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A new paradigm in parking management: From quantitative models to stakeholder participation

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Abstract

This study investigates the selection process of "Parking Management" strategies, a critical component of parking facility planning. An integrated approach is developed, combining quantitative assessment models with those based on expert and user opinions, to select effective "Parking Management" strategies. Additionally, parking strategies for the Trabzon-Ortahisar district were determined by analyzing observed on-site parking behaviors. The study hypothesized that conventional approaches would be insufficient for selecting parking management strategies and would fail to adequately adapt to user profiles and parking usage patterns. At this stage, car parking strategies selected through traditional methods—such as car parking capacities, usage rates, projection studies, and data obtained from user and car parking surveys—were compared. The AHP (Analytical Hierarchy Process) method was used as the selection criterion. As an outcome, the study proposes a method that incorporates user opinions to determine optimal strategies for addressing parking problems caused by the imbalance between parking spaces and parking demand.

Keywords: parking management, analytical hierarchy process, Trabzon, transportation planning

1. Introduction

There has been a steady increase in private car ownership due to accelerated industrialization, leading to higher urban economic growth, increased incomes, improved living standards for urban residents, and significant population growth (Shen, 1997). The rapidly growing economy, along with policies and subsidies, and the rising use of private vehicles in urban areas, have made car parking a major concern for urban transport planning and traffic management worldwide (Parmar et al., 2020). The surge in private vehicle ownership continually heightens the need for parking spaces (Open Government Data (OGD) platform India, 2018). This growth rate has not allowed for adequate off-street parking capacity, especially in city centers and central business districts, leading vehicle owners to park on the roadside. Consequently, enhancing parking spaces through effective parking management strategies is recognized as a key solution to alleviating urban congestion (Shen et al., 2020).

In recent years, the evolving understanding of car park management has shifted towards the rational allocation of existing resources rather than creating new supply. Previously, strategies focused on maximizing supply and minimizing prices, which proved ineffective. Currently, the primary objective is optimizing parking supply (Moeinaddini et al., 2013). Initial parking policies aimed to solve these problems by increasing supply to meet demand, based on minimum parking requirements (Dave et al., 2019). However, supply-oriented approaches have inadvertently increased car ownership and reduced public spaces available for physical activities, public transport, and other essential recreational, social, cultural, and economic activities.

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Today, parking demand management is the most prevalent approach to addressing these issues by designing policies that reduce demand and encourage modal shifts (Yan et al., 2019). Users can adapt to parking policies by altering their parking behavior, mode of transport, destination, schedule, or activities. Additionally, parking policies serve as a revenue source for local governments while balancing the need to manage transport demand and discouraging long-term use of parking spaces to protect urban vitality (Coombe et al., 1997). Within car parking strategies, the focus should be on enforcing maximum parking requirements rather than encouraging minimum parking requirements.

In the past, parking problems were addressed by increasing the supply of car parks, a paradigm that prioritized drivers within the transport system (Weinberger et al., 2010). Consequently, the demand for car parking spaces has also risen. Urban areas face significant challenges such as traffic congestion, air pollution, and environmental degradation, all of which complicate the functioning of transportation systems (Tafidis et al., 2017).

Initially, the management of parking focused on safety and the regulation of traffic flow on streets (Marsden, 2006). This led to the development of policies aimed at managing on-street parking, considering parking standards in new developments, and providing off-street public off-street parking facilities (Shoup, 1999; 2005). Parking Management (PM) emerged as a system offering various solutions to parking demand beyond merely creating new parking spaces. PM includes plans, policies, programs, and strategies to address potential parking issues (Litman, 2024). It also supports land use planning efforts, enhances pedestrian accessibility, and identifies transit priorities and flows (Delaware Valley Regional Planning Commission, 2004). PM refers to strategies and practices that enhance the efficiency of parking facility usage (Barhani, 2007). It identifies current or potential parking problems, estimates the costs and possible revenues from parking areas, and clarifies car park management strategies and their implementation (Okubay, 2008). Proper implementation of PM provides socio-economic and environmental benefits by maximizing the efficiency of parking spaces. Given the current challenges with parking areas, the selection of appropriate management and strategy choices is critical. Effective parking management significantly contributes to the sustainability of urban transport development (Thanh, 2017).

Several international studies analyze user parking behavior. Research indicates that well-designed parking regulation frameworks contribute to more efficient use of the transport network, lower emissions, higher densities, and better urban design (IHT, 2005; Shoup, 2005; Stubbs, 2002; Valleley et al., 1997). Conversely, poorly designed policies can have detrimental effects. For instance, Shoup (2006) reviewed 16 surveys in 11 international cities and found that, on average, 30% of cars in traffic are searching for a parking space, with an average search time of 8.1 minutes. In a survey on illegal parking, 48% of respondents admitted to parking illegally (RAC Foundation, 2004). The choice of a parking space is influenced by social, economic, and environmental factors such as age, income, number of available parking spaces, parking costs, accessibility, and search time. The time spent searching for a parking space significantly impacts total travel time, making the time factor crucial in drivers' parking space selection behavior (Polak & Axhausen, 1990).

Chien et al. (2020) analyzed people's on-street parking selection behavior by considering a fuzzy multi-attribute decision-making process for optimal parking space selection. Inspired by such multi-criteria decision-making models, this study applies the Analytic Hierarchy Process (AHP) to incorporate both user and expert inputs into a coherent decision framework. The study emphasized factors affecting driver behavior, showing that distance to the parking space, walking distance, lane condition, and the condition of available parking spaces significantly influence drivers' choices. Han et al. (2018) proposed a parking space selection model for mixed land use, considering common parking policies for visitor parking. This model incorporated variables such as age, gender, parking duration, search time, number of available free spaces, total number of parking spaces, and conditions in other car parks, and was validated using TransCAD software.

Asakura and Kashiwadani (1994) investigated the effect of a parking information system on drivers' parking space selection behavior. They developed a multinomial logit (MNL)-based disaggregated choice model, considering factors like parking fee, walking distance, and availability information. The study found that drivers with incomplete information prioritized parking fees over walking distance and safety.

Waraich and Axhausen (2012) presented a model focusing on parking space choice to analyze individual behavior. They developed a utility function for a parking space by evaluating each attribute's preference weight score that influences a person's choice from a given set of options. This model predicted user behavior using the multi-agent transportation simulation toolkit (MATSim) framework, integrating an evolutionary algorithm to include parking features impacting decision-making.

Demir (2019) analyzed changes in roadside parking user behaviors in Istanbul using approximately eight years of parking data. The study examined the effects of fee increases and short-term free parking practices, evaluating occupancy rates based on user preferences data. Seasonal average parking time was analyzed with time series, and the parking tariff model in the transportation master plan was assessed using regression analysis, identifying inconsistencies.

Additionally, several studies, including those by Sattayhatewa and Smith Jr. (2003), Hess and Polak (2009), and Chaniotakis and Pel (2015), have developed discrete choice models to predict user behavior. These models consider variables such as parking fees, length of stay, proximity to the final destination, and the availability of public transport. Kelly and Clinch (2006) expanded on this work by incorporating variables like parking frequency, trip purpose, and monthly income.

There are numerous studies in the literature focused on car park planning and strategy development. These studies encompass car park management, strategy evaluation and planning, car park operation, pricing policy, cost-benefit analysis, site selection of car parks, and sustainable innovative parking solutions. However, these studies predominantly capture the rational aspect of parking behavior, often neglecting the individual psychological characteristics of drivers. They do not adequately consider usage habits, traffic cultures, transport purposes, mobility trends, or car park users' opinions about the current situation.

While numerous studies have focused on parking pricing (Shoup, 2006; Kelly & Clinch, 2006), facility location (Chien et al., 2020), and user behavior modeling (Han et al., 2018; Waraich & Axhausen, 2012), relatively few have developed an integrated approach that combines user preferences, expert opinions, and traditional demand-based models. Furthermore, there is limited research on participatory strategy selection methods tailored to mid-sized cities like Trabzon, where topographical constraints and user habits strongly influence parking behavior. This study aims to address these gaps by offering a hybrid methodological framework for the selection of parking management strategies. This aim directly responds to the deficiencies identified in previous studies that either rely solely on demand estimation or focus exclusively on user behavior modeling, as outlined in the literature.

Analysis has shown that there is a lack of studies where users are directly involved in the process, the selected strategies are tested in the field, and multiple methods are employed simultaneously. This study aims to address these gaps by providing a healthier and more realistic approach to the applicability of parking strategies. By increasing the detectability of potential short- to medium-term problems before implementation and incorporating expert opinions alongside demand-capacity calculations and heuristic decisions, the scientific rigor of the study will be enhanced. Unlike conventional studies that rely solely on demand projections or user behavior models, this study adopts a holistic approach by integrating traditional quantitative methods, user profiles, and expert evaluations within a participatory planning framework. This integration provides a more realistic and inclusive basis for the selection of parking management strategies.

This study contributes to the literature by integrating demand-based modeling, user preferences, and expert judgment through an AHP-based participatory framework. Unlike conventional parking studies that rely solely on quantitative forecasting, this approach introduces a multidimensional decision-making model tailored for urban parking strategy formulation.

2. Study Area and Method

2.1. Study Area

This study contributes to the literature by integrating demand-based modeling, user preferences, and expert judgment through an AHP-based participatory framework. Unlike conventional parking studies that rely solely on quantitative forecasting, this approach introduces a multidimensional decision-making model tailored for urban parking strategy formulation.

