EXAMINING THE RELATIONSHIP BETWEEN SPATIAL DEMAND AND URBAN STREET ORGANIZATION: THE CASE OF KARDITSA CITY, GREECE

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Abstract

Social structures, economic organization, and the spatial configuration of urban space have long been understood as being shaped through a complex and symbiotic relationship. From a theoretical perspective, urban space is produced through the transformation of the natural environment into a structured built environment, giving rise to land-use patterns redefining existing forms of urban organization. In turn, these configurations attract population flows, thereby generating conditions for urban development and further transformations of the urban structure. Assuming that urban form's spatial organization reflects the socio-economic forces and processes that have shaped it over time, this paper builds on graph-theoretic modeling and on correlation analysis of network topology measures with land rent values and land-use indicators across the urban network, to examine the degree of urban spatial organization in relation to the demand for urban space. The analysis focuses on the road network of the city of Karditsa, Greece, and provides empirical insights into the connectivity, efficiency, and overall spatial organization of Karditsa's urban system, while also highlighting the extent to which the demand for urban space contributes to urban fabric's formation and evolution.

Keywords: urban development; land uses; rent values; network central nodes; urban centers.

JEL Classification: R12, R14, O18, P25.

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1. Introduction

The spatial distribution of economic activities and land use within cities has been a central topic in urban economics and geography since the beginning of the previous century (Capello, 2016; Polyzos, 2023). Classical approaches have established the theoretical basis for analyzing how transport networks and urban form jointly shape spatial demand (Polyzos, 2019), consistently demonstrating that road networks are not neutral infrastructures but active determinants of the spatial distribution of economic activity and land values. For instance, von Thünen's (1826) land rent theory provides a foundational framework for understanding how distance from a central point and transportation costs shape land values and determine agricultural and urban uses' allocation. Building on this rationale, Christaller's (1933) central place theory emphasized urban hierarchy and the role of accessibility, introducing the notion of "economic distance" as a key determinant of centrality and service provision. Losch's (1940) extended this framework with the configuration of a demand cone highlighting the interaction between accessibility, profit maximization, and consumer costs. Further contributions from urban economics' theories refine this understanding by explicitly addressing internal city structure. For instance, Burgess' (1925) concentric zone model proposed that urban land uses are arranged in rings radiating from the city center, reflecting processes of urban expansion and restructuring. Beyond linear development, Hoyt's (1939) sector model suggested that land uses are forming wedge-shaped sectors that reflect the influence of accessibility on land rents and urban growth dynamics. Subsequently, Harris and Ullman's (1945) multiple nuclei model provided a polycentric view of the city, where multiple centers (commercial, industrial, or residential) jointly structure land use patterns and urban demand.

In parallel, contemporary research has increasingly emphasized the quantitative analysis of urban systems through network-based approaches, applying graph theory (Diestel, 2005) and the network paradigm (Albert and Barabasi, 2002; Barthelemy, 2011; Tsiotas, 2019) to represent road systems as graphs, enabling the measurement of topological attributes, such as connectivity, centrality, and accessibility (Barthelemy, 2011; Osman, 2014; Tsiotas and Polyzos, 2018; Arif and Gupta, 2020). In transport geography, relevant studies (Rodrigue et al., 2023; Tsiotas and Ducruet, 2021; Tsiotas and Kallioras, 2025) have shown that nodes configuration, graph density, and overall network topology directly influence mobility patterns as well as land value distribution. Spatial networks analysis (Barthelemy, 20111 Tsiotas and Polyzos, 2018) further provides a ground for linking urban form to economic outcomes (Polyzos, 2023), demonstrating that highly connected areas tend to exhibit higher land demand, whereas poorly connected locations are often associated with underutilization. These approaches allow for the empirical assessment of how network efficiency (Capello, 2000; Barthelemy, 2011), node importance (Xue et al., 2017), and network resilience (Barthelemy, 2011; Tsekeris and Tsiotas, 2026) relate to rent levels (Andersson et al., 2006; Porta et al., 2006) and land-use patterns (Li et al., 2019; Zhao et al., 2022; Feng et al., 2026). Empirical literature (Benjamin and Sirmans, 1996; Porta et al., 2006; Safaralizadeh et al., 2024) further confirms that proximity to main roads, measures of network centrality, and accessibility to urban amenities significantly affect residential and commercial property values. At the same time, there is empirical evidence (Acheampong and Silva, 2015; Zeng et al., 2020; Tsiotas, 2021; Silva and Hurtubia, 2025) of a bidirectional relationship between transport infrastructure and urban development, where roads both respond to and shape underlying economic demand. In this context, areas with higher land demand tend to attract more intensive connectivity (Polyzos, 2019, 2023), while network design itself can either enable or constrain urban expansion (Tsiotas, 2017; Polyzos, 2023). Nevertheless, medium-sized cities remain relatively underexplored in the literature, as most studies focus on large metropolitan areas (Porta et al., 2006; Barthelemy, 2011; Boeing, 2017, 2019), leaving important gaps in understanding how these mechanisms operate in smaller urban systems.

Overall, relevant literature establishes a strong and consistent link between urban road network structure, land-use patterns, and spatial demand. Classical urban economic theories (Burgess, 1925; Christaller, 1933; Lösch, 1940; Alonso, 1967) provide the conceptual foundation, while modern network analysis and empirical studies (Porta et al., 2006; Barthelemy, 2011; Tsiotas and Polyzos, 2017; Tsiotas et al., 2017; Tsiotas, 2021) offer the methodological tools to measure and model these relationships in a quantitative context. Building on this framework, this paper examines the topological features of the road network of Karditsa, Greece –a medium-sized city of approximately 50,000 inhabitants (Polyzos, 2019, 2023)– in relation to rent levels, to explore how urban connectivity and accessibility shape the spatial distribution of demand. Karditsa's urban road network is modeled as an undirected, distance-weighted graph, allowing for an assessment of network efficiency and connectivity while also revealing how the spatial attractiveness of specific areas contributes to the formation of the urban fabric. The overall approach aims to provide a quantitative foundation for urban planning and policy, bridging traditional urban economics with contemporary spatial network analysis.

