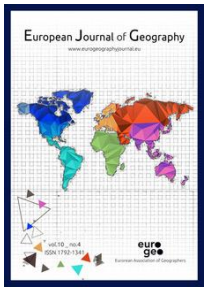

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Associating walkability features with pedestrian activity in a central Athens neighborhood.

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Abstract

Everyday human activity is crucially defined by walkability at neighbourhood level, and accordingly, this paper sets a dual focus: to map basic pedestrian accessibility infrastructure and to investigate the factors influencing walking patterns in such areas. The study area is Koukaki, a neighborhood in Athens' municipality. The methodological framework consists of four steps: a) Evaluating neighbourhood-level pedestrian accessibility with emphasis on vulnerable users, b) Selecting a centrality cluster, as an area of dense human activity (high density of non-residential uses), c) data collection of pedestrian flow and d) interpretation of the results. The results showed that human flows have substantial positive correlation with commercial activities, but negative with residential uses. In addition, they appear to have strong positive correlation with local network centrality (space syntax), sidewalk width and functional density. Finally, the evaluation of pedestrian infrastructure demonstrated that pedestrian movement cannot be adequately sustained in Koukaki, thus needing serious interventions.

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1. INTRODUCTION

Cities are the spatial setting of society and "the place where all kinds and classes of people are mixed so as to produce a common, though constantly changing and ephemeral life" (Harvey, 2012), forcing this heterogeneous ensemble to interact (Sennet, 1977). It constitutes a place of exchanging, activities, communication and a place of collective and organized life. The essential feature of the city is therefore concentration and coexistence (Lefebvre, 2007). Cities, as complex entities (Gallegos, 2017; Gonzalez, 2017), consist of many different urban processes and one of the most notable is the everyday urban mobility which is directly related to human activity (Urry, 2007; Middleton, 2018). An average daily routine contains a multitude of different activities thus making movement an important element in contemporary urban environments.

Walking is a fundamental aspect in cities since it constitutes the most primitive way of urban mobility. It is free of charge, it allows social interactions thus it enables practices of encounter and exchange (economic, social etc.) in the public space. That explains why, infrastructure ensuring pedestrian accessibility to every citizen -including persons with reduced mobility- is of utmost importance for a city. Especially in the car-oriented Athenian urban environment in which pedestrian movement is constrained by the intense vehicular traffic. In other words, the ability to walk safely and comfortably is in the core of a socially and spatially just city.

As Speck indicated in his book "Walkable City" (2013), "walk has to satisfy four main conditions: it must be useful, safe, comfortable, and interesting". Walkability infrastructure addresses two of these conditions (comfort and safety), thus additional walkability aspects are of importance when we are considering recreational and utilitarian walking. In this context, this paper has a two-fold focus. Firstly, to map and assess the basic pedestrian accessibility infrastructure in a larger residential area, and secondly to investigate the factors influencing pedestrian movement that occur in places crucial for pedestrian activity especially in a centrality cluster with dense human activity. We have to underline that pedestrian activity formulates various typologies of pedestrian movement due to the different functional and morphological features of the urban environment (central areas, residential areas, industrial areas, etc.). Hence, we chose to focus on central areas as they constitute the most critical parts of a neighborhood.

The structure of paper extends in five sections, which are then sub-divided into different entities. The second section contains the relative literature review. In the third section, we describe the dataset used in the research analysis and the methodology followed. Next section contains the various characteristics of the study area, the accessibility assessment in conjunction with the analysis of the various walkability aspects and their relation to pedestrian movement within the selected centrality cluster. In the last section, we present the conclusions of the research along with thoughts beyond the findings.

2. LITERATURE REVIEW

Walking is the most elemental way of transport, allowing people to get around and reach destinations, as well as to experience the urban space (Millan, 2009). Furthermore, walking can be conceptualized as a vital and accessible physical activity. Walking is

convenient, it does not require special equipment, and it is inherently safe (Vlastos and Milakis, 2006).