Trabzon is a city situated directly along the coast, continuing to evolve and expand. Historically, Trabzon developed in a linear corridor oriented parallel to the sea, extending along the east-west axis up until the 2000s. Following this period, the city began to experience more compact growth in the southern settlement areas, reflecting a shift in urban expansion patterns.

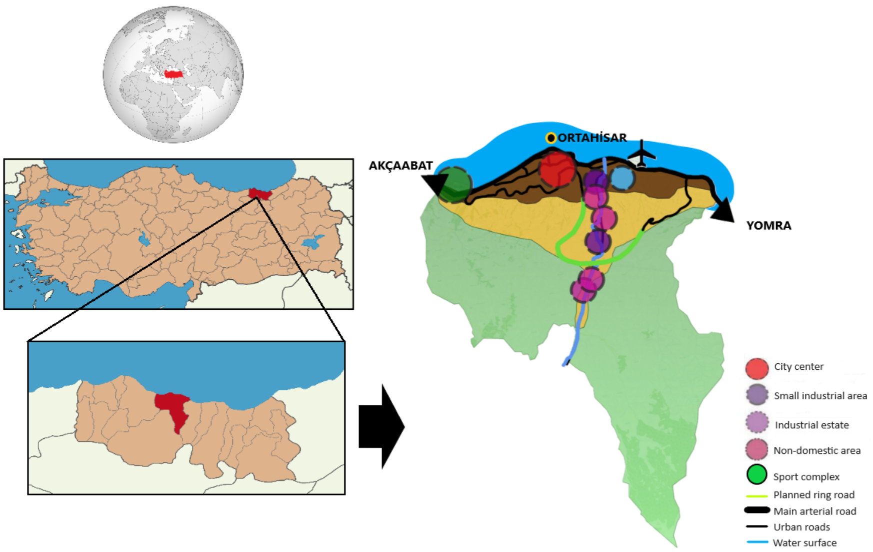

Figure 1 Location and land use structure of Ortahisar district

The transport network in Ortahisar district primarily extends along the east-west axis, parallel to the city's coastline, facilitating connections with coastal districts. Another critical transportation corridor is the E-97 motorway, which runs linearly from north to south, linking Ortahisar with Gümüşhane. This motorway is significant as it provides direct access to Trabzon International Airport and Trabzon Port, intersecting with the city's main axis. This intersection plays a pivotal role in bolstering the city’s economic activity, investment prospects, and tourism potential by enhancing logistics and passenger transport. The city center is situated in the northern part of Ortahisar and is closely integrated with the historical bazaar. The north-south axis, stretching from Ortahisar to Maçka, includes non-residential urban service areas, commercial establishments, and higher education institutions.

The Ortahisar district was selected based on multiple criteria. As Trabzon’s historic and administrative center, it hosts the city's highest concentration of commercial, touristic, and public institutions. It contains the most congested road segments and the most frequently used curbside and facility-based parking zones. Data availability from the municipal parking operator (TRABİTAŞ), the diversity of parking types, and the observed mismatch between parking demand and supply further justified its selection. In addition, Ortahisar’s physical structure—marked by narrow streets, steep terrain, and pedestrian-heavy zones—provides a representative setting to analyze the city’s broader parking challenges.

Among the city's most frequented streets are Devlet Sahil Yolu Street, Cumhuriyet Street, Tanjant Street, Kahramanmaraş Street, Gazipaşa Street, Uzun Street, Semerciler 52 Street, and Kunduracılar Street. Kahramanmaraş Street, notably one of the most heavily trafficked streets, extends from Trabzon Meydan Park—renowned for its historical significance—towards the Hagia Sophia. This street is a focal point of the city due to its commercial areas, financial institutions, and accommodation services. It is also well-served by public transport, features accessible pedestrian pathways, and offers ample parking opportunities. The locations mentioned above are visually presented in Figure 1 and Figure 4-5, providing spatial clarity regarding the distribution of parking-intensive road segments and user movement patterns.

In terms of parking infrastructure, Trabzon predominantly relies on roadside parking, which is prevalent on streets and avenues adjacent to or near major traffic routes. Off-street parking facilities are strategically located near busy streets and are concentrated in the city center, providing additional parking options.

The Ortahisar district was selected as the study area at the district level, as it constitutes the historical and functional core of Trabzon. This area hosts the city's most intense parking problems due to its role as the primary commercial, administrative, and transportation hub. The spatial concentration of public institutions, historical zones, and pedestrian-dominated streets results in a critical mismatch between parking supply and demand. Therefore, Ortahisar offers a representative urban context to examine integrated parking management strategies.

In the Ortahisar district of Trabzon, a total of 57 parking facilities were identified and classified as either on-street or off-street. Among these, 45 are off-street parking lots, including open-air and structured facilities. However, it was observed that 8 of these off-street lots were out of service, and 1 was allocated for exclusive use by a hospital. The remaining 12 parking facilities consist of on-street parking areas, which are concentrated along central urban axes—particularly around Meydan Square and Hagia Sophia Square—and are primarily designed for parallel parking. In addition, 8 major roadside corridors were identified as key parking axes, reflecting the circulation-dependent character of on-street parking in the area.

2.2. Methodology

2.2.1. Research Questions

In line with the aim of this study, the following research questions were formulated:

What are the most appropriate and applicable policy alternatives for the city center of Trabzon (Ortahisar), considering local demand characteristics, user behavior, and expert evaluations?

Sub-Questions:

- How do users' parking preferences and behaviors influence the prioritization of strategy alternatives?
  - This question is grounded in behavioral parking models that account for user decision-making in mixed-use contexts, as demonstrated by Han et al. (2018) in Transportation Research Part C
- To what extent can traditional parking demand calculations be reconciled with user expectations and expert opinion?
  - Previous studies (e.g., Q. Han et al., 2018; Shen et al., 2020) highlight that standard projection models often omit qualitative perspectives, underscoring the need for integrative approaches—though empirical integration remains limited. One analogous study combining GIS and AHP for decision criteria integration is Aydınoğlu and Iqbal (2021) in ISAG-2019 proceedings
- How can the Analytic Hierarchy Process (AHP) be used to synthesize multiple inputs (user surveys, parking data, expert assessments) into a robust strategy selection model?

- The effectiveness of AHP in participatory transportation planning has been demonstrated in studies such as de Luca (2014) in Transport Policy, which emphasizes public engagement integration in transport decision-making using calibrated AHP frameworks

2.2.2. Technical Flow

The study employs a hierarchical framework where each stage influences subsequent stages. The initial phase involves the preparation of the Analytic Hierarchy Process (AHP) method, which is informed by results from the "Car Parking Survey" and the "User Survey." The strategies derived from these surveys were then adapted to account for the city's physical structure, parking usage patterns, and urban mobility, and were subsequently presented to experts for evaluation.

The first stage of the study, strategy determination through traditional methods, forms the foundation of the approach. The strategies developed from census studies, demand forecasts, and projections will influence the formulation of questions for users and the AHP study, thereby shaping expert opinions and, consequently, the study's outcomes. Following the initiation by the decision-maker, strategy options were refined using professional expertise, field studies, and urban knowledge.

A key aspect of this study, distinguishing it from others, is the inclusion of car park users in the strategy selection process. This inclusion aims to assess the practical applicability of the proposed strategies within the city context. Scientific results often diverge from practical applications, which underscores the importance of incorporating user perspectives. At this stage, the strategies, based on traditional methods and projections, were communicated to users, and their feedback was collected. This feedback, alongside insights into user parking habits, informed the development of a methodology. The outcome of this dual approach produced strategies with potential solutions to the city's parking issues. Following the study, it is essential to rank these strategies based on their importance. Flowchart of the methodology is given in Figure 2.

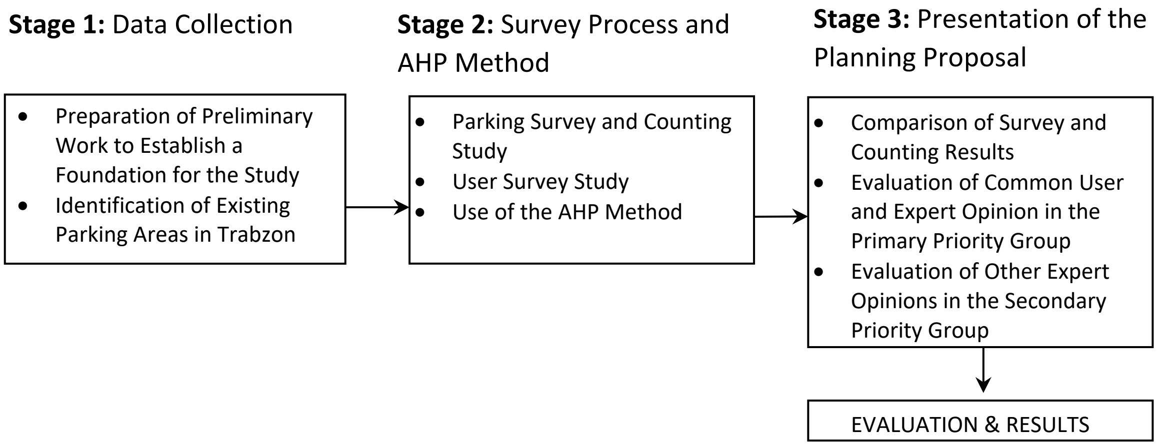

Figure 2 Flowchart of the methodology

STEP 1: In the study, the initial step involved analyzing the car parking inventory data provided by Trabzon Metropolitan Municipality. Using this data, the locations of roadside and off-street parking areas managed by municipal and private enterprises within Ortahisar district were identified through on-site inspection and observational studies.

