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Research Article

Evaluation of the Location and Accessibility of Parking Lots using GIS-Based Analyses

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Abstract

This study investigates the spatial distribution and accessibility of parking facilities in İzmir, Türkiye, with a focus on their integration with public transportation systems. The analysis examines three types of parking facilities: on-street parking, off-street outdoor parking, and off-street indoor parking (parking garages). Using GIS-based methods, service areas were delineated for each parking type based on 400m and 800m walking thresholds, evaluating their proximity to public transportation stations, including rail transit stations, transfer hubs, and ferry ports. The results indicate that on-street parking is concentrated in high-density commercial areas, while off-street indoor parking is primarily located near major urban attractions. However, access to public transportation stations is limited, especially for off-street indoor parking facilities. In contrast, off-street outdoor parking facilities, although high in capacity, face challenges with public transport accessibility, particularly in the southern parts of the city. Strategic parking placement in areas such as Karşıyaka, close to rail stations and ferry terminals, illustrates a more effective multimodal transport integration. The study emphasizes the need for improved parking management and a more balanced distribution of parking infrastructure across the city to enhance accessibility to public transportation and promote sustainable urban mobility.

Keywords: *Parking Lot, GIS, Service Area, Network Analysis, Public Transportation, Accessibility*

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Kent İçi Otopark Alanlarının CBS Tabanlı Analizlerle Konumu ve Erişilebilirliğinin Değerlendirilmesi

Öz

Bu çalışma, İzmir, Türkiye'deki otoparkların mekânsal dağılımını ve erişilebilirliğini, özellikle de toplu taşıma sistemleriyle entegrasyonlarını incelemektedir. Analiz, üç tür otoparkı ele almaktadır: yol üzeri otoparklar, açık alan otoparkları ve kapalı alan otoparkları. GIS tabanlı yöntemler kullanarak, her otopark tipi için 400 m ve 800 m yürüme mesafeleriyle hizmet alanları belirlenmiş, bunların demir yolu istasyonları, transfer noktaları ve feribot terminalleri gibi toplu taşıma istasyonlarına yakınlıkları değerlendirilmiştir. Sonuçlar, yol üzeri otoparkların yoğun ticaret alanlarında yoğunlaştığını, kapalı alan otoparklarının ise genellikle büyük kentsel cazibe noktalarına yakın olduğunu göstermektedir. Ancak, özellikle kapalı alan otoparklarının toplu taşıma istasyonlarına erişimi sınırlıdır. Diğer taraftan, açık alan otoparkları, yüksek kapasiteye sahip olmalarına rağmen, özellikle şehrin güney kesimlerinde toplu taşıma duraklarına erişimi sınırlıdır. Karşıyaka ilçesinde, demir yolu istasyonlarına ve feribot istasyonlarına yakın stratejik otopark yerleşimi, daha etkili bir çoklu taşımacılık entegrasyonunu göstermektedir. Çalışma, daha iyi bir otopark yönetimi ve şehrin genelinde daha dengeli bir otopark altyapısı dağılımının gerektiğine, bunun da toplu taşıma erişilebilirliğini artırarak sürdürülebilir kentsel mobiliteyi teşvik edeceğine vurgu yapmaktadır.

Anahtar kelimeler: *Otopark, CBS, Hizmet Alanı, Ağ Analizi, Toplu Taşıma, Erişilebilirlik*

1. Introduction

The rapid pace of urbanization, coupled with the increasing number of motor vehicles, has significantly intensified the complexity of urban transportation systems, leading to numerous challenges such as traffic congestion, insufficient parking capacity, and unregulated parking practices (Parmar et al., 2020; Aydinoglu and Iqbal, 2021; Jonuzi et al., 2024). As an essential component of urban transportation infrastructure, parking facilities play a crucial role in ensuring the efficiency and sustainability of transportation networks. The inadequacy of available parking spaces forces drivers to spend excessive time searching for vacant spots, thereby exacerbating congestion and disrupting traffic flow (Aliniai et al., 2015; Levy and Benenson, 2015). Additionally, the scarcity of parking facilities often compels motorists to travel extra distances in pursuit of parking, leading to increased fuel consumption, elevated carbon emissions, and environmental degradation (Ozturk and Kilic-Gul, 2020; Aydinoglu and Iqbal, 2021). This issue is particularly pronounced in central business districts and densely populated commercial areas, where prolonged searches for parking result in wasted time, higher individual costs, and adverse environmental impacts (Karimi et al., 2020). Consequently, as urban transportation efficiency declines, the implementation of sustainable mobility policies becomes increasingly challenging.

