84% of the corridors exceeds this value. Moreover, the median value of the sample is 2305,33m and the standard deviation is 3146,07m. Regarding the location of the corridors: 22,18% is located at a central zone, 21,10% at an intermediate zone, and the rest 56,73% at a suburban zone. The maximum width is 80m (Poseidonos III) and the minimum width is 10m (Aigaleo). The average corridor width equals to 31,20m, and 36,49% of the corridors exceeds this particular value. Furthermore, the median value of the sample is 28m and the standard deviation is 13,01m. Concerning the maximum allowed speed: 2,35% of the corridors' network will have maximum speed value 30km/h, 20,32% will have maximum speed value 40km/h, 35,26% will have maximum speed value 50km/h, 18,07% will have maximum speed value 60km/h, and the rest 23,99% will have maximum speed value 70km/h. As for the car circulation: 45,47% of the corridors' network accommodates BRT movement, 8,40% will accommodate simple buses, 11,94% streetcars and 34,18% Light Rail or Tram.

Concerning the pedestrian infrastructure: 38,91% will have adequate pedestrian infrastructure (at least 2,1m sidewalk width and the appropriate number of crosswalks), 32,39% will have moderate pedestrian infrastructure (increased sidewalk with and greater number of crosswalks) and the rest 28,69% will have enhanced pedestrian infrastructure, meaning increased sidewalk width (even greater than 3m), no obstacles and considerable density of crosswalks. As for the cycling infrastructure: 17,11% will share the road with other vehicles (exclusive lane or shared lane) and 82,89% is proposed to have separated cycling track. Finally, regarding the land uses: the majority of the network (65,47%) is proposed to accommodate mixed land uses and the rest 34,53% will promote zoning.

5. DISCUSSION

The present work develops a method for planning multimodal corridors through the reconceptualization of urban arterials. The application of this method to the main urban core of metropolitan Athens may redefine the Greek capital's stance towards sustainable mobility. More specifically, the city by adopting this work will achieve a genuinely multimodal network of strategic corridors, a unified urban fabric and a reduced car traffic. Moreover, the suggested method is expected to protect important central areas from through traffic (ring roads formulation), and therefore shape better conditions for pedestrians, cyclists and other vulnerable road users. These expectations are line with the findings of several studies (Hess, 2009; McAndrews and Marshall, 2018; McLeod and Curtis, 2019) that demonstrate the necessity of prioritising multimodal corridors and reconfiguring car-based ones.

In this context, our method will notably enhance the transport equity in the area, thus contributing to an acceptable accessibility level for all (vulnerable groups such as disabled people, elderly, children, pregnant women, female road users, migrants and other minorities as well as residents that do not possess a private vehicle or visitors that cannot rent one, etc.). In addition, the desirable characteristics of the corridors proposed (speed limit, modes infrastructure, land uses, etc.) could bridge the gap between planning and implementation. It is quite important for new methods to accompany planning strategies with specific design details, as they strengthen their integrity as well as their feasibility (Duckworth-Smith, 2013).

The current study has notable value, as it deals with the integration of multimodality in a car-oriented urban environment. We should note once again that the current street functional classification system is dictated by a car-oriented approach which gives an undoubted priority to motor-vehicles, undermines the role of sustainable modes, and is not compatible with the urban characteristics of the city. As a result, this car-oriented hierarchy does not allow the existence of multimodal corridors in the city, which could improve urban environment and quality of life. Our work could function as a decision support tool for municipalities, transport authorities, practitioners and policy makers that deal with urban mobility planning processes and could be applied to other cities with comparable characteristics; especially with radial-centric road networks. Apparently one of the most intriguing elements of the research is, that despite any drawbacks that may arise in the implementation of the plan, the rationale introduced could influence the existing formal planning procedures. Finally, this research can play notable role in the difficult task of paving the way for a new mobility culture that will pay less attention to cars, and more to people. Interestingly, this mobility culture will promote users' co-existence, and not separation, when possible, following a "shared mobility" narrative (Holden et al, 2020).