2. Data and Methods

Assuming that the spatial form of urban organization is shaped by spatial demand (Bento et al., 2005; Clifton et al., 2008; Polyzos, 2019, 2023), this study addresses the research question of whether the structural properties of Karditsa's major urban network (conceptualized as determinants of spatial organization) and rent prices (used as a proxy for spatial demand) are related. The study area is the Municipality of Karditsa (Tsiotas, 2017), for which primary data on geographic location, land use, and rent levels were collected from online sources (Spitogatos, 2024; YPEN, 2024). The methodological approach employs complex network analysis (Albert and Barabasi, 2002, Barthelemy, 2011; Tsiotas and Polyzos, 2018) to examine the structure and centrality of the urban road network and unveil how these spatial patterns relate to land value formation. In particular, the analysis seeks to identify the relationship between economic centers (Polyzos, 2023) and their corresponding topological centers (Koschutzki et al., Tsiotas, 2017) within the urban system. In technical terms, in the first stage, all nodes of the study area were mapped based on their geographical coordinates (x, y) in the WGS84 reference system (NIMA, 2000). Each node is uniquely defined, and a set of basic network measures was computed for all nodes using the Gephi (Bastian et al., 2009) software. A complementary database of rental prices was also constructed using data retrieved from a Greek rental search web platform (Spitogatos, 2024). Following this, institutionalized land-use categories were assigned to each spatial unit according to their building block's registry based on the General Urban Plan (GUP) of the expanded Municipality of Karditsa (Hellenic Republic, 2016; YPEN, 2024). The resulting integrated dataset was used for correlation analysis conducted in IBM SPSS (George and Mallery, 2024), where the variables included in the empirical analysis are summarized in Table 1.

Table 1: Variables included in the analysis

Variable	Description
LONG	Longitude (x).
LAT	Latitude (y).
Land Rent	Land Use Prices, per square meter (€/m^2).
Land Use: Residence	General Residential Land Use.
Land Use: Green Space	Green Spaces.
Land Use: Local Center	Land Use of Local Centers – Distinct Neighborhood Area.

Variable	Description
District	
Land Use: Tourism Areas	Tourism and Recreation Land Uses.
Land Use: Specific Land Uses	Specific Land Uses (e.g., industrial parks, sports complexes, schools, hospitals, protected urban spaces, etc.).
Land Use: Urban Center Area	Land Use for Urban Centers and Central Functions.
(Node) Degree	The number of graph edges being adjacent to a given node *i*. It expresses the communication potential of a node.
Weighted Degree	The sum of weights of the links being adjacent to a given node.
Eccentricity	The longest shortest path originating from a given node.
Closeness centrality	The average path lengths originating from a given node to all other nodes in the network. It is a measure of accessibility.
Clustering Coefficient	The probability a node to have neighbours connected. It is computed on the number of triangles configured by node to the number of the total triplets shaped by this node.
Betweenness Centrality	The proportion that is defined by shortest-paths passing through a given node to the total shortest-paths in the network. It expresses intermediacy.

Table 1 brings together a coherent set of variables operationalizing the relationship between spatial position, land-use structure, and urban network topology, thereby providing an integrated empirical framework for examining how spatial demand is reflected in both land values and network configuration. In this context, the null hypothesis (H_0) in this research assumes that topological centers are not associated with economic centers, whereas the alternative hypothesis (H_1) posits that there is a statistically significant relationship between network topology and urban morphology, aiming to to assess the extent to which the topological structure of urban space influences rent levels as an expression of spatial demand. In detail, the geographic coordinate variables (*LONG*, *LAT*) provide the foundational spatial reference system of the analysis, enabling the precise localization of each node within the urban fabric of Karditsa. In parallel, the *Land Rent* variable captures the economic dimension of spatial demand, expressed through rental prices per square meter, and serves as a direct proxy for land value formation within the city. The *Land-Use* variables introduce a functional layer to the analysis by distinguishing between key categories of urban activity, including *Residential areas*, *Green Spaces*, *Local Center District*, *Tourism and Recreational Areas*, *Specific Land Uses*, and *Urban Central Areas*. This classification allows for a structured interpretation of how institutionalized and de facto land-use patterns interact with both accessibility and economic valuation. Finally, the set of network topology varaibles (*Degree*, *Weighted Degree*, *Eccentricity*, *Closeness Centrality*, *Clustering Coefficient*, and *Betweenness Centrality*) provides a multidimensional characterization of each node's structural position within the urban road network. Collectively, these measures of network topology capture different aspects of connectivity, accessibility, and intermediary potential (Tsiotas and Polyzos, 2018; Tsiotas, 2019), which are central to understanding how spatial structure conditions movement, interaction, and, ultimately, urban economic outcomes. Taken together, the variables in Table 1 form an operational bridge between urban economic theory and spatial network analysis, enabling the empirical testing of whether topologically central locations correspond to economically central areas, thereby linking the structural properties of the urban network to patterns of land value and spatial demand.

3. Results and Discussion

3.1. Correlation of rental values with centrality measures

The results of the bivariate correlation analysis are shown in Table 2, complemented by some corresponding spatial distribution layouts and boxplots shown in Figures 1, 2 and 3. Beginning with Figure 1, the boxplots examination indicates that rent prices vary across different levels of network degree. In particular, the boxplot corresponding to degree $k = 2$

exhibits a higher average rent value compared to the other categories, while degree $k = 4$ also shows relatively elevated values compared to other degree cases ($k = 1$, 3, and 5). However, inspection of the mean-value trajectory across degree classes suggests that higher network degree does not systematically correspond to higher rent levels. This pattern indicates a non-linear and non-monotonic relationship between network connectivity and land values, rather than a simple positive gradient. More broadly, the observed distribution in Figure 1 points to an urban structure characterized by polycentric tendencies, where spatial demand and land value formation are not exclusively concentrated at the most highly connected nodes. This interpretation is further supported by the presence of designated local center and neighborhood-scale land-use areas within Karditsa's urban fabric, which reinforce a multi-nodal configuration of economic activity and spatial demand.

Table 2: Measures of GTN's network topology across different levels of link filtering

		Pearson Correlation	**Sig. (2-tailed)**	**N**
Value/sqrm	Land Rent	1		1291
	LONG	.034	.216	1291
	LAT	.230**	.000	1291
	Degree	.191**	.000	1291
	Weighted Degree	-.015	.597	1291
	Eccentricity	-.162**	.000	1291
	Closness Centrality	.434**	.000	1291
	Clustering	-.012	.678	1291
	Betweeness Centrality	.079**	.005	1291

(Own elaboration)

In general, an urban center is defined as the spatial concentration of economic activities and urban functions (Tsiotas, 2017; Yu et al., 2021; Polyzos, 2023). Contemporary large cities are increasingly understood as polycentric systems, characterized by the emergence of multiple centers that redistribute functions across peripheral and intermediate zones (Polyzos, 2023). In line with von Thünen's (1826) model, increases in distance from the urban center are associated with declining land values, ceteris paribus, while the relocation of economic activity toward central locations implies a higher land rent gradient due to increased accessibility and competition for space (Polyzos, 2023). Within this theoretical framework, urban land values are determined not by a single central point, but by a network of interacting nodes that jointly structure spatial accessibility and economic attractiveness. The analysis of the topological layout in Figure 1 supports this interpretation. Nodes with higher degree values are predominantly concentrated in the central areas of the network. In particular, nodes corresponding to higher connectivity classes (notably degree 4) are primarily located within the urban core, while lower-degree nodes (1–3) are more frequently distributed toward the periphery of the urban fabric. This spatial pattern suggests that peripheral areas are characterized by reduced connectivity and fewer direct interactions within the network structure.