Strategic planning of parking infrastructure is essential for optimizing urban transportation systems and regulating traffic flow. Inadequately located or poorly designed parking facilities contribute to increased congestion, impede pedestrian movement, and diminish the overall functionality of urban transport networks (Farzanmanesh et al., 2010; Demir et al., 2021). Therefore, parking area planning must incorporate multiple factors, including land use patterns, population density, economic considerations, public transportation integration, and regional transportation demand (Mingardo et al., 2015). Moreover, ensuring the accessibility of parking facilities is a key priority, not only for private vehicle users but also for pedestrians who require safe and convenient access to parking areas (Jonuzi et al., 2024). A well-structured parking management strategy should aim to provide sufficient parking opportunities while simultaneously promoting integrated solutions aligned with sustainable transportation objectives (Sola et al., 2018).

Improving parking accessibility contributes to the overall efficiency of urban transport and facilitates a more structured traffic flow (Mcshane ve Meyer, 1982). Developing policies and strategies to enhance parking accessibility is therefore critical in fostering sustainable urban mobility (Ford et al., 2015; Tome et al., 2018). In this context, innovative approaches such as smart transportation systems, digital guidance technologies, and demand-based parking management have gained

prominence as effective tools for improving parking efficiency.

Various analytical and systematic methodologies are utilized to determine optimal parking locations. Geographic Information Systems (GIS)-based spatial analyses, multi-criteria decision-making (e.g., Analytical Hierarchy Process (AHP), TOPSIS, and Fuzzy AHP) techniques (Kirlangicoglu, 2016; Ozkan et al., 2020; Bilgilioglu, 2022; Elmacioglu et al., 2025), and spatial modeling approaches facilitate the strategic placement of parking infrastructure (Farzanmanesh et al., 2010; Karimi et al., 2020; Jonuzi et al., 2024). The application of such methodologies enables a more accessibility-oriented approach to parking planning, thereby improving the overall performance of transportation systems (Mitropoulos et al., 2023). Additionally, incorporating factors such as user preferences, regional traffic dynamics, and infrastructure capacity in parking location assessments is fundamental to achieving sustainable and efficient parking management (Dinda et al., 2019; Ozturk and Kilic-Gul, 2020).

Urban parking planning is not only crucial for private vehicle users but also for pedestrians, public transport passengers, and cyclists (Levy and Benenson, 2015; Aydinoglu and Iqbal, 2021; Demir et al., 2021). A well-planned parking infrastructure alleviates congestion, enhances transportation network efficiency, and supports overall urban mobility (Aliniai et al., 2015; Kulinich and Lee, 2016). Moreover, providing accessible and cost-effective parking solutions fosters the sustainable development of commercial, administrative, and social activities (Karimi et al., 2020; Jonuzi et al., 2024). Therefore, parking planning should not be perceived merely as an infrastructure solution but rather as a multidimensional strategy aimed at advancing urban sustainability and improving quality of life. Aslan and Aydar (2022) investigated the car park problems in Çanakkale, Türkiye, via GIS-based analysis to find suitable locations for street-parking. Gulhan and Ceylan (2010) stated that the lack of planned parking spaces (open, multi-story, underground) in the city causes irregular car parking problem for the city of Denizli. Özkaraca and İnceoğlu (2021) investigated the accessibility to Düzce University from different perspectives one of which is the car parks.