STEP 2: The study began by analyzing the car parking inventory data obtained from Trabzon Metropolitan Municipality. Based on this data, the locations of both roadside and off-street parking areas managed by municipal and private entities within Ortahisar district were identified through on-site detection and observational studies. Field studies were conducted to assess the data from Trabzon Metropolitan Municipality and associated units. These studies highlighted deficiencies in parking areas and identified problematic regions within the city. Subsequently, a "Car Parking Survey" was executed within these identified areas. This survey involved collecting data from parking operators to determine various physical characteristics of the parking facilities, including types, capacities, ground features, fee tariffs, and construction dates. Additionally, a census study was performed to assess capacity usage and occupancy rates, which are crucial for the study. The car park survey form is detailed in Table 1.

Table 1 Car Parking Survey Form

GENERAL INFORMATION	
Parking Code and Name:	
District:	
Neighborhood:	
Street-Number:	
Location:	
Phone:	o o No Phone
Type:	o Parking lot o Covered o Multi-story o Roadside o Parking meter
Ownership:	o Private o Municipality o Association o Foundation o Other: ....
Operation:	o Private o Municipality o District Municipality o Association o Foundation o Other:..........
Number of Staff:	
Year Opened for Service:	
PHYSICAL CONDITION	
Capacity (Vehicles)	
Structure Type:	o Reinforced Concrete o Steel
Number of Floors:	
Area (m²):	
Above Ground:	o Yes o No
Surface Type:	o Soil o Concrete o Asphalt o Paving Stone o Gravel o Other........
Entrance/Exit:	o Single o Double
Barrier:	o Single o Double
Information System:	o Single o Double
Horizontal Marking:	o Single o Double
Vertical Marking:	o Single o Double
Fire Control:	o Single o Double
Elevator:	o Single o Double
Security Camera:	o Single o Double
Average Number of Tickets (Daily):	
Working Days:	o Weekdays o Every Day o Specific Days (................ ....)
Working Hours:	o 8 AM - 6 PM o 24/7 o Other (....................)
Busiest Days:	o Monday o Tuesday o Wednesday o Thursday o Friday o Saturday o Sunday
Busiest Hours:	
FEE (TL) (Automobile)	
Paid Parking?	o Yes, Paid o No, Free
Fee Schedule:	
Payment Types:	o Cash o Credit Card o Special Card o Trabzon Card
Subscription:	o Available o Not Available
Number of Subscribers:	
Automatic Entry System:	o Available o Not Available
ISSUES	
o Infrastructure Issues (Ground Coating, Lighting, Security, Unit Vehicle Parking Space, etc. Specify ......) o High Demand o Low Demand o High Fee o Low Fee o Traffic	

Field studies are completed by photographing the areas, recording the GPS coordinates of the surveyed locations, and updating the parking area data using digital processing. This process also involved identifying physical inadequacies within the car parking areas. Additionally, car park counting procedures were conducted. These counts were performed in areas with high traffic density and associated parking issues. Car park counting sheets were utilized to document daily capacity usage, fill out roadside parking sheets, and create roadside parking observation charts. Parking counts were systematically conducted across three distinct time periods throughout the day: morning hours (approximately 09:00), midday (around 12:00), and late afternoon to early evening (around 17:00). These specific intervals were purposefully selected to capture the dynamic fluctuations in parking demand associated with typical urban mobility patterns. The morning and evening periods coincide with peak commuting hours, reflecting residential-to-workplace and return flows, whereas the midday period was intended to observe the relative stasis of parked vehicles and parking turnover influenced by commercial, administrative, and recreational activities in the city center. This temporal stratification enabled a more representative and nuanced understanding of diurnal parking behaviors in the study area. Observations and counts were made for both roadside and facility parking areas. An example of a count sheet is provided in Table 2.

Table 2 Car Park Census Sheet

	Park Area Name	Street Name	Capacity	Parking Angle	Number of Vehicles		
					09:00	12:00	17:00
1							
2							
3							
4							
5							

The data obtained from the questionnaire study were processed using the QGIS 3.10 software, incorporating the attributes of each car park. The processed data were then transferred to Excel, where statistical distributions of responses were analyzed. Demand, projection, and capacity calculations were performed based on the occupancy information collected. Annual statistics on usage, occupancy rates, future population, and vehicle usage rates for the city were utilized, along with projection calculations for Ortahisar district using traditional methods, to develop car park management strategies. These strategies were subsequently evaluated through the "User Surveys" study. User feedback was sought to assess their perspectives on these strategies and to refine the strategies based on their suggestions and opinions. This approach aimed to evaluate the practicality of the proposed strategies in real-world conditions and gauge public acceptance and engagement with the system. Car park user surveys were conducted in Ortahisar city center, with participation from 442 residents. User survey study points and the Car Park User Questionnaire Form are presented sequentially in Figure 3 and Table 3.

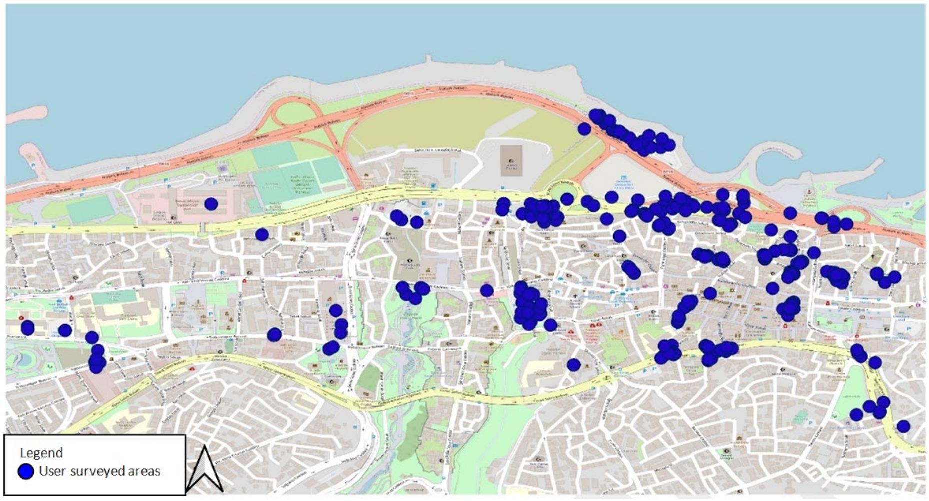

Figure 3 User survey study points

Table 3 Car Park User Questionnaire Form

GENERAL INFORMATION

<table>
<tr><td>District:</td><td></td></tr>
<tr><td>Neighborhood Name / Neighborhood Code:</td><td></td></tr>
<tr><td>Street-Number:</td><td></td></tr>
<tr><td>Location:</td><td></td></tr>
<tr><td>Phone:</td><td></td></tr>
<tr><td colspan="2">USER DEMOGRAPHIC DATA</td></tr>
<tr><td>Age:</td><td></td></tr>
<tr><td>Gender:</td><td>o Female o Male</td></tr>
<tr><td>Place of Birth:</td><td></td></tr>
<tr><td>Reason for Being in the Area:</td><td>o Home o Work o Education o Shopping o Other</td></tr>
<tr><td colspan="2">TRANSPORTATION DATA</td></tr>
<tr><td>From Which Neighborhood Did You Come to the Parking Lot?</td><td>............................../ o Home o Work o Other</td></tr>
<tr><td>Do You Own a Private Vehicle?</td><td>o Yes o No</td></tr>
<tr><td>What Mode of Transportation Do You Use for Home-Work Purposes?</td><td>o Own Vehicle o Shuttle o Bus o Minibus
o Company Vehicle</td></tr>
<tr><td>How Long Will Your Vehicle Typically Remain Parked?</td><td></td></tr>
<tr><td>How Long Has Your Vehicle Been Parked So Far?</td><td></td></tr>
<tr><td>What Are Your Usual Parking Hours?</td><td>o 08:00-10:00 o 10:00-12:00 o 12:00-14:00
o 14:00- 16:00 o 16:00- 18:00 o 18:00 -</td></tr>
<tr><td>Do You Have Difficulty Finding a Parking Space?</td><td>o Yes o No</td></tr>
<tr><td>Are You Satisfied with the Parking Fees?</td><td>o Yes, I Am Satisfied o No, I Am Not</td></tr>
<tr><td>Where Do You Typically Park Your Vehicle During the Day?</td><td>o Roadside o Side Street o Open Parking Lot o Covered Parking Lot</td></tr>
<tr><td>How Many Hours Do You Park Your Vehicle During the Day?</td><td>o 0-2 Hours o 2-4 Hours o 4-6 Hours o All Day</td></tr>
<tr><td>Have You Ever Paid a Parking Fine for Your Vehicle?</td><td>o Yes o No</td></tr>
<tr><td>How Do You Reach Your Destination After Parking Your Vehicle?</td><td>o On Foot o By Bus o By Minibus o By Bicycle
o By Shuttle</td></tr>
<tr><td colspan="2">STRATEGY DETERMINATION</td></tr>
<tr><td colspan="2">What Is Most Important to You in Parking Areas?</td></tr>
<tr><td colspan="2">o Proximity to the target o Security o Fee o Roadside Parking o Nearby Parking</td></tr>
<tr><td colspan="2">What Is the Maximum Distance You Prefer to Park Your Vehicle?</td></tr>
<tr><td colspan="2">o 0-50 Meters o 51-100 Meters o 101-150 Meters o 151-250 Meters o 251 Meters and Above</td></tr>
<tr><td colspan="2">Would You Like to Reserve a Parking Space in Advance?</td></tr>
<tr><td colspan="2">o Yes o No</td></tr>
<tr><td colspan="2">Would You Use Shared Parking Areas?</td></tr>
<tr><td colspan="2">o Yes o No</td></tr>
<tr><td colspan="2">Would You Use an App to Check Parking Availability on Your Phone?</td></tr>
<tr><td colspan="2">o Yes o No</td></tr>
<tr><td colspan="2">Are You Satisfied with the Parking Fees? If Not, What Is Your Suggestion?</td></tr>
<tr><td colspan="2">o Yes, I Am Satisfied
o No, I Am Not ....</td></tr>
<tr><td colspan="2">Should Parking Fees Be the Same Everywhere or Vary Based on Location, Type, and Duration?</td></tr>
<tr><td colspan="2">o Yes, They Should Vary
o No, They Should Be the Same</td></tr>
<tr><td colspan="2">Would You Consider Using Another Mode of Transportation After Parking Your Vehicle? If Yes, What Is Your Preference?</td></tr>
<tr><td colspan="2">o Yes, I Would Consider (...........................)
o No, I Would Not</td></tr>
<tr><td colspan="2">Would You Prefer a Nearby High-Fee Parking Lot or a Distant Low-Fee Parking Lot?</td></tr>
<tr><td colspan="2">o Nearby and High-Fee
o Distant and Low-Fee ....</td></tr>
<tr><td colspan="2">If You Could Benefit from Public Transportation at a Discount by Using It Frequently, Would Your Usage Increase?</td></tr>
<tr><td colspan="2">o Yes, It Would Increase
o No, It Would Not</td></tr>
<tr><td colspan="2">If Infrastructure and Routes for Bicycle Transportation Were Strengthened Across the City, Would You Use a Bicycle as a Means of Transportation? If Your Answer Is No, What Is the Reason and Which Mode of Transportation Do You Prefer?</td></tr>
<tr><td colspan="2">o Yes, I Would Use It
o No, I Would Not Use It, Because ....
Transportation Preference ....</td></tr>
</table>