In this context, walkability is an emerging issue -for citizens, researchers, urban/transport planners and authorities- that has evolved into an umbrella term which can be described as the quality of urban environment to support and promote safe and pleasant walking for all street users -including people with reduced mobility, women, young children and elderly (Forsyth and Southworth, 2008; Bartzokas-Tsiompras et al. 2020a; 2020b). Therefore, it is considered a fundamental aspect of accessibility and has been investigated in different ways by many researchers (e.g. Axelson et al., 1999; Alfonzo et al., 2008; Dalal et al., 2011; Mougiakou and Photis, 2014, Bartzokas-Tsiompras & Photis, 2019; Paraskevopoulos et al., 2019; Bartzokas-Tsiompras et al., 2021a;2021b). Walkability is a fundamental human right since it is at the core of what is called accessibility, giving special focus on walking. Thus, the necessary infrastructure which facilitates safe and comfortable walking to all street users is a crucial element of the walkable city. The basic infrastructure for ensuring an adequate accessibility level, is public space, and especially the road network, sidewalks included, which crucially affects neighbourhood walkability. Hence, this specific network offers, or rather has to offer, the possibility of direct access and movement within the urban fabric for all, especially for people with reduced mobility, including sufficient unobstructed sidewalk width, existence of tactile paving and curb ramps, adequate lighting etc. (Mehta, 2007).

However, utilitarian and recreational walking is found to be significantly associated with various urban features, such as street connectivity, land-use diversity and proximity to walking attractors (e.g. transportation facilities, commercial and retail land uses) (Frank et al., 2005; Cervero, 1996; Cervero & Kockelman, 1997; Owen et al, 2007; Bartzokas-Tsiompras & Photis, 2017). What is more, a plethora of studies (e.g Waitt et al., 2019) highlights the crucial aspect of walkable accessibility to such destinations. Studies regarding pedestrians have shown that people seek out concentration of other people (Alexander, et al., 1977; Geddes & Vaughan, 2014) and are attracted to places that allow them to walk up and down, meet their friends, stroll and browse (Alexander et al., 1977). Therefore, a crucial aspect of walkability is walk-accessible place attractiveness (Bielik, et al., 2018; Kang, 2018), meaning the degree to which a place attracts pedestrian movement.

A more complete view on street connectivity is proposed by space syntax, which quantifies the network-based accessibility and attractiveness (Hillier, B. & Iida, S., 2005; Hillier et al., 1993; Penn et al., 1998) of the urban grid and recently has been utilized in numerous walkability studies (e.g. Koohsari et al., 2013; Jabbari et al., 2017; Koohsari et al, 2016). We should underline that space syntax theory, a graph theory approach for quantitatively interpreting urban morphology (Hillier & Hanson, 1984; Hanson & Hillier, 1987; Hillier et al., 1987; Penn, et al., 1998), describes and measures the configurational properties of urban space (visibility, topology, geometry) and its potential to attract human activity and pedestrian movement (Hillier, et al., 1996/2007; Hillier, 1999). As it is evident, there are various urban features that affect pedestrian movement, and there are several studies investigating this interaction. In this research we explore how the different features affect pedestrian movement in a central residential neighborhood of Athens.

3. METHODOLOGY

The methodological framework of this research consists of 7 steps, which are also illustrated in the figure below (Figure 1). The first step is the selection of the study area. We selected a central neighborhood of Athens, in order to identify and highlight the walkability aspects as well as their interaction with the urban environment in these urban typologies. The next step includes the audit of the basic pedestrian infrastructure. More particularly, we examine the following features throughout the study area: (a) sidewalk width, (b) tactile paving and (c) curb ramps.

Then, we proceed to the third step in which we perform a combinatorial evaluation of the pedestrian infrastructure, in order to gain an overall view towards walkability potentials of the study area. The criteria used for this evaluation are divided into three categories, in order to demonstrate how the available network alters, when physical difficulties in walking increase. More specifically, the first category requires the total width of the sidewalk to be at least 1,5m *(min sidewalk width* $\geq$ *1,5 m)*, as the minimum requirement to ensure comfortable movement of one person per direction on the sidewalk. Therefore, this category ensures an adequate level of service for able-bodied pedestrians. The second category requires a) the total width to be at least 1,5m, *(min sidewalk width* $\geq$ *1,5 m)* b) the existence of tactile paving and c) the presence of two curb ramps per sidewalk section. Finally, the third category maintains the criteria of tactile paving existence and curb ramps existence, but increases the minimum required total sidewalk width to 2,1m *(min sidewalk width* $\geq$ *2,1 m)*, which according to the Greek urban planning legislation (Ministry of Environment, Regional Planning and Public Works, 1996) constitutes the minimum width for the service of any person as well as the installation of streetscape features (e.g. streetlamps, trees, etc).

After the evaluation of the pedestrian infrastructure, we proceed to the definition of the main study area. A basic prerequisite is the determination of the active centres of our neighborhood, as clusters of dense human activity, by implementing the methodology described in relevant research (Paraskevopoulos & Photis, 2020). At next (step 5), we select one of the determined centrality clusters, and its corresponding streets as the main study area. The criteria for this selection are the size and the shape of the cluster as well as the existence of public transport infrastructure.