İzmir, the third most populous city in Turkey, is situated around a gulf, similar to cities such as Barcelona and San Francisco. The city offers a range of public transportation options, including metro, tram, bus, and ferry, providing a multimodal transport infrastructure comparable to many medium- and large-sized European cities (Cigu et al., 2018; Maciulyte-Sniukiene & Butkus, 2022). In recent years, the modal share of active mobility modes—particularly e-bikes, bike-sharing systems, and e-scooters—has steadily increased. These modes have been increasingly studied for their potential to enhance last-mile connectivity through integration with public transportation systems (Guzel et al., 2025; Pekdemir et al., 2024; Altintasi

and Yalcinkaya, 2024). This evolving mobility trends have positioned İzmir as a favorable city for the development of innovative strategies aimed at decreasing car dependency and promoting sustainable urban mobility.

As for parking strategies, the Izmir Metropolitan Municipality has developed a Carpark Master Plan to i.) meet the city's parking needs, ii.) determine the potential parking locations in near future (EPI, 2019). However, even for the master plan, the integration of car parks with the public transportation facilities were not deeply investigated. Therefore, it is crucial to assess the accessibility of existing parking facilities and evaluate their integration with public transportation systems, which is the focus of this research.

This research examines the spatial distribution of parking facilities across key urban areas, emphasizing their accessibility to public transportation facilities, including rail transit stations, transfer hubs, and ferry ports. To this end, a GIS-based analysis was conducted to define the service area of the car parks, which later used to evaluate the accessibility to public transportation facilities. The findings concluded to a deeper understanding of the spatial distribution of parking infrastructure and its implications for sustainable urban mobility, offering insights into potential policy interventions to enhance accessibility.

2. Material and Method

2.1 Study Area and Distribution of Parking Lots

The study focuses on İzmir, Türkiye's third-largest city, which faces growing parking challenges due to rapid population growth and increasing vehicle ownership, particularly in central business districts. The research examines the spatial distribution of parking lots across key areas of the city, emphasizing their accessibility to public transportation stations (rail transit stations, transfer hubs and ferry ports), commercial zones, and high-density residential areas. The analysis considers different types of parking lots as listed as follow:

- On-Street Parking: Along roadways, typically in commercial or residential areas.
- Off-Street Outdoor Parking: Generally designed designated open areas, near commercial centers or public transportation hubs.
- Off-Street Indoor Parking (Parking Garages): Multi-level structures typically located near major public transport facilities.

It is important to note that this study considers only parking facilities managed by İZELMAN, a municipal company. The classification of parking lot types along with their corresponding features is presented in Table 1, while the spatial distribution of these parking facilities across the city is illustrated in Figure 1. The year of the parking data used for this analysis is 2025, which

ensures the most up-to-date and relevant information on street and sidewalk infrastructure.

Table 1. Parking lot types and corresponding features

Parking Lot type	Number	Capacity (min-max)
On-street	48	12-133
Off-street Outdoor	11	41-353
Off-street Indoor	23	62-1170

2.2 GIS-based Service Area Determination and Accessibility Evaluation

Before conducting the accessibility evaluation, a geodatabase was created to support the analysis, consisting of point data for parking lots and rail transit stations, and line data for the pedestrian network. ArcGIS Pro 2.5 software was used for this purpose. To evaluate the accessibility of parking facilities to public transportation facilities, service areas were delineated for each parking lot type based on walking travel times. Specifically, 5-minute and 10-minute walking thresholds, corresponding to distances of 400 meters and 800 meters, respectively, were employed, assuming an average walking speed of 4 km/h. This analysis was conducted separately for different parking facility types to assess their proximity to public transportation facilities. The service area analysis was carried out using ArcGIS Pro 2.5 software, specifically utilizing the Network Analyst extension. For this analysis, a pedestrian-based network dataset was created by combining the most recent street and sidewalk data from OpenStreetMap and the İzmir Metropolitan Municipality's Department of Transportation. The network was limited to pedestrian-accessible paths only, excluding motor vehicle routes, to ensure a more accurate representation of walking accessibility. The "Service Area" tool within the ArcGIS Network Analyst extension was used to generate 400 m (approximately 5-minute) and 800 m (approximately 10-minute) walking buffers from the centroid of each parking lot location. These areas were used to evaluate whether the facilities fell within effective walking proximity to major public transportation facilities, such as rail transit stations, ferry terminals, and intermodal transfer hubs. By adopting this approach, a comprehensive evaluation of the spatial relationship between parking infrastructure and transit accessibility can be evaluated, identifying potential gaps and opportunities for improvement in alignment with sustainable mobility objectives.