If Pedestrian Paths Were Strengthened Across the City, Would You Use Walking as a Means of Transportation? If Your Answer Is No, What Is the Reason and Which Mode of Transportation Do You Prefer?
o Yes, I Would Walk o No, I Would Not, Because .... Transportation Preference ....
YOUR COMMENTS AND SUGGESTIONS

The aim of the study is to incorporate user input into strategy selection through survey studies. Initially, parking strategy selection was conducted using traditional methods, where parking lot occupancy and usage rates were determined, and strategy choices were made based on these results, without considering user preferences or usage habits. In the subsequent stage, user involvement was integrated into the strategy selection process through survey questions. The strategies identified from occupancy and usage data were presented to parking users via the "User Survey" study to observe their responses and attitudes. This phase aimed to refine the strategies by incorporating user feedback and addressing their suggestions and complaints. The goal was to evaluate the applicability of the proposed strategies in real-world conditions and assess public engagement with the system. Car park user surveys were conducted in Ortahisar city center, involving 442 participants.

The Analytic Hierarchy Process (AHP) is employed as the primary multi-criteria decision-making (MCDM) method to prioritize parking management strategies. While AHP constitutes the methodological framework, the criteria evaluated within this framework—such as demand level, land-use compatibility, accessibility, implementation cost, and user satisfaction—represent the evaluative dimensions informed by literature review and expert opinions. This distinction is critical: AHP is the decision-making tool, whereas the listed items are criteria structured and weighted within that tool. The Analytic Hierarchy Process (AHP) study, conducted with 13 experts in transportation, further advanced this process. The study began by defining the decision-making problem and setting strategy selection as the objective. Necessary decision criteria were identified through the "User Survey," and possible decision alternatives were outlined. A hierarchical structure was established to organize these alternatives. Importance levels for each criterion were determined using pairwise comparisons, and the prioritization of alternatives was based on these comparisons. The agreement rate was calculated from the expert prioritization data. Alternatives were ranked according to their priority values, and sensitivity analysis was performed to finalize the study.

The AHP method, a well-established Multi-Criteria Decision-Making (MCDM) technique, was utilized in this study. AHP, as defined by Zionts (1979), is a decision analysis method used to address complex decision problems across various fields. It involves analyzing complex situations and making informed decisions (Darko et al., 2018). The technique is known for its pairwise comparison approach and is widely applied in decision support systems (Podvezko, 2009). AHP integrates both qualitative and quantitative factors, allowing for a comprehensive evaluation of criteria (Sáenz-Royo et al., 2024). Multi-criteria decision-making focuses on modeling and analyzing decisions based on multiple criteria (Dağdeviren & Eren, 2001; Kocamustafaoğulları, 2007). AHP's ability to incorporate subjective and objective considerations makes it a robust tool for decision-making (Canhasi, 2010).

In the AHP approach, criteria were compared using a matrix format with values ranging from 1 to 9. A value of 1 was placed along the diagonal of the matrix, representing the comparison of each criterion with itself. The criteria compared in this study included:

- P1: Safety
- P2: Proximity to the target
- P3: Reserved parking space
- P4: Shared parking space
- P5: Predisposition to mobile applications

- P6: Wage sensitivity
- P7: Sensitivity to pedestrian transportation

Table 4 provides a sample expert evaluation.

Table 4 Questionnaire Study Where Comparison Values are Obtained

Criteria	Preferred																	Criteria
Safety	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	Proximity to the target
Safety	9	8	7	**6**	5	4	3	2	1	2	3	4	5	6	7	8	9	Reserved parking space
Safety	9	8	7	6	5	4	3	2	1	2	3	**4**	5	6	7	8	9	Shared parking space
Safety	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	Predisposition to mobile applications
Safety	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	Wage sensitivity
Safety	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	Sensitivity to pedestrian transportation
Proximity to the target	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	Reserved parking space
Proximity to the target	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	Shared parking space
Proximity to the target	9	8	7	6	5	**4**	3	2	1	2	3	4	5	6	7	8	9	Predisposition to mobile applications
Proximity to the target	9	8	7	6	5	4	3	2	1	2	3	4	5	**6**	7	8	9	Wage sensitivity
Proximity to the target	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	Sensitivity to pedestrian transportation
Reserved parking space	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	**8**	9	Shared parking space
Reserved parking space	9	8	**7**	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Predisposition to mobile applications
Reserved parking space	9	8	7	6	5	4	3	2	1	2	3	**4**	5	6	7	8	9	Wage sensitivity
Reserved parking space	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	Sensitivity to pedestrian transportation
Shared parking space	9	8	7	6	5	4	3	2	1	2	3	4	5	6	**7**	8	9	Predisposition to mobile applications
Shared parking space	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	Wage sensitivity
Shared parking space	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	Sensitivity to pedestrian transportation
Predisposition to mobile applications	9	8	7	6	5	**4**	3	2	1	2	3	4	5	6	7	8	9	Wage sensitivity
Predisposition to mobile applications	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	Sensitivity to pedestrian transportation
Wage sensitivity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	Sensitivity to pedestrian transportation

STEP 3: Based on the survey studies and expert consultations conducted for strategy selection, a prioritization of the strategies deemed suitable for the city was necessary. The results from the survey and the Analytic Hierarchy Process (AHP) study led to the categorization of strategies into two main groups:

First Priority Group: This group comprises strategies that were consistently identified as top priorities based on both user feedback and expert opinions. These strategies are considered the most critical for addressing the city's parking and traffic issues.

Second Priority Group: This group includes strategies where there was a discrepancy between user and expert opinions. Although these strategies may not align fully with user preferences, experts believe they could significantly enhance traffic flow and overall quality if implemented.

This prioritization helps in focusing efforts on strategies with the greatest consensus and potential impact while also considering expert recommendations for additional improvements.

2.3. Integration of Data Sources

In this study, a multi-layered methodological approach was employed to ensure a comprehensive assessment of parking management strategies in Ortahisar. Firstly, field-based parking inventories and temporal occupancy counts provided empirical data on the actual spatial and temporal demand for parking. These were conducted at multiple time intervals during a typical weekday to reflect peak and off-peak usage patterns.

Secondly, a user survey was designed to capture individual-level perceptions, preferences, and behavioral tendencies regarding parking availability, accessibility, pricing, and enforcement mechanisms. These user insights allowed the study to incorporate demand-side sensitivities into the strategy selection process.

Thirdly, expert opinions were collected from 13 professionals including transportation planners, municipal officers, and academic experts involved in the city's transportation planning. These inputs were structured into pairwise comparisons using the Analytic Hierarchy Process (AHP), and consistency ratios were applied to filter reliable responses. Seven expert responses passed the $CR<0.1$ threshold and were used to construct the final decision matrix.

The integration of these data sources followed a tiered logic: parking inventory and counts identified physical constraints and baseline conditions; user surveys provided behavioral and perceptual dimensions; and expert evaluations offered strategic prioritization using quantitative weighting. The final outcome was a harmonized framework wherein empirically observed conditions, user-side feedback, and expert-driven weights were triangulated to propose context-sensitive parking strategies.