The sixth step consists of two distinct components. The first component refers to the measurement of the pedestrian flows. In particular, pedestrians were enumerated twice during the day (noon and afternoon), both on weekdays and on weekends and the measurements in each road segment lasted fifteen minutes (15'). The second component relates to the examination of urban characteristics and specifically functional features and pedestrian infrastructure (as described in previous steps).

Regarding functional features, it should be mentioned that we recorded every existing land use of the ground floor, in front of the buildings' entrance. Then, we categorized these land uses into 6 categories: 'Residential', 'Open Public Space', 'Commercial', 'Community', 'Workplace' and 'Empty Space'. In more detail, 'Residential' refers to the residential activities found on the ground floor of the sample streets. 'Open Public Space' signifies open spaces such as parks, squares, school courtyards, etc. 'Commercial' refers to uses that meet the needs for commerce or recreation (e.g. commercial shops, cafes, cultural sites). 'Community' refers to the wide range of uses that serve the daily needs of citizens and go beyond the narrow context of commercial uses (e.g. places of worship, healthcare, public or municipal services, education, etc.), 'Workplace', which includes

offices, crafts, etc. and 'Empty Space', which contains uses such as permanently closed shops, spaces for renting or abandoned buildings.

In addition to the data extracted from on-site observations, the present study utilizes space syntax analysis to obtain more comprehensive findings for the area. This study focuses on pedestrian movement; therefore, we selected the space syntax measure of local angular choice (also known as local angular betweenness) in order to explore the inherent property of the network to attract pedestrian movement. More specifically, angular choice (Normalized Angular Choice) with low metric radius (800 meters) is undertaken because it is considered to be the most powerful tool for measuring accessibility within street networks (Al Sayed, et al., 2014). The 800-metres radius is selected, as a typical walkable radius that corresponds well with walking patterns (Geddes & Vaughan, 2014)

After the recordings of the urban features, we proceed to the analysis and visualization of results (step 7) by implementing brief descriptive statistical analysis and exploratory spatial analysis to gain a more detailed view regarding the emerging walkability patterns of the study area. Finally, the last step combines the aforementioned data and investigates potential correlations (Spearman's rho correlation method) between pedestrian flows and urban environment characteristics. This step allows us to draw conclusions about factors that influence human flows in centrality clusters.

Regarding the data, we should point out that the pedestrian flows dataset and the urban features are derived from on-site observations that took place in the year 2018. The only data obtained from external sources were the digital files of blocks that were retrieved from Hellenic Statistical Authority (ELSTAT).