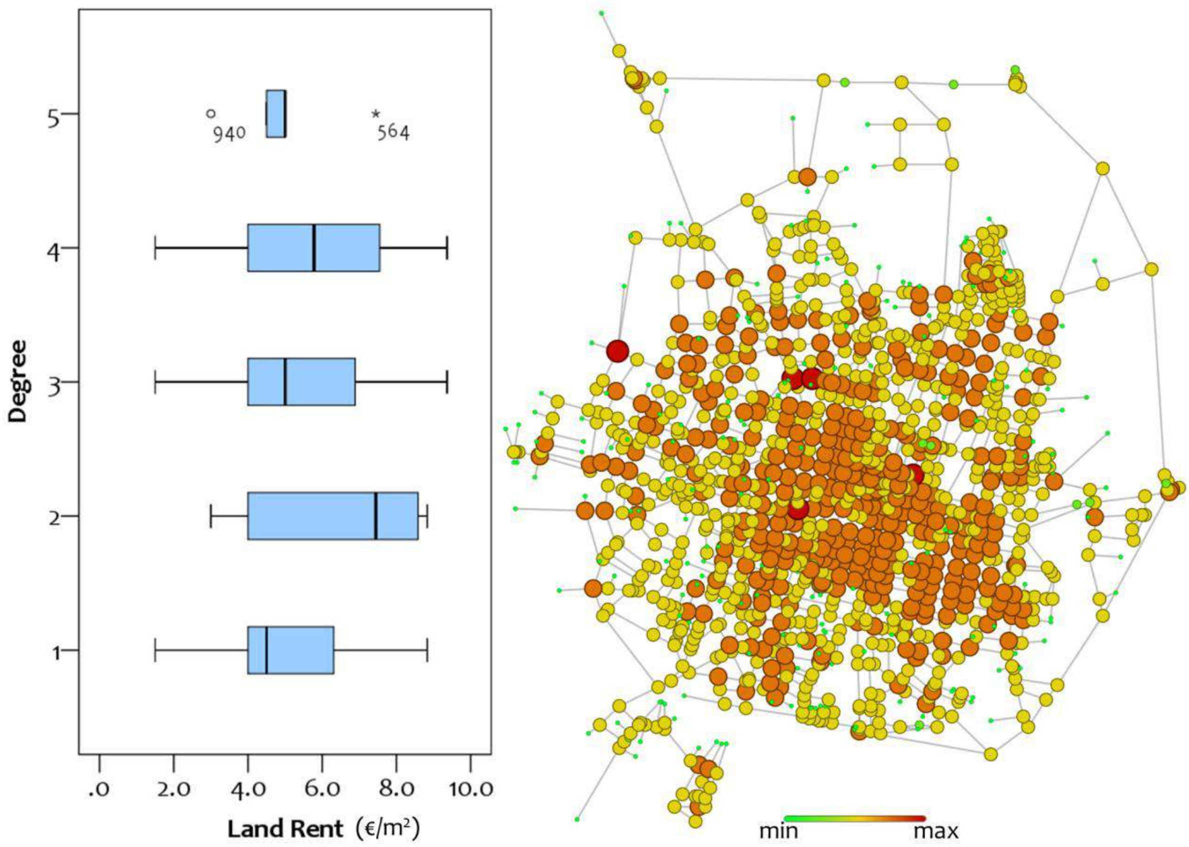

Figure 1. (Left) Correlation (box) plot of the variables Land Rent and node Degree and (right) the geo-referenced layout of the node degree's spatial distribution (red colored and larger in size nodes corresponds to higher values of node degree).

The correlation analysis reported in Table 2 further reveals a positive, albeit moderate, relationship between closeness centrality and rent levels, describing that nodes occupying more central positions within the network tend to be associated with higher land rents. This result is consistent with von Thünen's (1826) bid-rent framework, according to which urban space is allocated according to the ability of agents to pay for accessibility advantages. It also aligns with the Central Business District (CBD) concept (Burgess, 1925), which emphasizes the role of central locations in minimizing transport costs and maximizing accessibility, thereby attracting activities with higher bid-rent capacities, particularly commercial uses. In this context, centrality exerts a clear influence on land values, as centrally located areas offer superior access to goods, services, and interactions (Polyzos, 2023), which is reflected in higher rent levels. Nevertheless, such concentration pressures may also generate diseconomies that limit further centralization. For the case of Karditsa, the results suggest that average rent increases with closeness centrality, thus reinforcing the interpretation that topological centrality is a key determinant of spatial variation in land values within the urban system. Moreover, the topological layout in Figure 2 indicates that most nodes exhibiting high closeness centrality (depicted in dark red and larger in size nodes) are concentrated in the municipal core of Karditsa. This spatial pattern suggests that the urban center operates as the principal accessibility hub within the network, comprising nodes that can reach all other parts of the system through shorter average path lengths. In contrast, peripheral areas of the municipality display a considerably lower concentration of highly central nodes, implying weaker integration into the overall network structure and longer travel distances to other locations within the system.

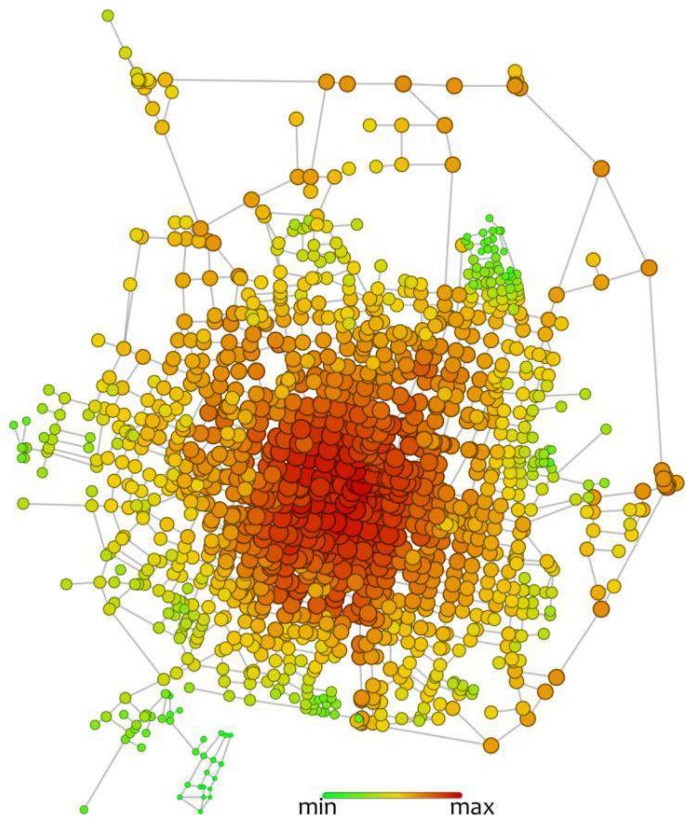

Figure 2. The geo-referenced layout of Closeness Centrality's spatial distribution (red colored and larger in size nodes corresponds to higher values of closeness centrality).