3. Analysis and Findings

This section provides an analysis of the results derived from field studies and survey data. Strategy selection was informed by the findings from the parking lot survey, user survey, and Analytic Hierarchy Process (AHP) study. The choices were made based on a comprehensive evaluation of these studies and analyses.

The term parking survey refers to the field-based inventory and occupancy count of on- and off-street parking lots, while the term user survey denotes a questionnaire conducted with individual users to gather opinions, preferences, and behavioral patterns regarding parking practices.

3.1. Parking Survey Results

An examination of the parking infrastructure in Trabzon reveals a diverse array of parking facilities. It has been identified that both licensed parking businesses, regulated by the Zabıta Directorate, and unlicensed operators are present in the city. Municipal parking operations are managed by TRABİTAŞ, a municipal company, which oversees both off-street and roadside parking lots. TRABİTAŞ operates 13 off-street and 6 roadside parking facilities. Among the 13 off-street parking lots managed by the municipality, 2 are enclosed and 11 are open-air facilities. The total capacity of these off-street parking lots is 1,025 vehicles, and all are currently in active operation.

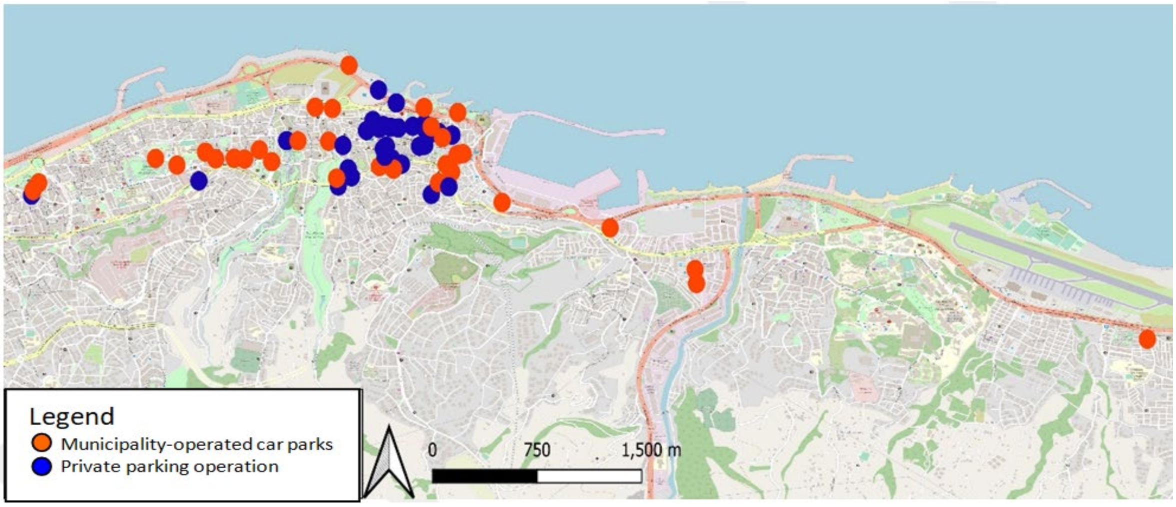

Figure 4 Location of parking lots in Ortahisar district (Source: Produced within the scope of the study)

As part of the study, 57 parking lots in Ortahisar were inspected. Of these, 12 are roadside parking facilities and 45 are off-street parking lots. During the on-site observation and identification studies, it was noted that 8 of the off-street parking lots were out of service, and 1 was designated as a hospital parking lot serving patients and their families. Roadside parking areas, which are concentrated in the city center and around Hagia Sophia Square—a prominent and dynamic area—are primarily designed for parallel parking.

A comprehensive parking lot inventory survey was conducted across 69 parking lots, with a detailed "Parking Lot Survey" carried out in 32 of these facilities. The surveys aimed to assess various aspects of the parking lots, including types, capacities, ground features, fee structures, and construction dates. In addition to evaluating these physical characteristics, a census was performed to determine capacity utilization and occupancy rates. This analysis highlighted parking areas facing capacity issues. Location of off-street and roadside parking lots with capacity problems are given in Figure 6.

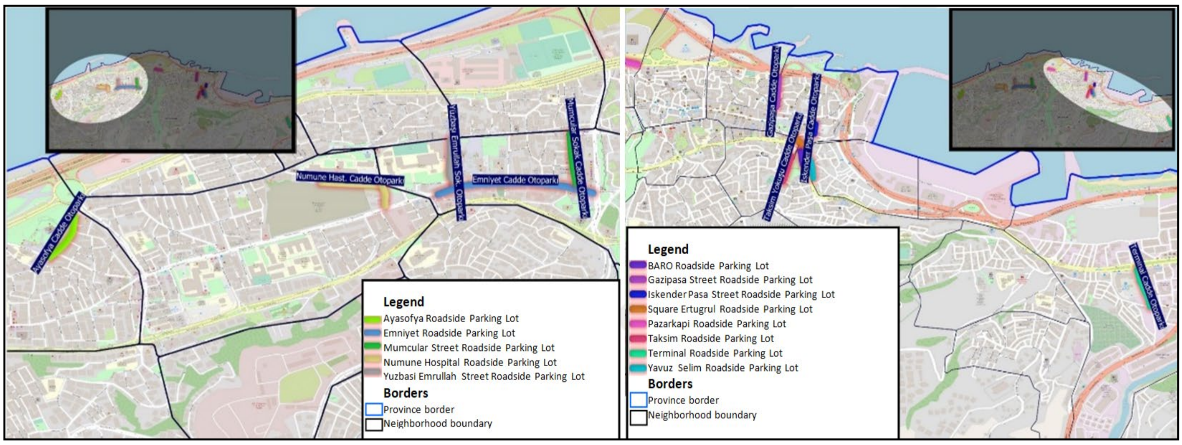

Figure 5 Roadside parking areas

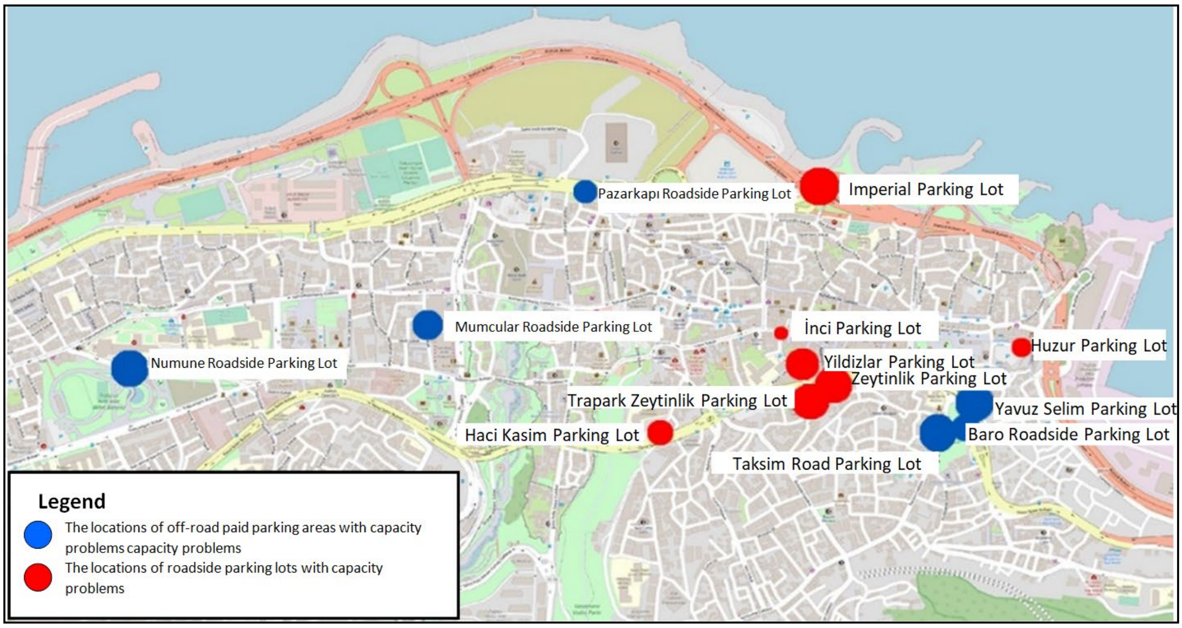

Figure 6 Location of off-street and roadside parking lots with capacity problems

Ortahisar district serves as the central hub of Trabzon province in terms of social, economic, and spatial aspects. This centrality leads to the concentration of various issues, including transportation, accessibility, and parking challenges, within the district. The current population of Ortahisar and projected population figures for the year 2040, based on the development areas outlined in the master development plans, are provided below. Current and 2040 Population Projections for Ortahisar District are given in Table 5.

Table 5 Current and 2040 Population Projections for Ortahisar District

Current Population	328.509
Additional Population Expected in 2040	322.899
Total Population in 2040	651.408

In 2021, the population of Ortahisar district was recorded at 328,509. By 2040, the population is projected to increase by an additional 322,809, resulting in a total estimated population of 651,408. Several approaches for calculating parking demand based on vehicle numbers are outlined below (Özdirim, 1994):

West German Criteria: This method, considered applicable to Turkish cities, suggests that one parking space should be provided for every 5-8 cars in the city center.

U.S. City Standards: In large cities across the United States, it is estimated that 12% of all vehicles will be parked in the city center during peak hours. In smaller cities, this percentage increases to 18%. To estimate parking demand, the total number of vehicles is calculated using coefficients of 5 and 8, based on the West German criteria, for both the current year and the year 2040. Ortahisar District City Center Parking Demand According to the First Method (According to 5-8 coefficients) and Parking Demand for the City Center of Ortahisar District According to the Second Method (According to 12% and 18% rates) are given in Table 6 and 7.