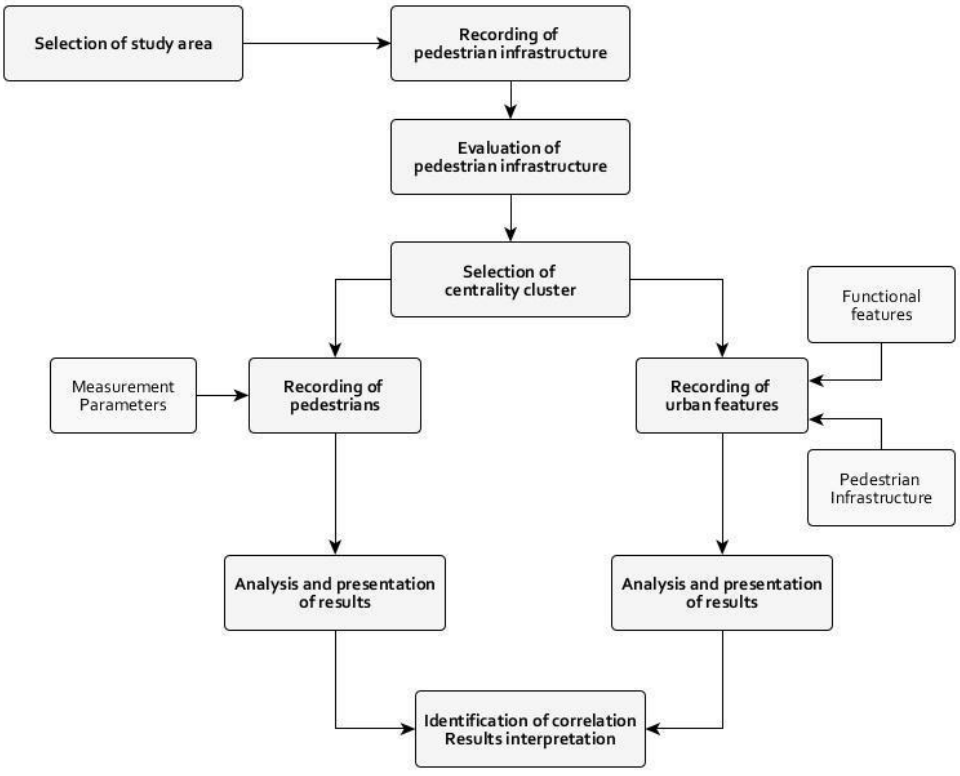

Figure 1. Methodological framework

4. ANALYSIS/RESULTS AND DISCUSSION

The study area is the neighborhood of Koukaki, which is located at the western part of the Municipality of Athens and is adjacent to archaeological sites of international importance, such as the Acropolis and the Philopappou Hill. Koukaki is a place with a diverse morphological and functional character. More specifically, the central and south-western part of the area has numerous high-rise buildings (mainly apartments), constituting one of the most densely populated areas in the municipality of Athens. On the contrary, the northern part of the study area which neighbors with the Philopappou Hill, is characterized by an entirely different building morphology and real estate values (lower heights, higher values, etc).

Throughout the recent years Koukaki is facing a radical transformation from a residential neighborhood with small retail and craft shops into a central area with cultural and recreational activities, taking place after the evening. It should be noted that the skyrocketing of Airbnb services in the area and the construction of significant cultural centers in its surroundings such as the Acropolis Museum or the National Museum of Contemporary Art played a considerable role towards the aforementioned direction.

4.1 Pedestrian accessibility

At first, the evaluation of pedestrian infrastructure is implemented. We created a combinatorial map illustrating the three accessibility categories that were defined in the previous section.