Next, Figure 3 shows boxplots capturing the relationship between land rent (value/m^2) and node eccentricity, which is a fundamental measure in network analysis for centrality (Tsiotas and Tselios, 2022) assessment. Eccentricity $e(v)$ of a node v in a connected graph G is defined as the maximum shortest-path distance $d(v,u)$ between v and any other node u in the network (Hage and Harary, 1995; Koschutzki et al., 2005; Tsiotas and Tselios, 2022), where $d(v,u)$ denotes the length of the geodesic path connecting the two nodes. Within this framework, higher eccentricity values indicate more peripheral and less accessible positions in the network structure. The results in Figure 3 suggest that increases in land rent are associated with decreases in eccentricity, indicating that higher-value locations tend to occupy more central and accessible positions within the urban network. This relationship is further supported by the Pearson's correlation coefficient (−0.162) and the associated p-value (0.0) shown in Table 2, which confirm a statistically significant, albeit weak, negative correlation between the two variables. The mean values' trend across eccentricity classes further illustrates variation in rent distribution, with the highest average rents observed at the lowest eccentricity levels (32, 33, 34). Beyond these values, average rents remain generally lower and do not exhibit a consistent monotonic pattern. Overall, the rents' distribution across eccentricity's levels does not follow a strictly linear or uniform trend, highlighting the multivariable nature of urban land valuation processes. This suggests that while network centrality plays a measurable role in shaping rent gradients, it interacts with additional spatial, functional, and institutional factors that jointly determine the observed heterogeneity in land prices.

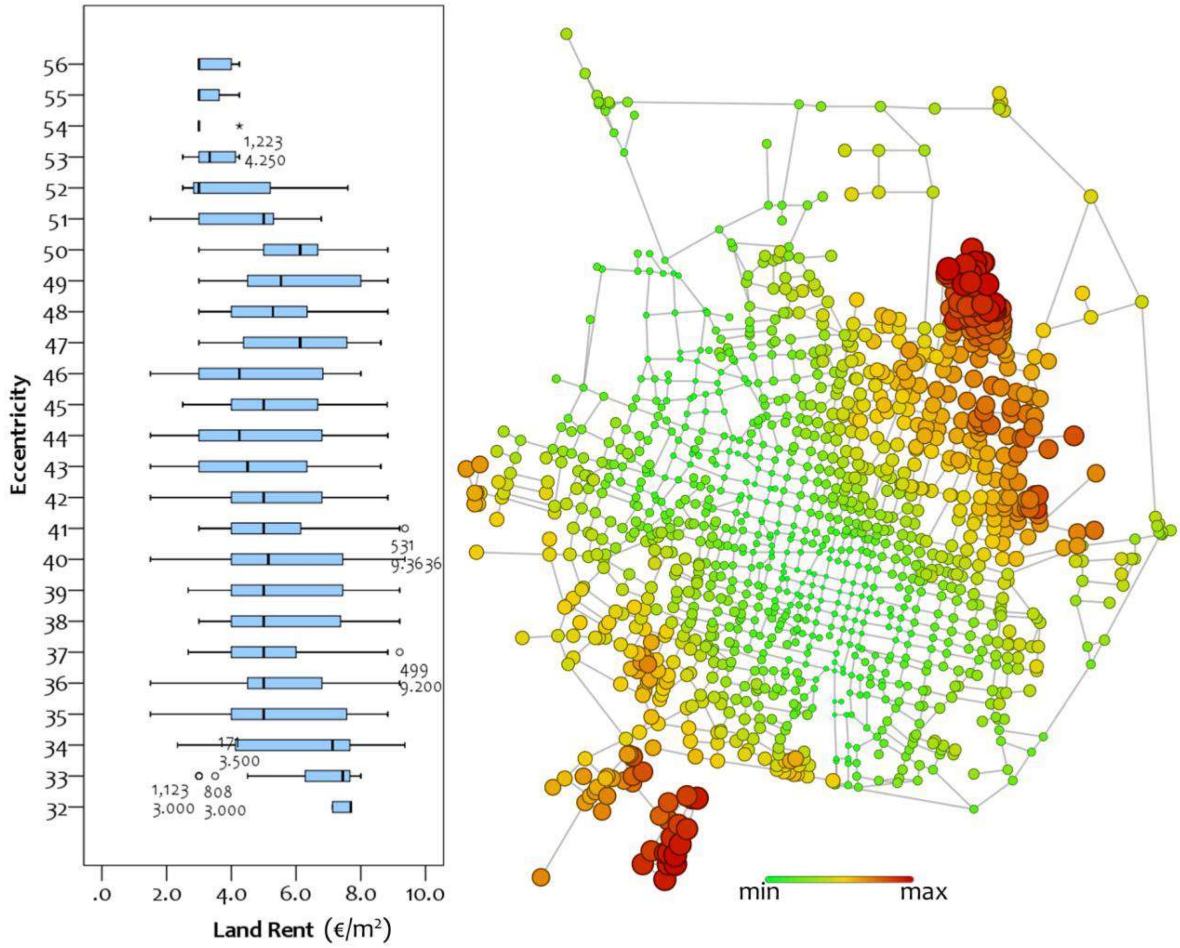

Figure 3. (Left) Correlation (box) plot of the variables Land Rent and Eccentricity and (right) the geo-referenced layout of eccentricity's spatial distribution (red colored and larger in size nodes corresponds to higher values of eccentricity).

Further, the eccentricity's spatial distribution in Figure 3 depicts the structural asymmetry of nodes within the urban network of Karditsa. Provided that eccentricity can be seen as a measure of a node's relative peripherality (Tsiotas and Tselios, 2022) within the network, the observed spatial pattern in Figure 2 reveals a clear zonal formation, where the most central nodes configure a contiguous core area illustrated in small-sized green nodes corresponding to eccentricity values between 30 and 39. This zone occupies the structural center of the network and reflects the highest accessibility levels in terms of maximum network distance. Surrounding this core, an intermediate ring of nodes (depicted in larger in size green colored nodes), exhibits eccentricity values between 40 and 49. These nodes are less centrally integrated but still maintain relatively moderate maximum distances to all other nodes in the system. Finally, nodes with the highest eccentricity values (50 and above), shown in red color, are predominantly located at the periphery of the urban fabric, indicating weaker integration and greater remoteness from the network core. Overall, the results in Figure 3 highlight a pronounced spatial clustering of nodes according to eccentricity levels, with a clear gradient of decreasing centrality from the urban core toward the outskirts.