Table 6 Ortahisar District City Center Parking Demand According to the First Method (According to 5-8 coefficients)

Coefficient	Current Situation (Vehicle)	Year 2040 (Vehicle)
5	12.746	32.570
8	7.966	20.356

According to the second method, the large city coefficient is 12% and the small city coefficient is 18%. Parking demand according to these approaches is given in Table.

Table 7 Parking Demand for the City Center of Ortahisar District According to the Second Method (According to 12% and 18% rates)

Percentage (%)	Current Situation (Vehicle)	Year 2040 (Vehicle)
12	7.647	19.542
18	11.471	29.313

Given that Ortahisar does not exhibit metropolitan characteristics at the national or global level, and considering the relatively high projection values for 2040, it is deemed appropriate to apply the criterion of one vehicle per eight vehicles in the city center. According to this approach, the current parking demand is calculated at 7,966 vehicles, while the projected demand for 2040 is 20,356 vehicles. In response to these projections, traditional calculation methods suggest that strategies aimed at enhancing the efficiency of existing parking spaces will be optimal, especially considering the anticipated population growth and the resulting increase in parking space requirements. Therefore, the following strategies are proposed for the city:

Strategies to Increase Parking Lot Effectiveness:

- Sharing of Reserved Areas

- Strategies for Shared Parking Spaces between Locations

Given the challenges associated with creating new parking areas due to the city's morphological constraints or relocating existing parking facilities, these strategies aim to optimize the use of current resources and address the high demand for parking in the city center.

Setting Parking Maximums (Upper Limits of Standards):

This strategy aims to set maximum parking limits to manage demand effectively. The primary goal is to encourage users to adopt alternative modes of transportation, such as public transit, walking, cycling, or shuttle services.

Parking Pricing Strategies:

This approach seeks to alleviate parking issues and reduce urban transportation problems by influencing demand through pricing mechanisms.

Improving Pricing Methods and Providing Financial Incentives:

These strategies focus on developing a comprehensive pricing policy for parking areas and reducing demand by offering affordable transportation alternatives, thus encouraging users to switch to public transport. Based on demand and projection calculations, the implementation of these strategies is expected to alleviate future congestion and address bottlenecks in parking facilities effectively.

3.2. User Survey Results

The survey results indicate that the primary purpose for participants traveling to the region is business-related, followed by shopping and other activities. Notably, 97% of the participants use their own private vehicles for these trips to the city center. When parking, users typically prefer to park for a duration of 0-15 minutes. It has been observed that off-street open parking areas are generally favored by users. Figure 7 illustrates the preferences regarding travel and parking among the users.

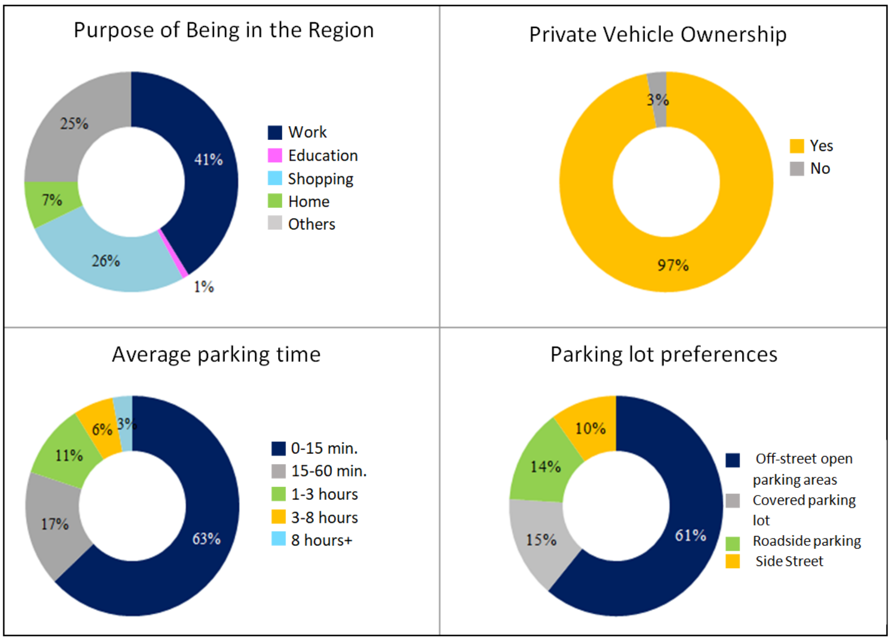

Figure 7 Users' travel and parking trends

The primary concern for users when selecting parking facilities is security, followed by proximity to their destination and the fee structure. An analysis of user preferences regarding the distance between parking areas and destinations reveals a relatively even distribution. Specifically, 23% of users consider distances ranging from 0-50 meters to be acceptable, 25% prefer distances of 51-100 meters, and 24% are comfortable with distances of 250 meters or more. However, the 51-100 meter range is the most frequently reported preference for walking distance. Figure 8 illustrates the distribution of these responses.

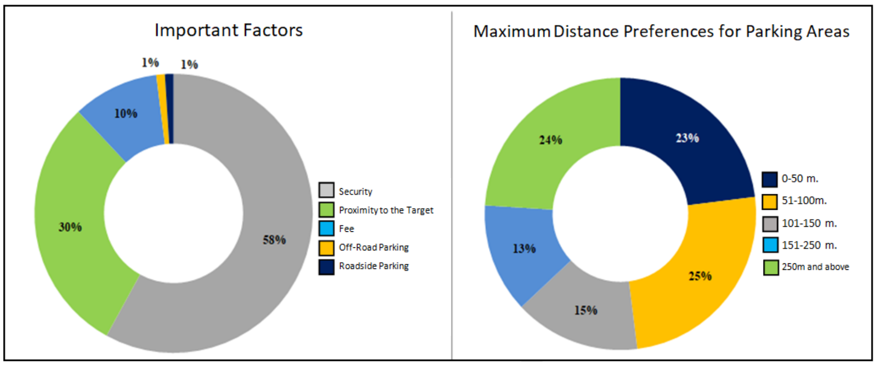

Figure 8 Issues of importance for participants in parking lots

In addition to socio-demographic and transportation data, the survey participants were queried on specific aspects to identify parking strategies that could enhance the efficiency and utilization of parking facilities in Trabzon. The survey addressed several key management strategies, including the use of reserved parking spaces, the implementation of shared parking arrangements, the potential for modal shifts in transportation, and preferences regarding possible changes in transportation modes. Users' attitudes and preferences towards strategies are given in Figure 9.

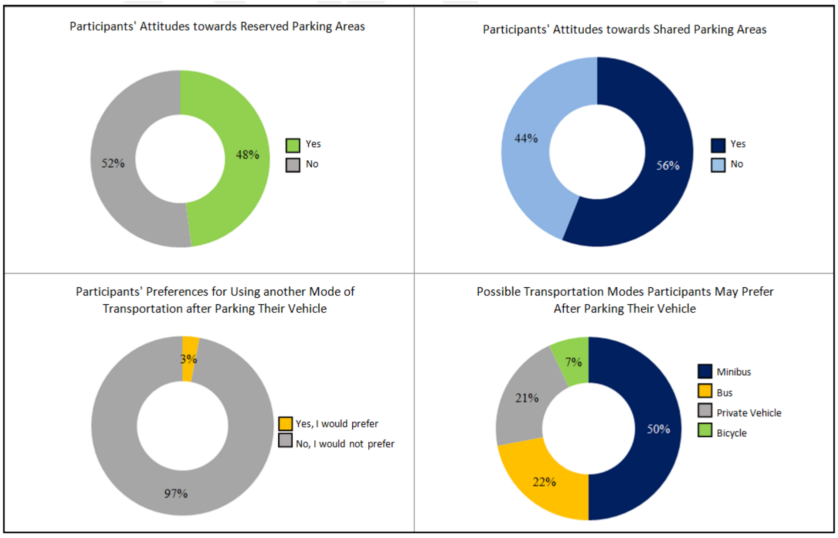

Figure 9 Users' attitudes and preferences towards strategies

Parking strategies play a crucial role in managing demand and promoting the use of alternative transportation modes such as public transit, cycling, and walking to alleviate urban traffic congestion. This section of the survey explored users' attitudes toward cycling and pedestrian transportation. Findings indicate that 60% of participants do not favor cycling, whereas 40% expressed an interest in using bicycles. Additionally, 19% of users indicated a reluctance to engage in pedestrian travel, while 81% reported a willingness to walk. Those who do not prefer walking or cycling cited factors such as challenging terrain, age, long distances, and safety concerns, preferring automobiles over these alternative modes. The Figure 10 illustrates the survey participants' responses.