3. Results and Discussion

The service area for 400 m and 800 m of each on-street parking location is provided in Figure 2. It should be concluded that on-street parking facilities are predominantly located in high-density central business districts, such as Konak and Alsancak, where demand for parking is intense due to the concentration of commercial and social activities instead of accessing to public transportation stations.

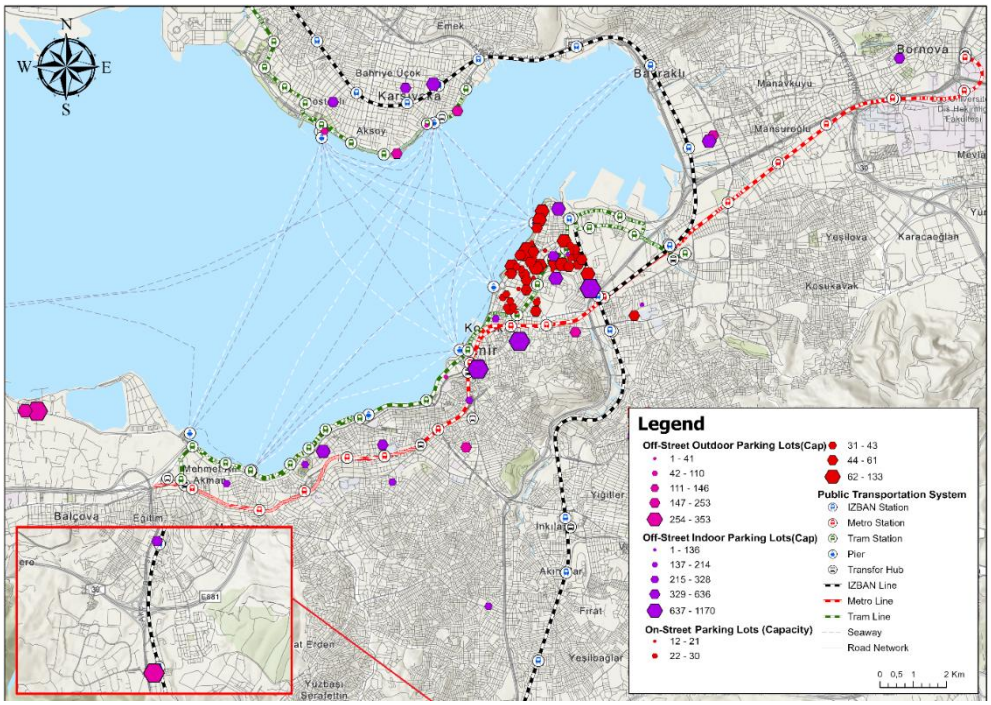

Figure 1. The location of parking lots within cities.

In contrast, the lack of such parking areas or the inability of the municipality to effectively manage existing parking spaces in the northern and inner parts of the city presents a significant issue for urban parking management. A more balanced distribution of parking facilities and improved management strategies are necessary for addressing these issues.