Moving on path centrality, the spatial layout of betweenness centrality in Figure 4 illustrates the complex topological procedure of betweenness centrality, which measures the extent to which a node acts as an intermediary in the flow of shortest paths (Koschutzki et al., 2005; Newman, 2010), capturing its bridge role (intermediacy) over network connectivity. In general, nodes with high betweenness values typically occupy strategic positions within the network (Barthelemy, 2011), such that their removal would substantially alter a large number of shortest paths and disrupt overall connectivity. In the case of Karditsa, Figure 4 illustrates that the majority of high betweenness centrality nodes (shown in orange and red on the map) are concentrated in the center and the ring road of the municipality. This suggests that the most central nodes play the most important role in connecting the entire network highlighting at the same time the importance of a ring road for the urban fabric's connectivity.

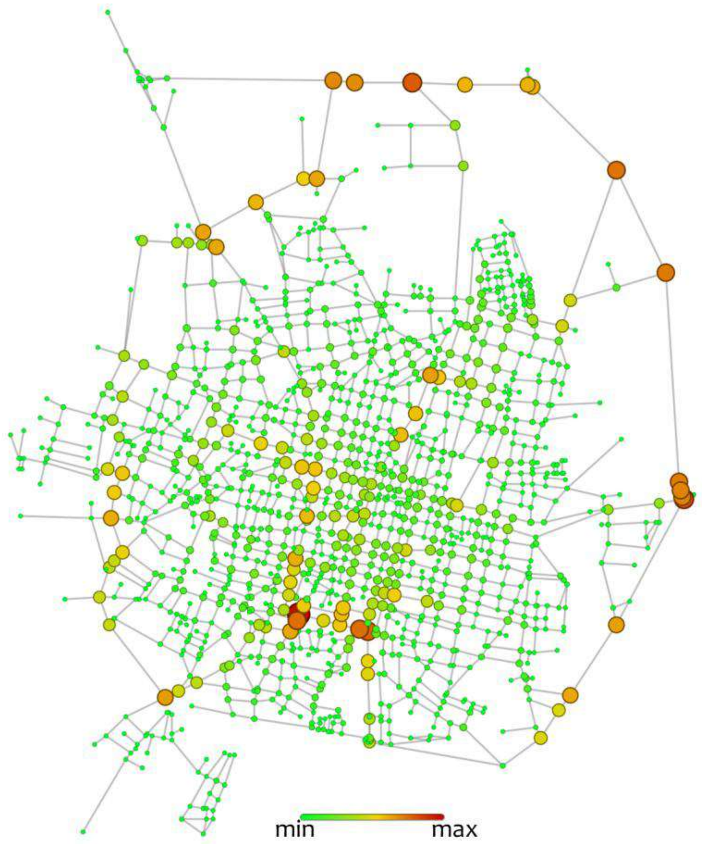

Figure 4. The geo-referenced layout of Betweenness Centrality's spatial distribution (red colored and larger in size nodes corresponds to higher values of betweenness centrality).

In computational terms, the betweenness centrality results in Table 2 indicate a positive, albeit weak, correlation between land rent (price per square meter) and betweenness centrality. This suggests that nodes with higher intermediary importance tend, on average, to be associated with higher rental values. However, provided that ring-road positions do not exhibit high land rent values, the correlation shown in Table 2 does not imply a strictly monotonic relationship. This observation describes that betweenness alone does not fully account for variations in land prices and pointing to the influence of additional spatial, functional, and institutional determinants of urban rent formation beyond purely topological centrality.

3.2. Correlation of centrality measures with land uses

The error bars in Figure 5 illustrate the variation in average Degree across different land-use categories, computed under a 95% confidence interval. The results indicate that Degree Centrality is not uniformly distributed across land uses, but instead exhibits systematic variation depending on functional urban specialization. In particular, nodes associated with the identified land-use categories (category 1) tend to have average Degree values of approximately 3.05 connections and above, whereas nodes not assigned to a land-use category (category 0) tend exhibit lower average values, generally below 3.00 connections. These results suggest that functionally defined urban areas are more strongly integrated within the road network, reflecting higher levels of connectivity and interaction potential. In terms of interpretation, they support the assumption that land-use specialization is closely linked to the structural properties of the urban network, with more active or strategically located functions tending to occupy nodes with greater topological importance.

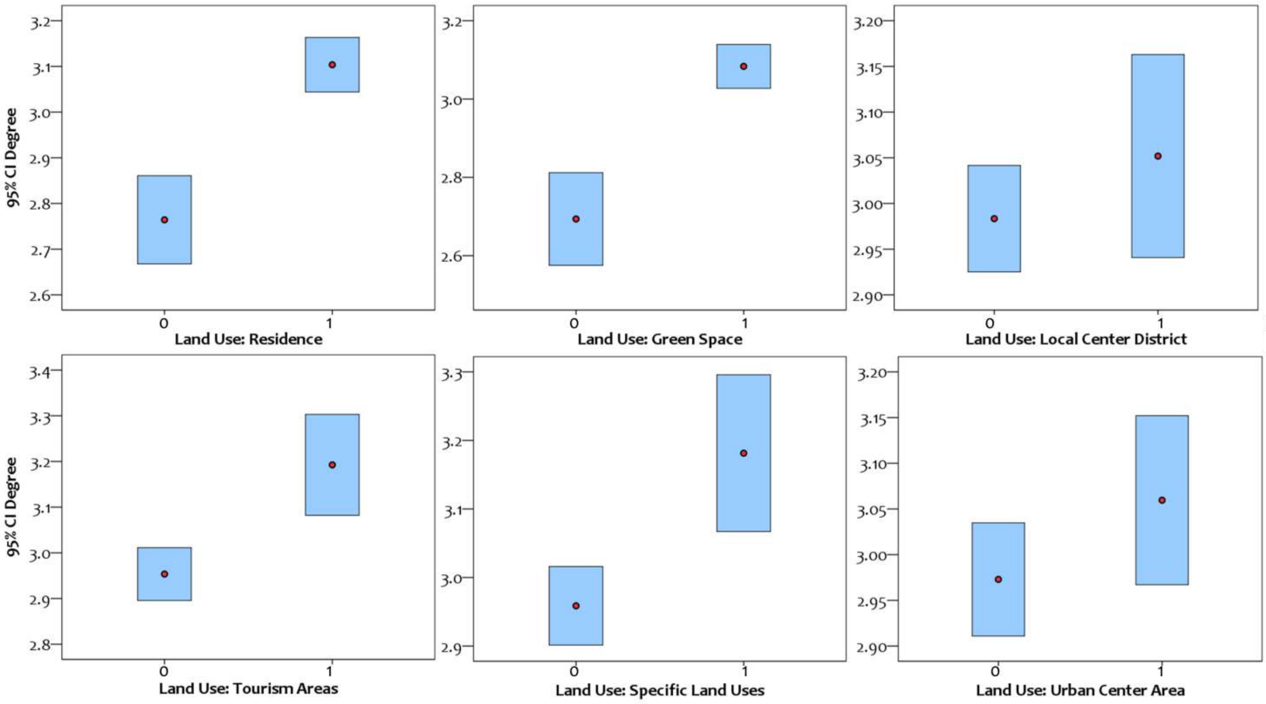

Figure 5. Error bars of 95% CIs for degree by land uses.