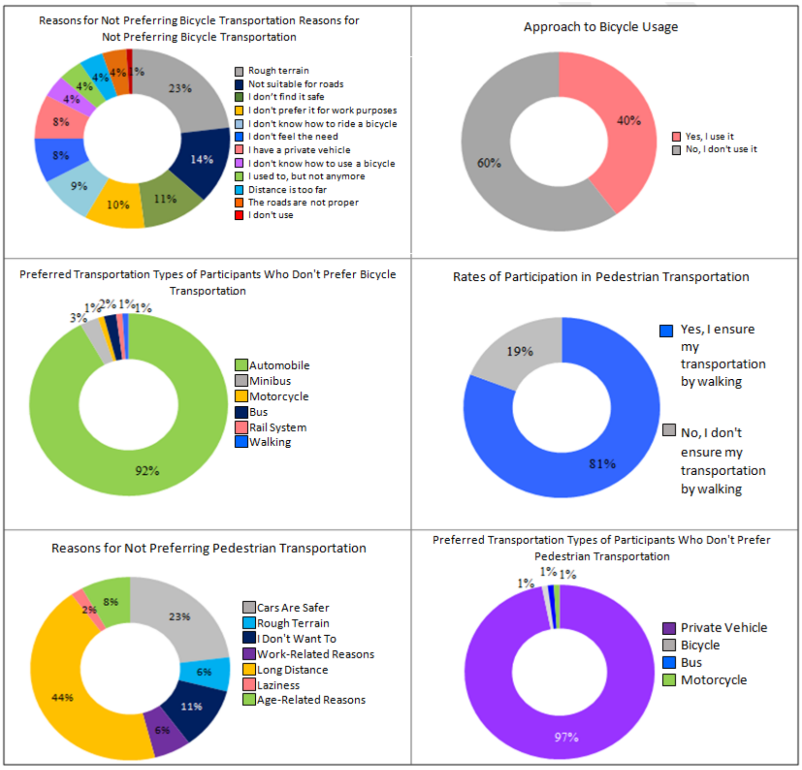

Figure 10 Users' attitudes towards pedestrian and bicycle transportation

The survey also assessed users' attitudes toward parking fees and fee policies. Of the respondents, 60% expressed satisfaction with the current fee structure, while 40% advocated for changes. The most notable suggestion was to adjust pricing policies, followed by requests for tariff reorganization, expansion of parking areas, and promotional campaigns. In the event that a distance-based pricing system were implemented, 66% of users indicated a preference for parking in areas closer to their travel destinations, even if this meant incurring higher fees.

The survey results reveal that parking lot users predominantly utilize parking for business and shopping purposes. A significant majority, 97%, own private vehicles. Due to the city's hilly terrain, transportation between residential areas and commercial centers is facilitated by inclined roads, challenging climatic conditions, and the linear layout of the city along the coast. These factors contribute to a high reliance on private vehicles. Consequently, users prefer parking facilities in proximity to their travel destinations. Despite the strong preference for private vehicles, improvements in pedestrian and bicycle infrastructure could lead to increased use of these modes. Additionally, policies that encourage public transportation may gradually reduce dependence on private vehicles, positively impacting urban traffic.

Based on the analysis of parking lot surveys, census studies, and user feedback, seven criteria have been identified as ideal for parking areas, considering their applicability and manageability for both the city and its users. These criteria are:

- Sensitivity to pedestrian transportation
- Fee sensitivity
- Reserved parking spaces
- Shared parking spaces
- Integration with mobile applications
- Proximity to destinations
- Security

These criteria will be prioritized using the Analytical Hierarchy Process (AHP) in the following section, after which short- and long-term parking strategies will be developed in alignment with the ranking results.

3.3. AHP Analysis Results

Based on the analysis of parking demand, user feedback, and operational deficiencies, a set of seven criteria was identified for evaluating and selecting parking management strategies. Following the methodology described in Section 2.2, the expert-based AHP process was conducted using criteria derived from both the user survey and demand analysis. These criteria were used in the Analytic Hierarchy Process (AHP) to structure expert decision-making:

- Security
- Proximity to Destinations
- Reserved Parking Spaces
- Shared Parking Spaces
- Integration with Mobile Applications
- Fee Sensitivity
- Sensitivity to Pedestrian Transportation

These criteria are consistent with common decision-making factors identified in previous AHP-based parking studies (Chien et al., 2020; Han et al., 2018; Waraich & Axhausen, 2012), ensuring both contextual relevance and methodological rigor.

As a result of the study, safety ranked first, followed by proximity to the destination and sensitivity to pedestrian transportation strategies. In the final phase of the study, expert opinions were collected to establish the priority weights among the evaluation criteria used in the Analytic Hierarchy Process (AHP). The expert group consisted of 13 professionals including academics in transportation planning and industrial engineering, as well as practitioners involved in the Trabzon Transportation Master Plan and municipal experts from relevant departments. Pairwise comparison forms were distributed, and the responses were analyzed to generate a combined criteria matrix. Among the 13 expert responses collected, consistency ratios (CR) were calculated for each pairwise comparison matrix in accordance with the standard AHP procedure. Based on Saaty's acceptable threshold of 0.1, 7 responses were found to be consistent (CR < 0.1) and thus were included in the final aggregation process. The geometric means of these consistent responses were used to construct the final pairwise comparison matrix, as shown in Table 8.

Table 8 Criteria Selection in Expert Study

	C1	C2	C3	C4	C5	C6	C7
Criteria	Security	Proximity to destinations	Reserved parking spaces	Shared parking spaces	Integration with mobile applications	Fee sensitivity	Sensitivity to pedestrian transportation
Expert 1	0.05620	0.246620	0.09861	0.117010	0.05068	0.07543	0.21577
Expert 4	0.20427	0.151990	0.14565	0.061157	0.03711	0.1528	0.219327
Expert 6	0.08725	0.156939	0.12909	0.059869	0.10857	0.1606	0.18244
Expert 8	0.31216	0.042956	0.06340	0.054122	0.04367	0.06836	0.19365
Expert 9	0.31073	0.145863	0.03804	0.048047	0.03124	0.21659	0.04659
Expert 12	0.22698	0.183322	0.06517	0.021029	0.05179	0.14038	0.03799
Expert 13	0.27864	0.156290	0.05580	0.060165	0.03525	0.12189	0.23213
Geometric Average	0.21089	0.15485	0.08511	0.060200	0.05119	0.13372	0.16113

A pairwise comparison matrix has been given based on the final priority weights presented in Table 9. This matrix reflects the relative dominance of each criterion over the others, consistent with the logic of the Analytic Hierarchy Process (AHP). The values were calculated using Saaty's fundamental scale, where each element of the matrix is obtained by dividing the relative weight of one criterion by another. The resulting matrix ensures reciprocal consistency and forms the basis for the prioritization results provided in Table 9.

Table 9 Criteria-to-Criteria Pairwise Comparison Matrix

Criteria	Security	Proximity	Reserved	Shared	Mobile	Fee	Pedestrian
Security	1.000	1.362	2.477	3.504	4.120	1.577	1.309
Proximity	0.734	1.000	1.815	2.571	3.026	1.151	0.960
Reserved	0.404	0.551	1.000	1.416	1.664	0.636	0.528
Shared	0.285	0.389	0.706	1.000	1.175	0.449	0.373
Mobile	0.243	0.330	0.601	0.851	1.000	0.382	0.318
Fee	0.634	0.869	1.572	2.228	2.619	1.000	0.828
Pedestrian	0.764	1.042	1.893	2.682	3.143	1.207	1.000

To ensure the internal consistency of expert judgments in the pairwise comparison process, the consistency index (CI) and maximum eigenvalue ($\lambda_{\max}$) were calculated according to the standard AHP methodology (Saaty, 1980). The calculated $\lambda_{\max}$ value is 7.716, and the resulting consistency index (CI) is 0.119. Since the number of criteria is 7, the corresponding Random Index (RI) is 1.32, and the consistency ratio (CR = CI / RI) is approximately 0.090. This value is below the commonly accepted threshold of 0.1, indicating an acceptable level of consistency in the aggregated matrix. Consistency Index and Maximum Eigenvalue ($\lambda_{\max}$) are given in Table 10.

Table 10 Consistency Index and Maximum Eigenvalue ($\lambda_{\max}$)

λ_{maks}	7.716179314
CI	0.119363219

To enhance methodological transparency, detailed normalization tables of the consistent pairwise comparison matrices used in the aggregation process are presented. The standard normalization step in AHP, in which each element is divided by the column sum to ensure comparability across criteria, is given in the Table 11.

Table 11 Normalization Stages

NORMALIZATION / 1st Stage							
	K1	K2	K3	K4	K5	K6	K7
K1	1	0.17	0.13	1	1	1	1
K2	6	1	1	6	6	5	5
K3	8	1	1	6	6	8	6
K4	1	0.125	0.167	1	4	9	6
K5	1	0.167	0.143	1	1	4	8
K6	6	0.167	0.111	6	5	1	9
K7	8	0.111	0.2	6	2	1	1

NORMALIZATION / 3th Stage							
	K1	K2	K3	K4	K5	K6	K7
K1	0.032	0.062	0.047	0.037	0.04	0.034	0.028
K2	0.194	0.365	0.364	0.222	0.24	0.172	0.139
K3	0.258	0.365	0.364	0.222	0.24	0.276	0.167
K4	0.032	0.046	0.061	0.037	0.16	0.31	0.167
K5	0.032	0.061	0.052	0.037	0.04	0.138	0.222
K6	0.194	0.061	0.04	0.222	0.2	0.034	0.25
K7	0.258	0.041	0.073	0.222	0.08	0.034	0.028

NORMALIZATION / 2nd Stage							
	K1	K2	K3	K4	K5	K6	K7
K1	0.032	0.062	0.047	0.037	0.04	0.034	0.028
K2	0.194	0.365	0.364	0.222	0.24	0.172	0.139
K3	0.258	0.365	0.364	0.222	0.24	0.276	0.167
K4	0.032	0.046	0.061	0.037	0.16	0.31	0.167
K5	0.032	0.061	0.052	0.037	0.04	0.138	0.222
K6	0.194	0.061	0.04	0.222	0.2	0.034	0.25
K7	0.258	0.041	0.073	0.222	0.08	0.034	0.028

NORMALIZATION / 4th Stage	NORMALIZATION / 5th Stage
0.564	14.053
3.19	13.167
3.804	14.079
2.483	21.387
1.732	20.818
2.513	17.562
1.513	14.393
AVERAGE (λmax.): 16.494	

To determine the prioritization degrees shown in Table 11, the standard Analytic Hierarchy Process (AHP) procedure was followed. In this process, the pairwise comparison values provided by the experts are first normalized. This normalization ensures that each column in the comparison matrix sums to one, making the values comparable across criteria. After normalization, the priority weight of each criterion is obtained by calculating the average of its normalized values across all comparisons. These average values represent the relative importance of each criterion and are referred to as the prioritization degrees. This method is widely recognized in the AHP literature (e.g., Saaty, 1980; Forman & Gass, 2001; Ishizaka & Labib, 2011) as a standard approach for deriving weights from consistent comparison matrices.