An examination of the distribution and service areas of off-street indoor parking facilities within the city revealed that these facilities were primarily concentrated in areas with major urban attraction locations, particularly in regions such as Bornova, Bayraklı, and Buca (Figure 3). As for the accessibility to transit hub locations, in door parking lots located in Buca, Bornova, Konak and Karşıyaka are accessible within 800 m service area. However, it appears that the primary intent behind the strategic placement of these parking structures is not necessarily to facilitate integration with public transportation stations, especially rail transit stations (see Figure 3). In high-commercial activity areas, such as Alsancak and Konak, the presence of high-capacity off-street indoor parking facilities suggests an urban planning strategy aimed at addressing the higher vehicular traffic generated by the area's commercial operations. Furthermore, in the northern part of the city, particularly in the Karşıyaka district, parking structures are strategically positioned in proximity to rail transit stations, in line with the Park & Ride strategy. This approach seeks to enhance overall transportation efficiency by encouraging users to park their vehicles and continue their journey via public transport, thereby promoting a

more integrated and sustainable urban mobility system. Furthermore, accessibility to ferry ports within 800 m service area was only valid for parking lots located in southern part of the gulf as shown in Figure 3. An analysis of the service areas of off-street outdoor parking facilities reveals that the highest parking capacity were located at İnciraltı Kent Ormanı, within the city's recreational and entertainment district (Figure 4a), and near the shopping mall in the Gaziemir region (Figure 4e). These parking facilities were characterized by higher capacity, largely due to their proximity to key urban attraction points. However, it is important to note that, despite their high capacity, these locations exhibited limited access to public transportation stations. In the Karşıyaka district, located to the north of the gulf, there were parking facilities in close proximity to rail system stations, transfer hubs, and the ferry terminal (Figure 4b). This strategic placement suggested that these parking locations have been effectively positioned to facilitate seamless multimodal transportation, supporting efficient connectivity within the urban transport network. The off-street outdoor parking lot located in Bayraklı (Figure 4c) lacked integration of public transportation facilities.

In addition to visual representation for accessibility evaluation, the statistical comparison has been made to highlight the specific differences in accessibility between various types of parking facilities and public transportation systems in İzmir, as tabulated in Table 2. It can be concluded that a substantial 81% of on-street parking lots are within 400 meters of tram stations, indicating a strong spatial correlation with this mode of transit. On the other hand, only 2% and 8% of on-street parking lots are within 400 meters of Izban and metro stations, respectively. A substantial majority of these lots fall outside the service areas of other major transit systems—94% are beyond 800 meters from İZBAN stations and 69% from metro stations—indicating a weak integration with regional rail systems. Average access distance is 400 meters in overall but higher for metro (493.3 m) and Izban (466.7 m). Off-street outdoor parking lots demonstrate relatively low levels of accessibility to public transportation facilities. Only a small portion—9% or less—of these 11 parking lots are located within 400 meters of any public transport node. The majority, ranging between 55% and 73%, fall outside the 800 m service area thresholds. Notably, these parking lots exhibit the highest average access distances among all categories, with 600.0 meters for metro stations and 520.0 meters for İZBAN. These figures indicate that off-street outdoor parking facilities are often positioned in locations that are not well integrated with major transit lines.

The off-street indoor parking lots, totaling 23 facilities, demonstrate relatively stronger integration with public transportation compared to other parking types. According to the data, 22% of these lots are located within 400 meters of İZBAN and metro stations, and 43% are within 400 meters of tram lines.