Next, the results presented in Figure 6 indicate that betweenness centrality varies across land-use categories in a broadly consistent manner. In general, nodes with high betweenness centrality are structurally important, as they frequently mediate flows between different parts of the network and can significantly influence overall accessibility (Wang et al., 2011), while those with low betweenness centrality appear less frequently on shortest paths and therefore play a more marginal role in network connectivity. In particular, nodes associated with a land use exhibit higher average betweenness values compared to those without a land-use classification, suggesting that functionally defined urban locations tend –on average– to occupy more intermediary positions within the network structure. At a first-order level of interpretation, these findings imply that nodes associated with land uses are more likely to serve as connectors within the urban system, facilitating movement and interaction across different city compartments. Secondarily, these findings reinforces the view that land-use specialization is not only associated with higher levels of activity, but also with increased structural importance in terms of network flow and spatial integration.

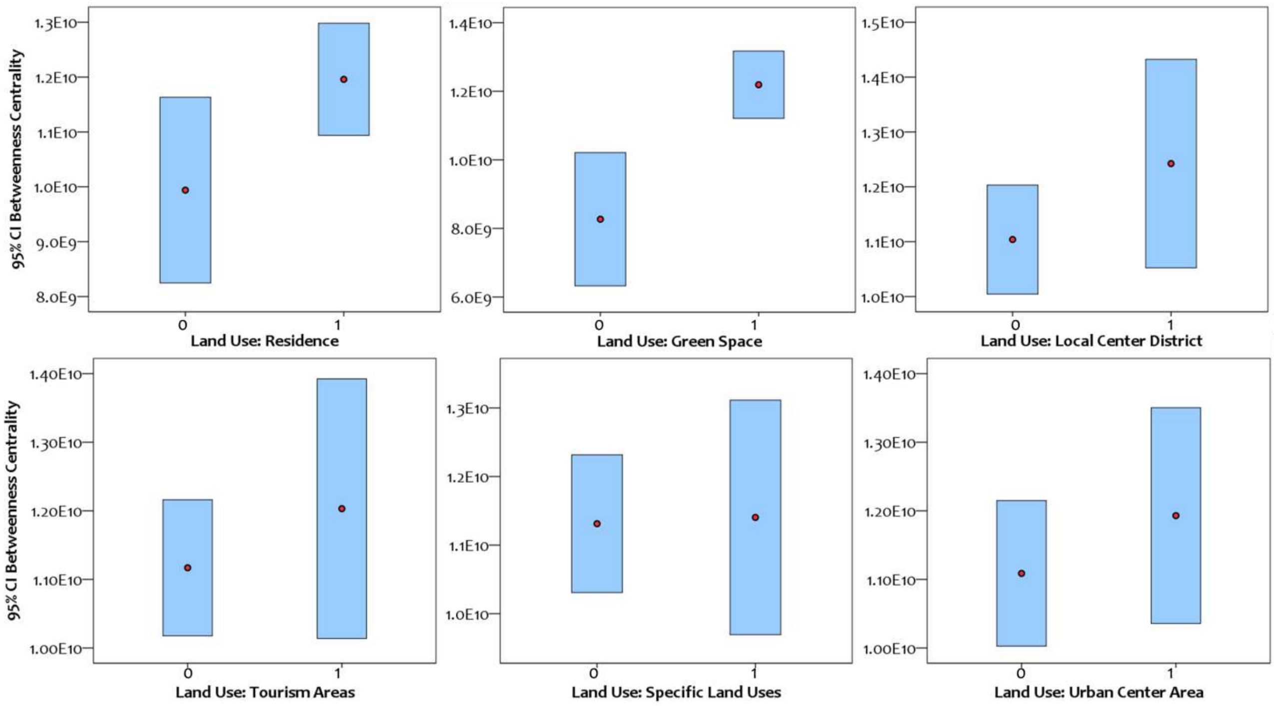

Figure 6. Error bars of 95% CIs for betweenness centrality by land uses.

According to the error bars in Figure 7, the total range of Eccentricity values for all land uses ranges from 40.25 to 41. However, for the "specific land uses" and "urban center-central functions" cases, the average Eccentricity of nodes associated with a land use is higher than those not assigned to a land-use, while for other cases of land uses this relationship appears reversed. This finding indicates either a trend towards decentralization of these land uses or the existence of more than one center within the urban fabric, therefore reinforcing the understanding of the complexity of the spatial organization of the Municipality of Karditsa. Next, closeness centrality is defined as the inverse of the total binary distance calculated on the shortest paths starting from a given node with destinations to all other nodes in the network (Tsiotas, 2021), expressing a node's accessibility in terms of steps of separation. The error bars in this case (Figure 8) indicate that all land uses are centrally located in the network and that the distance between nodes does not differ significantly, suggesting a homogeneous and accessible network in terms of main land uses.