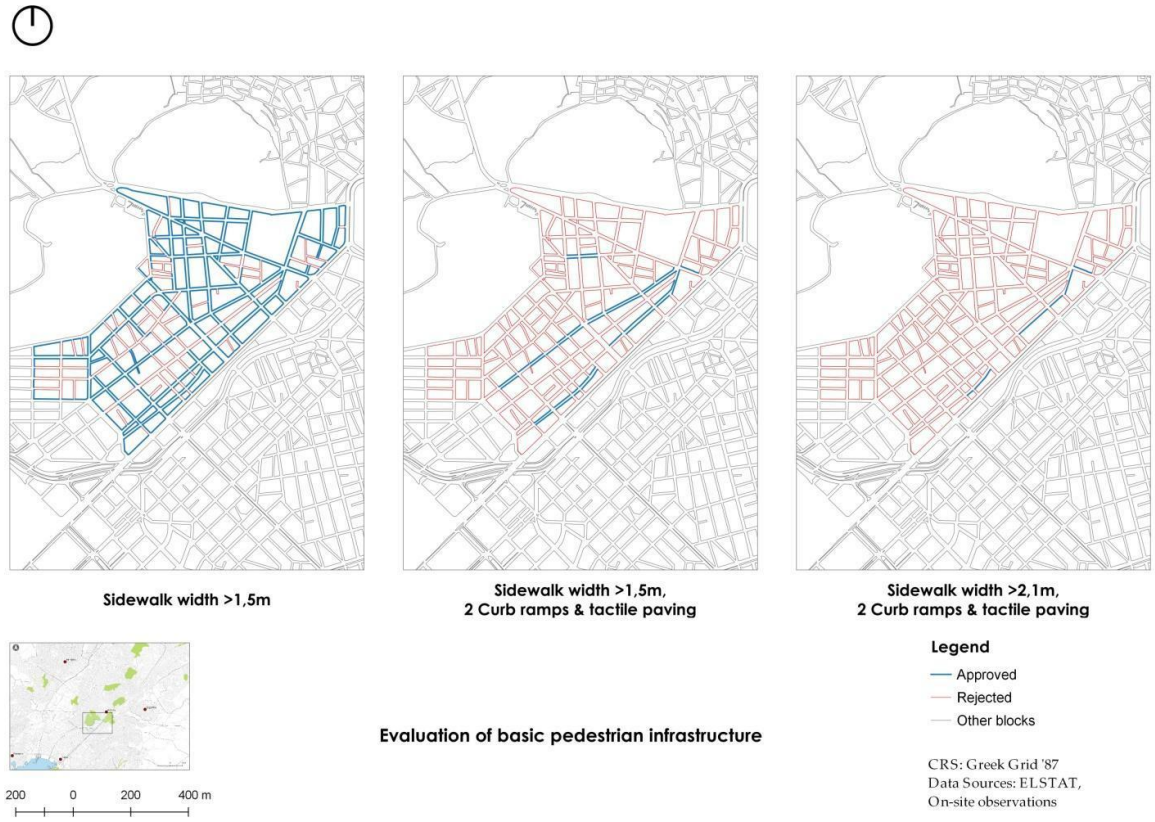

Figure 2. Evaluation of pedestrian infrastructure

From the map above (Figure 2), it can be clearly seen that the majority (65,8%) of the sidewalks meet the first requirements, allowing a relatively comfortable movement of an able-bodied person. The percentage satisfying the conditions of the second classification appears to be greatly reduced (9,5% of the sidewalks), meaning that there is a significant absence of the minimum width, which makes walking difficult or even impossible. Finally, the sections of sidewalks that are fully accessible to each category of users are extremely limited; they are only 504m (1,9%) in length and are located in the east edge of the study area. It is clear that the study area does not meet the requirements for equal and fair accessibility. Hence, this situation degrades the walkability of the area while promoting vehicular movement.

4.2 Centrality clusters

By recording and mapping the points of interest of Koukaki (Figure 3), one can understand how the neighborhood's pedestrian activity articulates. The area is defined by the semi-permeable barrier of Sygrou Avenue, the archaeological site of Olympus Zeus Columns, Philopappos Hill and Kallirois Avenue. The neighborhood's points of interest formulate centrality clusters, either as linear or circular shaped entities of commercial and recreational activities. The first cluster is located along Veikou and Dimitrakopoulou streets in the northeast part of the area between the metro stations of Akropoli and Sygrou-Fix, in great proximity with Sygrou Avenue. On the other hand, the second cluster is located around Zinni and Dimitrakopoulou streets in the southeastern part of the neighborhood, being considerably proximal to the National Museum of Contemporary Arts.

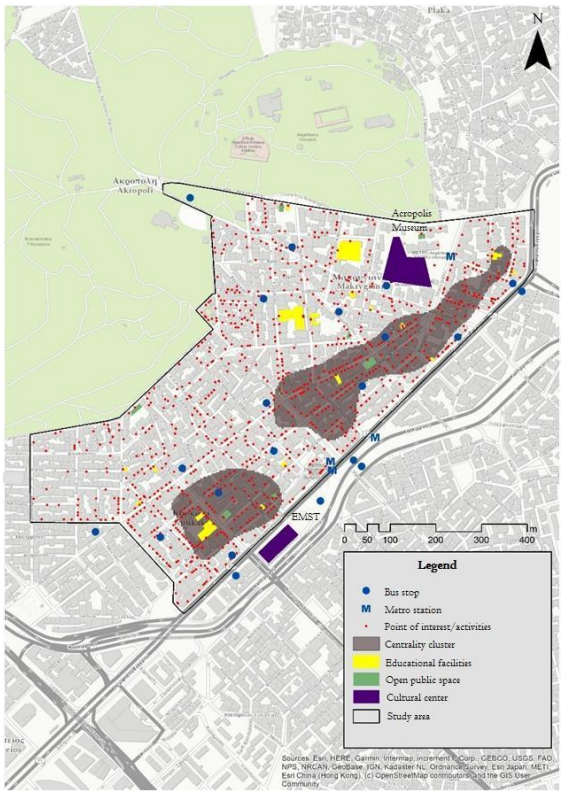

Figure 3. Centrality clusters of Koukaki

We chose to focus on the south-eastern cluster due to its size, its shape and the existence of a public transport stop within its boundaries.

4.3 Walkability aspects

4.3.1 Pedestrian Flows

The spatial pattern of the measured pedestrian flows is depicted on the map below (Figure 4).

Figure 4. Pedestrian flows

It is evident that some streets in the study area tend to be "attraction" poles contrary to other street segments in the network. More precisely, parts A and B of Dimitrakopoulou street exhibit the highest pedestrian flows. After these segments, part C of Dimitrakopoulou street and all parts of Zinni street follow in the "attractiveness" rank. Finally, Androutsou and Falirou streets are less attractive than the aforementioned streets while Vyzantiou and Botsari are the least attractive streets of the cluster.

4.3.2 Urban features

Pedestrian flows are an integral part of the urban environment and the result of its features. Therefore, this research examines the geography of the urban features and its relation to the pedestrian flow. The next map (Figure 5), depicts the sidewalks' width and the spatial pattern of land uses.

Figure 5. Sidewalk width and land uses

Almost 69% of the study area has pavements with more than 1.5 meters width which can be satisfactory for able-bodied pedestrians (Ministry of Environment, Regional Planning and Public Works, 1996). However, 5 parts of the study area's street network (Botsari A & B, Vyzantiou A & B & C) are less than 1.5 meters which make them inaccessible for pedestrian movement. Dimitrakopoulou, Zinni -which are the main attractors of the study area-and Androutsou C have satisfactory pavement infrastructure with more than 2.1 meters of width (Ministry of Environment, Regional Planning and Public Works, 1996).