Regarding the method developed, we ought to mention the following; Beginning with the new functional classification system, it is important that we adopt an integrated approach differing from the conventional one. This approach takes into consideration both the urban and transport dimensions of the network through proposing a two-dimensional matrix approach that addresses link significance and mode priority. Therefore, it is coordinated with various studies that go beyond the one-dimensional classification and follow more comprehensive strategies (Jones and Boujenko, 2009; Svensson, 2004, etc.). A crucial component of the proposed method is the integration of network analysis and visualization tools in the methodological process. Moreover, two key aspects of road network are utilised; continuity in all strategic routes, and connectivity, meaning the property of network edges to connect central areas. These two aspects are found in similar researches (Marshall, 2005; Friedrich, 2017), augmenting the efficiency of new classification techniques.

Moving to the corridors themselves, we should remark the fact that our method regenerates all the arterials within the main urban core. Hence, they form a wide network that spreads through the main urban core, covering areas with serious mobility issues (intense traffic congestion, inadequate public transport services, absence of cycling routes, poor pedestrian infrastructure, etc.). Furthermore, the categorisation of corridors according to their role in the wider network boosts readability and also ensures implementation feasibility. As a result, the corridors have considerable chances to achieve higher levels of liveability for their constituents (Appleyard et al., 2016). Concerning the design features, we should note that a detailed literature review including research articles, guidelines, projects, etc. contributed greatly in the making of our own proposals. Specifically, through this qualitative assessment of existing practices we defined speed limits, public transport type, lane width, cycling and pedestrian infrastructures, as well as streetscape features for each corridor category.

Finally, a fundamental component of the proposed method is the assessment of the existing situation which was based on a thorough analysis of urban and transport features. This extensive analysis involved on-site observations and secondary data analysis thus permitting a comprehensive understanding of the study area's identity. Tellingly, without this integrated basis, we would not have been able to construct our proposed method properly.

6. CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

This research introduces a method for formulating multi-corridors in the main urban core of a metropolitan city. These corridors occur from a new functional classification system that points towards sustainable and inclusive mobility and it is human-oriented. The proposed method is developed for an urban area with a population of approximately 4 million residents, thus concerning cities with similar size and significance. In case of cities with different size, then it is essential to adjust our proposed method in order to anticipate more efficient results and multiplying benefits afterwards.

Functional classification and multimodal corridors formulation constitute complex issues that cannot be fully analysed by one single research. Tellingly, this paper focuses on the metropolitan level and therefore formulates multimodal corridors in the strategic network of the city. Streets with local importance are excluded from our suggested method as they demand different analysis methods. In other words, a critical research step moving forward is the development of a similar method which would address local spatial level e.g. municipality or special zones. Furthermore, a possible research subject would be the creation of a method for planning "flexible multimodal corridors", which will change the mode priority during the day. Such a research could be beneficial for very complex urban systems, in which static solutions cannot meet their needs. Along with the aforementioned, another take could be the development of a complete evaluation framework, in order to identify the quality of the proposed multimodal corridors and their dynamics. This framework should adopt a multicriteria approach that engages a wide variety of perspectives (e.g. traffic modeling, operational issues, environmental impacts, societal issues, etc.), so that the results will be much more efficient and representative.

Moreover, we should note that new criteria and tools could be integrated into the methodological framework. For instance, the utilisation of more evidence-based tools in future research of this issue could advance even more the methodological process. Also, the connection of the multimodal corridors subject with innovative technologies and data sources (e.g. crowdsensing, questionnaire surveys, interviews, mobility data and activity data, ITS, etc.) in general, would be a substantial contribution to this field. New studies could relate the making of multimodal corridors with cost issues, in order to optimize their feasibility.

We believe, the elaboration of more research studies and projects about multimodality (planning or design level) in the future could contribute significantly to the making of more sustainable, just and inclusive cities.

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