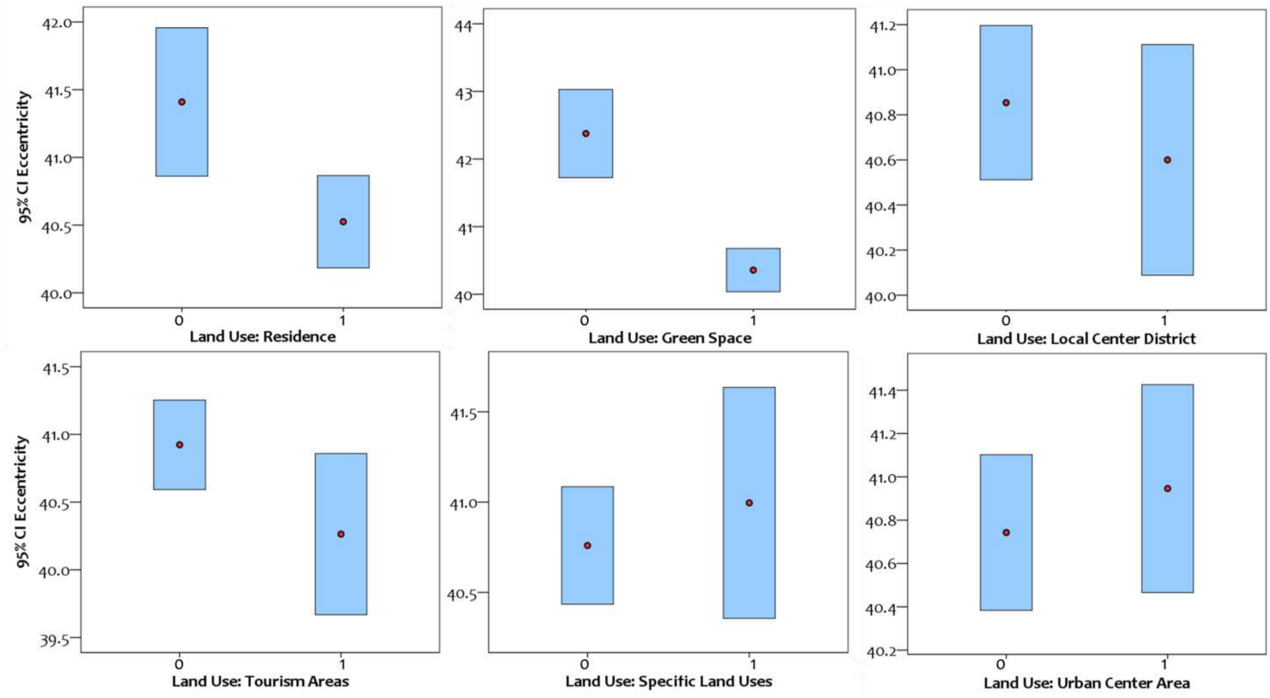

Figure 7. Error bars of 95% CIs for eccentricity by land uses.

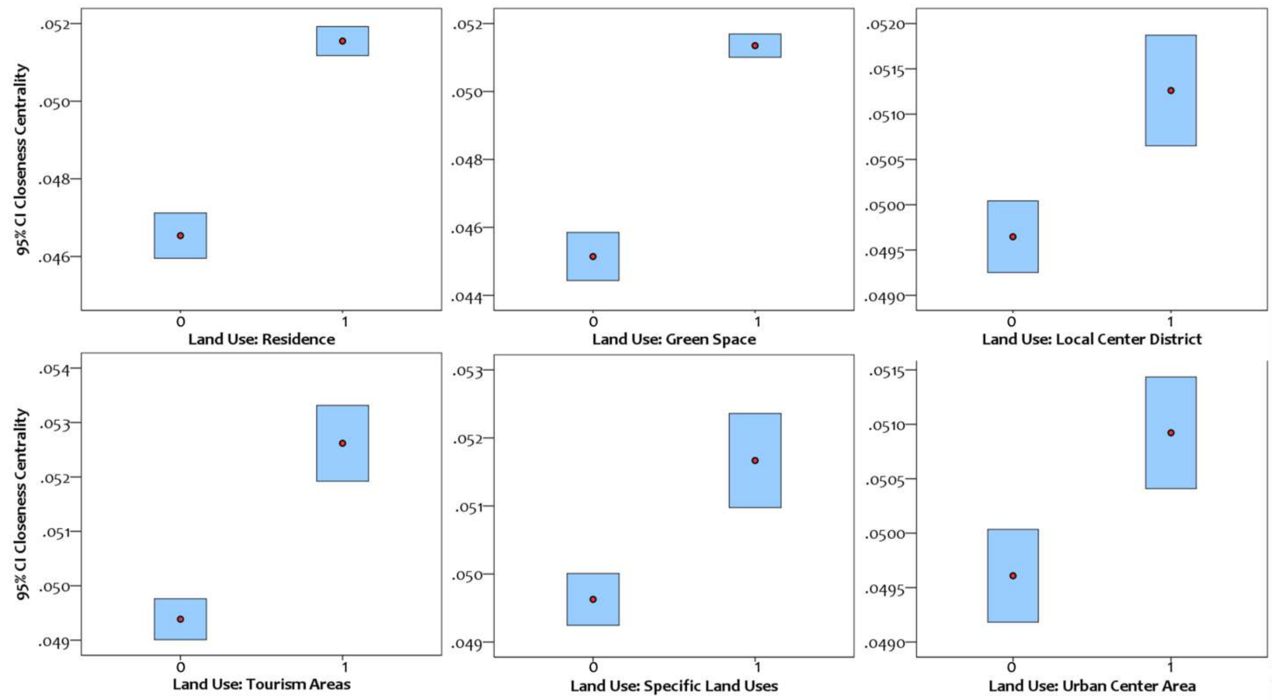

Figure 8. Error bars of 95% CIs for closeness centrality by land uses.

Finally, the clustering coefficient expresses the degree to which nodes tend to cluster together (Wang et al., 2011; Tsiotas, 2019), capturing the degree of mutual connectivity between a node's neighbors. Higher clustering coefficient values indicate denser mutual neighborhood connectivity and consequently cluster formation. In this context, Figure 9 shows that specific land uses, tourism-recreation, and urban center-central functions have the highest values of the basic measure, illustrating in general that geographically located land uses are more likely to form clusters.