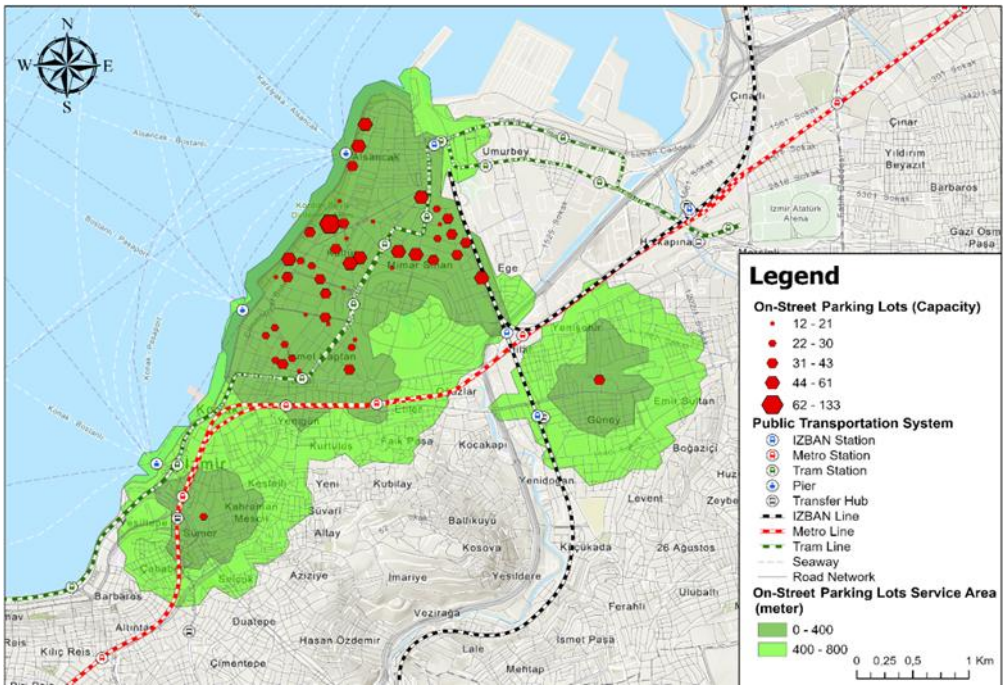

Figure 2. Service areas of on-street parking lots.

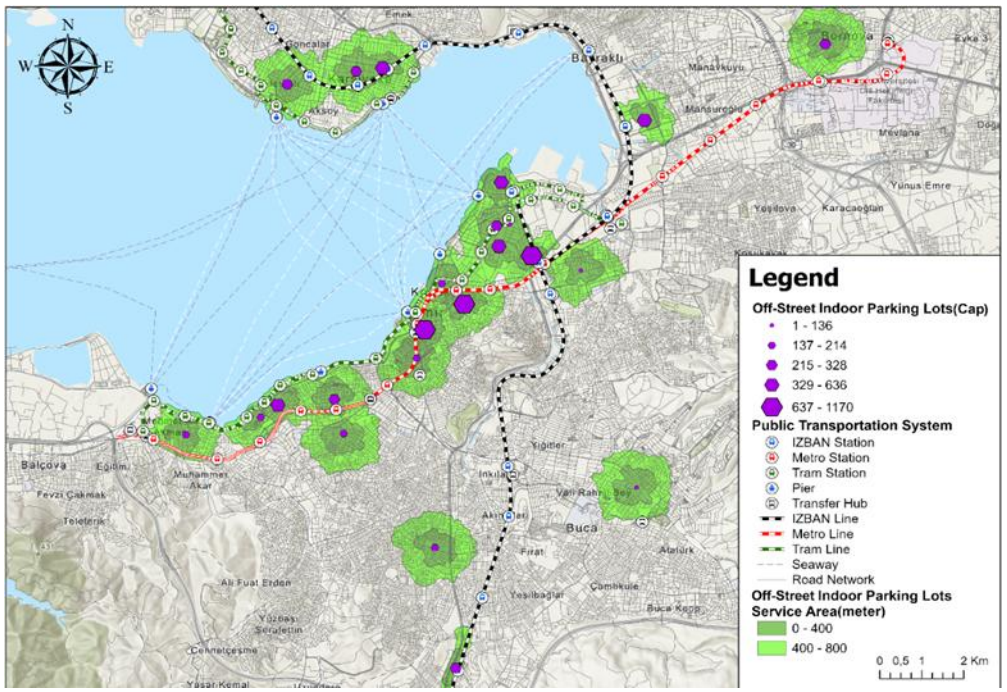

Figure 3. Service areas of off-street indoor parking lots.