The spatial pattern of land-uses (Figure 5) shows that the study area is mainly a commercial center and secondary office center (Malizia & Song, 2018). Dimitrakopoulou and Zinni streets, part B of Botsari and part A of Falirou, concentrate commercial activities while Androutsou C and Falirou B have mainly workplaces. Additionally, Androutsou B and Vyzantiou B have mainly empty spaces due to abandoned buildings and the vacant shops. Vyzantiou A, seems to be the only mainly residential part of the research area but we have to keep in mind that only ground floors are examined. Moreover, the functional typologies of the urban center show that none of the street segments are directed towards community activities which proves that the development of the centralities is retail-centric. Finally, Androutsou C and Botsari A have the most diverse land-useconsisted of "Commercial/Workplace" use and "Workplace/Empty space", respectively. The space syntax analysis of local scale (800m) is depicted on Figure 6, as well as the urban functional density.

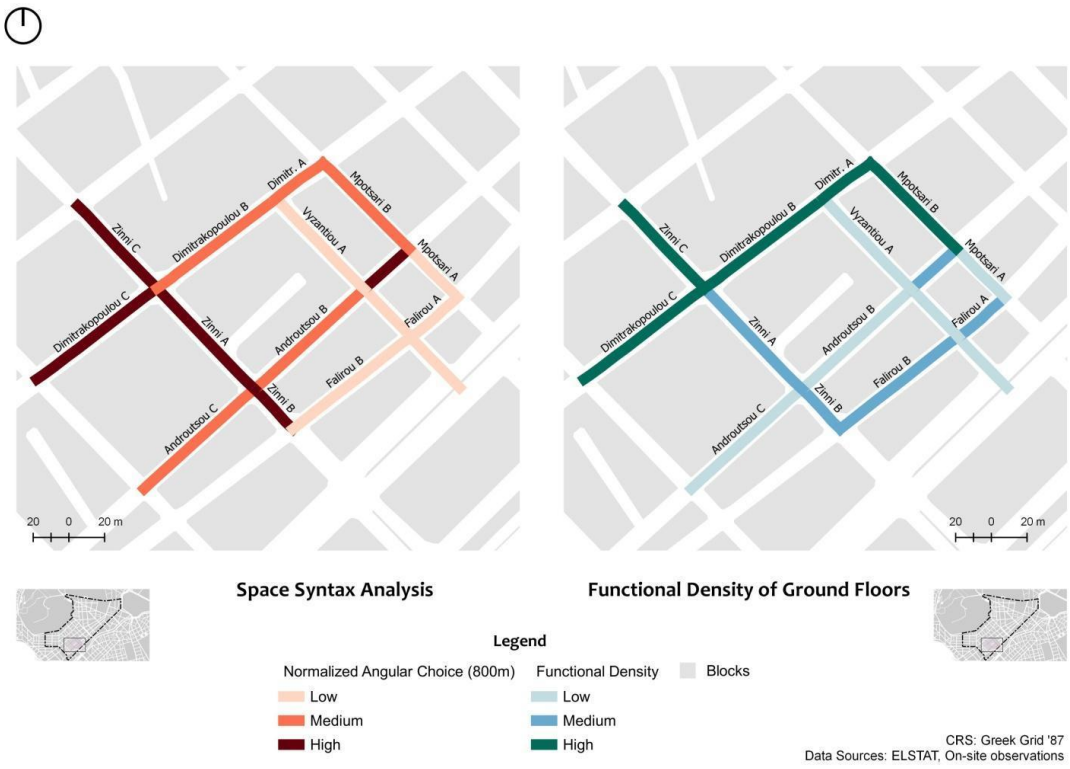

Figure 6. Space syntax analysis and urban functional density

Higher network centrality values appear in the local scale of the study area. Segments of Zinni street have the highest values, while Dimitrakopoulou, Androutsou and Botsari have medium network centrality values but Vyzantiou and Falirou streets are the most isolated ones. A radius of 2km from the study area is selected for the space syntax analysis in order to identify the network centrality pattern created inside the applied urban system and avoid edge effect. Functional density simulates the pattern created by the sidewalk width, the local network centrality pattern and the pedestrian pattern. We argue that an explanation can be found on the dense functionalities of Dimitrakopoulou and Zinni. Finally, low functional density is found in Vyzantiou, Androutsou B and Botsari A.