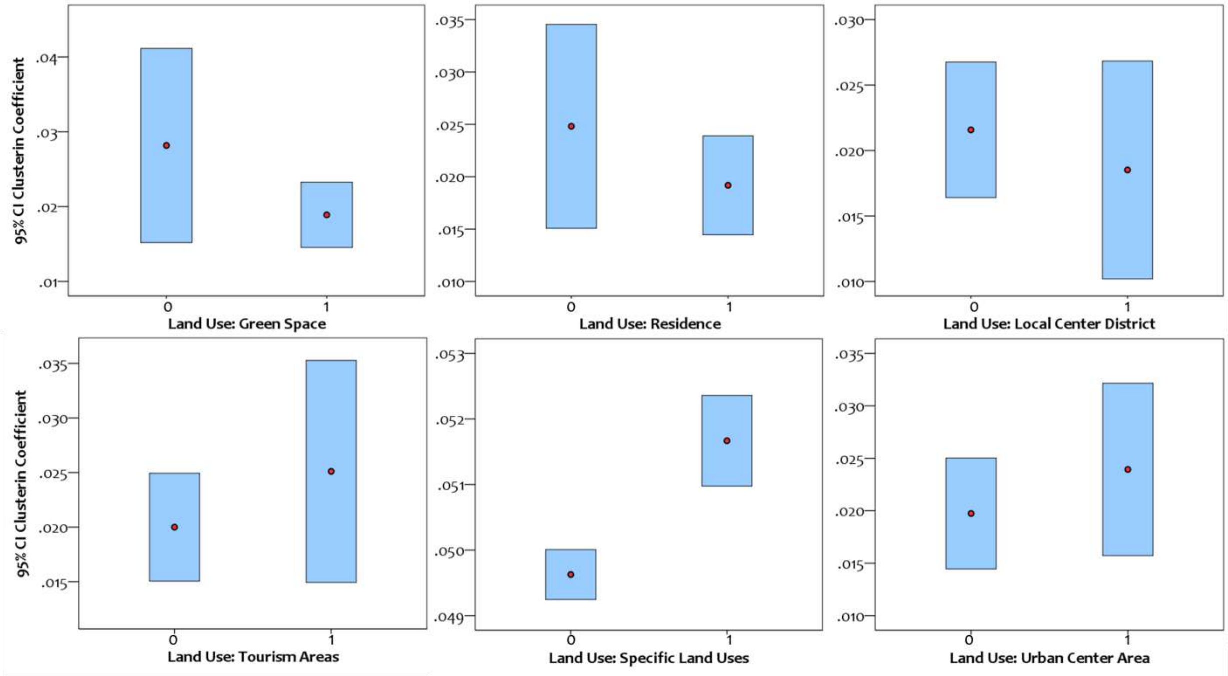

Figure 9. Error bars of 95% CIs for clustering coefficient by land uses.

The lack of an integrated policy in Greece on land use in recent years has significantly shaped urban, peri-urban, and rural areas (Petrakos and Psycharis, 2016; Polyzos, 2019). This has resulted in the creation of areas with mixed land uses, a phenomenon that has both positive and negative effects on the urban fabric and its inhabitants (Stefanou and Mitoula, 2006), where a typical example of a city with mixed land uses suggests the city of Karditsa. In particular, tourism and recreation land use's layout in Figure 10 shows scattered nodes within the urban center, indicating that this is not a common land use. This phenomenon may be due to two main factors: firstly, the fact that urban tourism has not developed to a high degree in Karditsa, and secondly, that tourism and recreation is incompatible with other dominant land uses, such as general residential use. Next, the distribution of general residential land use in the urban fabric of Karditsa, combined with the historical background of urban planning in Greece (Polyzos, 2023), implies that residential areas do not constitute a distinct zone in the city. General residential land use is part of an urban fabric with mixed land uses, in contrast to many European cities that apply "strict" land use zones (Stefanou and Mitoula, 2006). The case of mixed land use has both positive and negative outcomes. On the one hand, mixed land use can offer a more vibrant and dynamic urban environment, while, on the other hand, the incompatibility between certain uses (e.g., industry and housing) often leads to functional and environmental problems.

Figure 10. The geo-referenced layouts of the land use variables

From the urban green space layout (Figure 10), it can be observed that green areas are predominantly concentrated in the northwestern and southwestern sectors of the urban fabric. At the same time, a substantial share of the city's surface is occupied by green infrastructure, including parks, squares, and other recreational open spaces. This spatial configuration suggests a relatively well-developed system of urban green amenities embedded within the fabric of Karditsa. Provided that urban green space constitutes a key determinant of environmental quality and is widely recognized in the literature as positively affecting property values (Safaralizadeh et al., 2024), empirical studies further confirm that parks and forested areas exert a significant positive impact on residential prices, particularly when accessibility and proximity are taken into account. For instance, spatial econometric evidence (Panasolo et al., 2020) indicates that dwellings located in close proximity to urban parks tend to command higher prices, with this premium diminishing as distance increases. Within this framework, the spatial distribution of green areas in Karditsa may be interpreted as a factor contributing to localized variations in land value formation.

Next, the neighbourhood (local center) land-use category (Figure 10) represents a structured and functionally integrated urban unit operating as an intermediate scale between the household and the broader city center. It is characterized by a combination of social, infrastructural, and environmental functions, and is designed to accommodate the basic daily needs of residents, including education, retail activity, services, and leisure (Polyzos, 2023). In this paper's analysis, the spatial distribution of this land use reveals the existence of localized sub-centers, which contribute to the formation of smaller-scale neighborhood units within the wider urban system. This pattern is consistent with a polycentric urban structure, where basic services are partially decentralized, thereby enhancing the functional autonomy and internal cohesion of local urban units. Finally, the distribution of urban center and central function land uses (Figure 10) exhibits two main clusters: a highly concentrated core in the city center and a secondary, less dense cluster within the wider central area. The observed pattern of polycentricity in Karditsa may therefore be partly explained by the functional incompatibility between certain land-use categories, which encourages spatial clustering and differentiation of activities. A characteristic example is the spatial concentration of offices and retail establishments within central areas, both of which fall under institutionalized central uses defined by planning regulations. Their co-location in the urban core underscores the continued importance of centrality for commercial and professional functions, despite emerging decentralizing tendencies. Overall, the land-use distribution analysis suggests that most functions remain concentrated in or near the urban center, while also exhibiting elements of functional mixing across the urban fabric, indicating an absence of strong land-use segregation and points toward a mixed-use urban environment. Such mixed-use configurations are widely regarded in the literature as more sustainable (Kweon et al., 2010), as they enhance accessibility, reduce travel demand, and support more efficient urban form.

4. Conclusions

Rapid urban development and population growth in cities have been dominant phenomena over the last century, leading to significant changes in urban areas. This development is taking place at different rates in different countries around the world, but it raises one of the most fundamental concerns: *the direct impact on land prices and rents in relation to spatial forms and organization*. The constant need for housing and the coverage of human activities make space a mediating commodity where land uses are developed and the needs for both housing and economic activities are met. Understanding the mechanisms of urban development and fluctuations in rental prices enables the effective implementation of housing policies, the subdivision of urban centers, the improvement of spatial planning, and the uniform distribution of public infrastructure.

The analysis of urban networks is a methodological approach which, through graph modeling and measures of network topology calculation contributes to the identification of the central elements and topological characteristics of the network. At the same time, urban development theories provide a ground for interpreting the economic dimension of these centers. The correlation between centers with different dimensions (topological and economic) was investigated in this paper revealing that land uses are mainly concentrated in the topological center of the urban center of Karditsa, Thessaly, Greece. General residential land use and green spaces occupy the majority of nodes, while the remaining categories are sparsely scattered throughout the city. In the urban network of Karditsa prices do not show large deviations, but fluctuations are noticeable between the more central points and the points on the outskirts of the urban fabric. The correlation of major topological measures with land use documents the variation in rents per square meter between central nodes. Finally, it is important to emphasize that every urban society is unique, with its own particular characteristics and challenges to address. Sustainable urban development requires a tailored approach that takes into account the adoption of basic design principles and the implementation of measures to improve conditions in the city. It is important to address the specificities of each urban fabric through methods and tools, and to develop strategies that focus on people, society, and the environment, with the aim of eliminating the “mistakes” of the past and creating new prospects for cities.

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