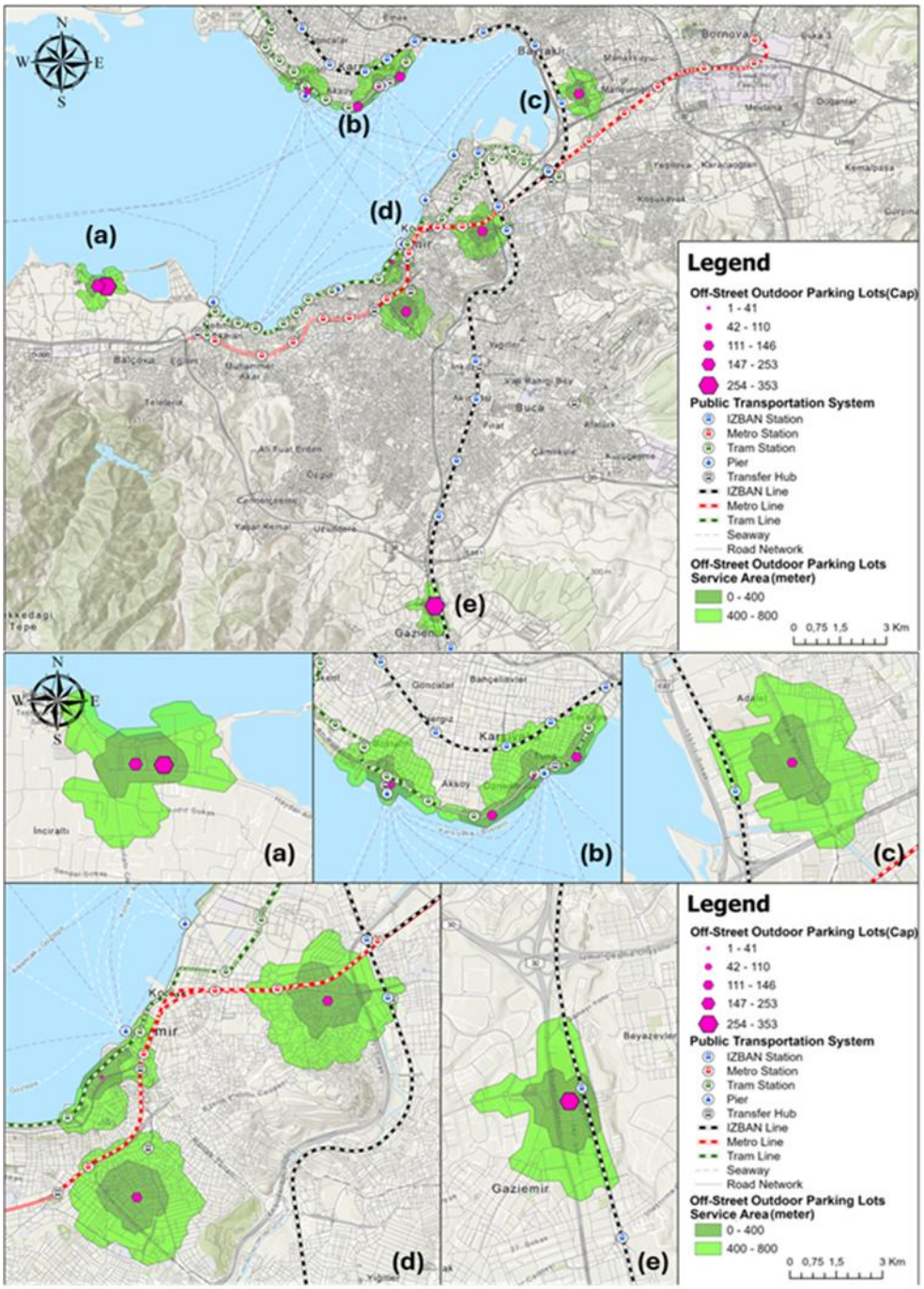

Figure 4. Service areas of off-street outdoor parking lots.

Table 2. Statistical analysis results of different parking lot types to public transportation facilities.