4.3.3 Interactions between pedestrian flows and urban environment

Our analysis highlights that only specific elements of the urban environment have substantial impact on pedestrian flow. However, features relevant to land-use distribution, network centrality as well as pedestrian infrastructure are highly important factors that affect pedestrian flow intensity. The correlations between pedestrian flows and the various urban features are depicted in Tables 1 and 2. Furthermore, scatter plots for the features with high positive correlation are depicted in Figure 7 and 8. Spearman's Rho correlation indicator is utilized since the datasets are not normally distributed.

As can be seen from table 1, pedestrian flows are highly correlated with commercial land uses, a finding consistent with the relevant literature. Interestingly, in our research area only Commercial land use has strong positive correlation with pedestrian flows. There is no strong correlation between other activities apart from Residential and Community land uses which have weak negative and weak positive correlation,

respectively. The negative correlation found between residential use and pedestrian flow demonstrates that citizens choose to live in more quiet/isolated areas.

Table 1. Correlation of (Spearman's ρ) pedestrian flows and land uses

	Residential (%)	Open public space (%)	Commercial (%)	Community (%)	Workplace (%)	Empty space (%)
Pedestrian flow	-0.37	0.21	0.55	0.34	-0.16	-0.20

Table 2. Correlation of (Spearman's ρ) pedestrian flows and urban features

	Functional Density (Uses/m)	Functional Diversity (Shannon entropy)	Sidewalk width (m)	Local Network Centrality (NACH 800m)
Pedestrian flow	0.72	0.21	0.88	0.69

However, the rest of urban characteristics appear to have stronger positive correlations with pedestrian flow. Pavement width exhibits the strongest positive correlation with pedestrian flow (*+0.88*). In addition, correlations between pedestrian flows and the characteristics of urban functional density and local network centrality are strongly positive. There is extensive literature highlighting the strong relation of network centrality and pedestrian movement (Hillier, et al., 1993; Berghauser Pont et al., 2019), and the emergence of central areas (Scoppa & Peponis, 2015; Porta, et al., 2012; Penn & Turner, 2004) which also appear within the Athenian urban environment in areas such as Koukaki.

Finally, urban functional density is the most important aspect of a vital and walkable urban centre (Jacobs, 1961) while it is further highlighted by the correlation with the pedestrian flows. However, there is no correlation of these two factors in our research area since (0.21). Thus, pedestrian flows are not connected to the diversity of our research area. It is worth mentioning again, that only ground floor land uses are recorded which may lead to less mixed land uses since Residential use and Workplaces are located in other floors of the buildings.

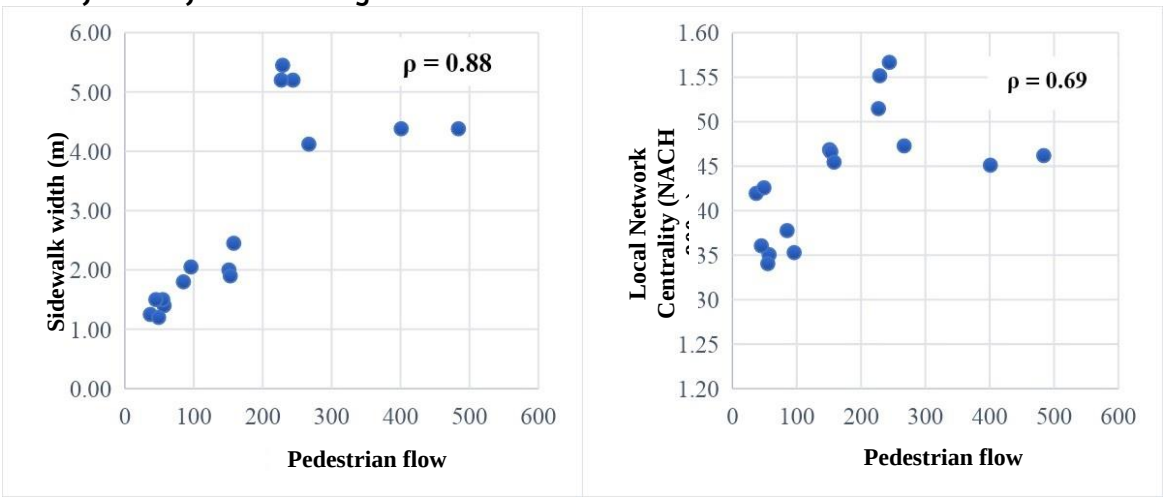

Figure 7. Scatter plot. Pedestrian flow and Sidewalk width (Left) & Pedestrian flow and Local Network Centrality-NACH 800m (Right)

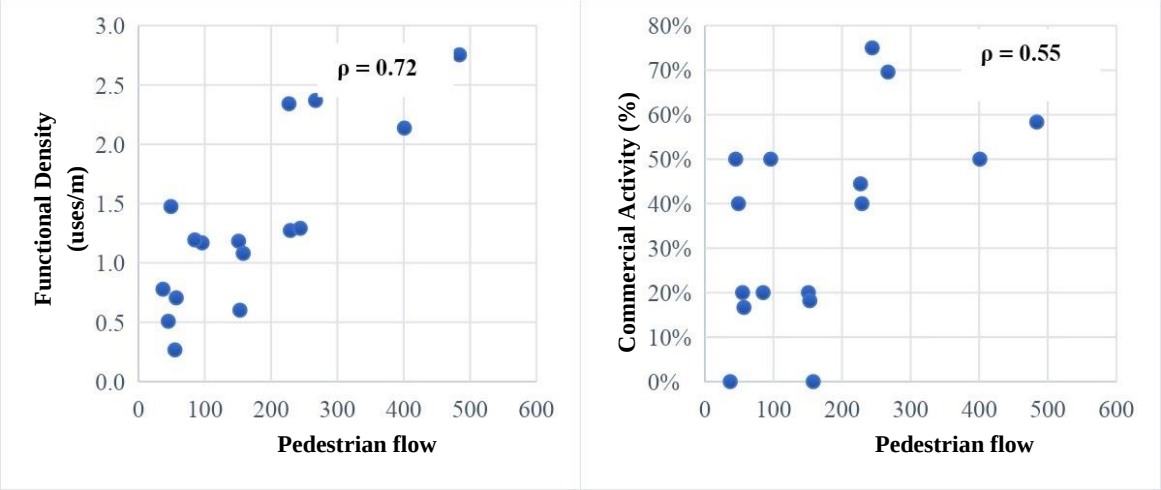

Figure 8. Scatter plot. Pedestrian flow and Functional Density (Left) & Pedestrian flow and Commercial Activity (Right)

To sum up, all aforementioned results prove that urban features such as Pavement Width, Functional Density, Local Network Centrality and Commercial activities have considerable impact on pedestrian flows. Dimitrakopoulou and Zinni streets are the most significant streets of the study area based on pedestrian flows and network centrality. Moreover, these streets have mainly commercial activities, high functional density and adequate sidewalk width. These characteristics are also necessary for areas which target towards encouraging walking and social interaction in the urban environment.

5. CONCLUSION

The present research led to various findings about Athens' walkability infrastructure and its interaction with the urban environment in central neighborhoods. Regarding pedestrian accessibility, it is evident that the existing conditions in Koukaki, cannot sustain safe and sufficient movement to all users in the city, and especially for vulnerable social groups, resulting in social exclusion and inequality, undermining the basic right of mobility. Moreover, the study area presents serious spatial contrasts, as segments at the southern part of the area are in significantly better condition than others. The current situation strongly dictates the urgent implementation of policy measures and interventions concerning the improvement of accessibility conditions in the area.

Focusing on the urban features, it should be noted that commercial activity is predominant in the area, as it occupies 30% of the uses in the studied street segments. It was also found that commercial and central streets in terms of space syntax have wider sidewalks. Focusing on the interaction between human flows and urban features, we identified the following: Pedestrian flows are positively correlated to commercial activity and negatively to the residential. Furthermore, they illustrate significant positive correlation with local space syntax centrality (angular choice 800m), sidewalk width and functional density (land uses per meter). Therefore, it is apparent that if the relevant planning authorities decide to increase the presence of pedestrians in the streets, then they ought to improve pedestrian infrastructure, enhance the connectivity of the area (e.g. creation of blocks openings), but also to increase the density of commercial or community activities (taking of course into consideration the capacity and the identity of the area and its citizens).

An interesting advancement of this work could derive from interviews and/or questionnaire surveys with citizens regarding the reasons affecting pedestrian movement in particular neighbourhoods and streets. Moreover, further research regarding the interactions between human flows and vehicular traffic throughout the day, could enrich this work. It is striking that the research findings can greatly contribute to a cohesive view of the function and the identity of street public space and its users. Furthermore, they provide the potential to be used as an input for the planning process for promoting the vitality and sociality of contemporary cities.

The research contribution of the paper constitutes a small but considerable step towards the efficient and just management of urban public spaces. Under these circumstances further research is needed in order to enlighten more crucial issues in the public realm of urban areas such as combined evaluation of accessibility and attractiveness of public spaces. A new research could either use features from our study highlighting other spatial and social issues of the city, or implement the suggested methodological approach to other study areas with similar characteristics in order to enrich the existing findings.

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