PTS	400 m	800 m	Out of Service Area	Average Access Distance (m)
	# of Parking Lot (in percent)	# of Parking Lot (in percent)	# of Parking Lot (in percent)	
On-street: 48 Parking Lot				
Izban	1 (2%)	3 (6%)	45 (94%)	466.7
Metro	4 (8%)	15 (31%)	33 (69%)	493.3
Tram	39 (81%)	45 (94%)	3 (6%)	253.3
Pier	10 (21%)	25 (52%)	23 (48%)	440.0
Transfer Hub	1(2%)	2 (4%)	46 (96%)	400.0
Off-street Outdoor: 11 Parking Lot				
Izban	1 (9%)	5 (45%)	6 (55%)	520.0
Metro	0 (0%)	3 (27%)	8 (73%)	600.0
Tram	4 (36%)	5 (45%)	6 (55%)	280.0
Pier	3 (27%)	5 (45%)	6 (55%)	360.0
Transfer Hub	3 (27%)	6 (55%)	5 (45%)	400.0
Off-street Indoor: 23 Parking Lot				
Izban	5 (22%)	9 (39%)	14 (61%)	377.8
Metro	5 (22%)	11 (48%)	12 (52%)	418.2
Tram	10 (43%)	14 (61%)	9 (39%)	314.3
Pier	1 (4%)	7 (30%)	16 (70%)	542.9
Transfer Hub	2 (9%)	7 (30%)	16 (70%)	485.7

*PTS=Public Transportation System

Accessibility to tram services is particularly high, with 14 out of 23 lots (61%) within 800 meters, and the average access distance to tram stops is the lowest among all public transport modes at 314.3 meters.

4. Conclusions and Recommendations

This study provided a comprehensive spatial analysis of parking facility distribution and their accessibility to public transportation in İzmir using a GIS-based service area approach grounded on pedestrian-accessible network datasets. The analysis revealed a predominant concentration of on-street parking facilities in central business districts such as Konak and Alsancak, where high parking demand stems largely from commercial activity rather than the intention to facilitate access to public transportation nodes.

Off-street indoor parking facilities were found to be mainly situated near major

urban attraction points (e.g., core center of Bornova, Bayraklı, and Buca regions). However, their integration with rail transit or other public transport systems remains limited, indicating a planning approach that prioritizes attraction-driven vehicle access over multimodal transport integration. In contrast, off-street outdoor parking lots offer high capacity but suffer from low transit accessibility, particularly in southern districts. An important exception is observed in Karşıyaka, where the strategic location of both indoor and outdoor parking facilities in close proximity to rail stations and ferry terminals reflects a successful application of Park & Ride strategies, enhancing multimodal connectivity.

The results underscore the necessity for a more balanced spatial distribution of parking infrastructure across the city and a strategic alignment with public transportation systems. To achieve this, it is recommended that future parking site selection processes incorporate multi-criteria decision analysis (MCDA) methods integrated with GIS platforms. Techniques such as the Analytic Hierarchy Process (AHP) or GIS-based MCDA can be utilized to evaluate potential locations based on multiple factors, including land use, proximity to public transit, pedestrian accessibility, and local parking demand patterns. Moreover, the statistical analysis of service area coverage and proximity ratios, comparing distances between parking lots and transport nodes, can identify areas of critical need and guide policy decisions more precisely. Integrating these methods would enable evidence-based planning and ensure a more efficient allocation of parking infrastructure.

Declaration of Ethical Standards

The authors declare that they comply with all ethical standards.

Credit Authorship Contribution Statement

Author 1: Methodology / Study design, Validation, Visualization, Writing – original draft, Data curation

Author 2: Resources, Research, Writing – original draft, Conceptualization, Methodology / Study design, Writing – review and editing, Supervision, Validation, Data curation

Author 3: Research, Writing – original draft, Conceptualization, Methodology / Study design, Writing – review and editing

Declaration of Competing Interest

The authors have no conflicts of interest to declare regarding the content of this article.

Data Availability

All data generated or analyzed during this study can be shared upon request.

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The authors obtained the parking data from the İzmir Metropolitan Municipality (IBB) open data portal and express their gratitude to IBB for granting access to this data.

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