The results of the geometrically averaged criteria were ranked from largest to smallest and the "Safety" criterion with the highest value of 0.210895 was the most preferred criterion by the experts in the study, followed by the "Proximity to Target" criterion with 0.154846. The order of preference of the criteria, where the expert opinions are analyzed and the criteria are calculated with the AHP method, is given in the Table 12.

Table 12 Prioritization of Criteria

Criteria	Selection	Preference order of criteria
Security	0.210895	1
Sensitivity to pedestrian transportation	0.161126	2
Proximity to destinations	0.154846	3
Fee sensitivity	0.133717	4
Reserved parking spaces	0.085109	5
Shared parking spaces	0.060199	6
Integration with mobile applications	0.051689	7

The expert study identified "Safety" as the highest priority criterion. Similarly, the user survey revealed that safety is the most significant factor for users when choosing parking facilities. This criterion is crucial in influencing users' preferences for parking location or type. According to the expert study, the second priority is "Sensitivity to Pedestrian Transportation, followed by "Proximity to Destination" as the third priority. These two criteria are interrelated and can be addressed through effective implementation and optimal strategies. Enhancing the pedestrian transportation system can encourage users to utilize parking facilities at various distances, as indicated by the balanced distribution of preferred distances in the user survey. Strategies that support and emphasize pedestrian transportation can revitalize urban mobility.

"Proximity to Destination" is the next priority criterion where pedestrian transportation cannot be sufficiently improved. Field observations and surveys reveal that the city's topographical challenges, such as sloping terrain, make pedestrian travel difficult, leading users to favor parking areas closer to their destinations. The survey data suggest that users predominantly rely on private vehicles due to the slope, distance, and climatic conditions. However, improving pedestrian infrastructure could increase users' willingness to use alternative modes of transportation.

The "Wage Sensitivity" criterion, derived from the survey, reflects a mixed response. While 60% of respondents are satisfied with the current tariff structure, 40% believe that prices should be more affordable. Nonetheless, when given a choice between safety, proximity to the destination, fare, and parking locations, fare was the most preferred issue after safety and proximity, aligning with the findings of the expert study.

4. Setting Properties in Strategy Selection

As previously outlined, three distinct methods were employed to develop the parking strategy: demand estimation, user surveys, and the Analytical Hierarchy Process (AHP). To ensure these methods collectively represent a coherent and meaningful framework, the results were integrated and applied to the Ortahisar city center. Each method supports and complements the others.

- The strategies identified through demand forecasting include:
- Sharing Reserved Areas
- Strategies for Shared Parking Spaces across Locations
- Parking Pricing Strategies
- Enhancing Pricing Methods and Providing Financial Incentives
- Park & Ride Strategy

While these strategies address the parking issues in the city, their practical applicability was questioned in relation to the city’s physical structure and established transportation patterns. Consequently, these strategies were presented to parking lot users through a survey to gauge their reactions and preferences. The strategies identified from the user survey include:

- Safe Urban Mobility
- Parking Pricing Strategies
- Sharing of Reserved Areas
- Strategies for Shared Parking Spaces between Locations
- Improving Pricing Methods and Providing Financial Incentives
- Enhancing Walking and Cycling Facilities

Based on the data obtained from both the demand forecasting and user survey, these strategies were used as criteria for the AHP study. The goal was to integrate demand results and user preferences with expert opinions to assess the suitability of the strategies for the city.

The criteria established for the AHP study are:

- Sensitivity to Pedestrian Transportation
- Fee Sensitivity
- Reserved Parking Spaces
- Security

- Shared Parking Spaces
- Integration with Mobile Applications
- Proximity to Destinations

Through these three studies, a prioritization hierarchy for strategy selection was developed. The prioritization is as follows:

- First Priority: Strategies where there is consensus between expert opinions and user preferences. These strategies should be prioritized in the decision-making process.
- Second Priority: Strategies favored solely by experts. These strategies are given secondary priority based on the city's structure, traffic culture, supply-demand balance, and expert knowledge and experience.

Figure 11 illustrates the prioritization exercise in strategy selection.

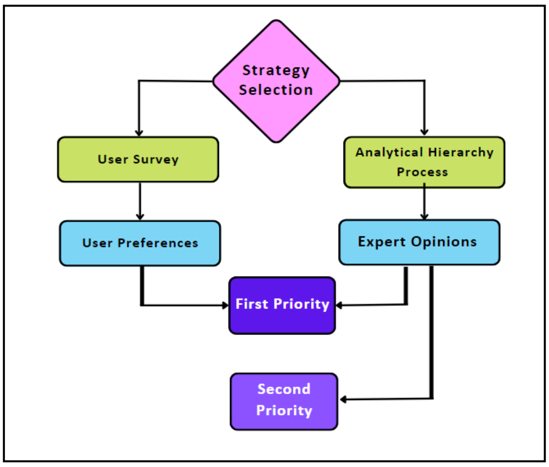

Figure 11 Prioritization study in strategy selection

First Priority Strategies are those where there is a consensus between user preferences and the AHP study results. These strategies are prioritized in the selection process. The most frequently preferred strategies include:

- Security
- Sensitivity to Pedestrian Transportation
- Proximity to Destination
- Integration with Mobile Applications

Among these, security emerges as the highest priority. Both users and experts agree that the safety of life and property in parking areas is paramount.

Second Priority Strategies consist of recommendations from experts that users have not favored but are proposed to maintain traffic flow and address parking issues in Trabzon Ortahisar city center. While these strategies are derived from data and expert evaluation, their applicability is context-sensitive and may vary depending on implementation capacity and behavioral adaptation. These strategies include:

- Positional Pricing
- Park & Ride System
- Expansion of Cycling Infrastructure

Positional Pricing aims to manage parking supply and demand by spatially varying parking fees, with the goal of reducing central area parking, especially roadside parking. Higher fees in a designated geographical area are intended to discourage parking in the city center, addressing traffic disruptions caused by high vehicle density and inadequate pedestrian routes.

Park & Ride (P&R) is another recommended strategy. Although users may not currently favor P&R, expert evaluations suggest it could support urban mobility improvements in the context of Ortahisar's morphological and traffic characteristics. The strategy is not prescriptive but proposed as a planning tool subject to contextual assessment. The P&R system is intended to provide an alternative to central city parking and improve overall traffic conditions.

Expanding Cycling Infrastructure is the final expert recommendation. Bicycles offer a modern transportation option for urban travel, either as a standalone mode or as a feeder to public transport. To increase cycling adoption, improvements should be made to the bicycle network, including the establishment of maintenance stations and rest areas. While current user preferences for cycling are limited, infrastructure enhancements—such as network continuity and support facilities—are expected to create enabling conditions, as supported by expert assessments. These do not represent forecasts, but context-informed recommendations.

All these studies and recommendations are grounded in demand calculation. While these models incorporate user preferences and expert inputs, the resulting strategies are indicative rather than predictive. They are intended to inform decision-makers within current constraints, not to prescribe long-term outcomes.

5. Results and Consideration

The key contribution of this research lies in its multi-layered integration of traditional demand-based models, real-time user preferences, and expert-based prioritization using AHP. This hybrid structure sets the study apart from existing literature by offering a more grounded and participatory approach to parking strategy selection. Parking management strategies represent an advanced approach in the contemporary planning paradigm, offering solutions to various parking-related issues such as capacity, volume, utilization, type, and operation. This approach aims to enhance the capacity of parking facilities through more efficient use, avoiding the need for additional infrastructure. It is particularly effective in regions with challenging geographical features and limited land use, such as Trabzon.

Survey data indicates that there are parking management strategies that the community will readily adopt due to their alignment with cultural habits and daily routines. The selected strategies are designed to formulate policies and programs that promote more efficient use of parking spaces, yielding economic, social, and environmental benefits. While these strategies typically provide a 5%-10% improvement in the short term, they can achieve 20%-40% efficiency gains in the long term through various combinations and effective practices. Implementing these strategies without constructing new facilities is both cost-effective and feasible.

The integration of field data, user preferences, and expert judgments enabled a multi-dimensional understanding of parking dynamics in Ortahisar. These findings validate the hybrid methodological approach outlined earlier, demonstrating how traditional data, user insights, and expert analysis can converge into implementable parking strategies. This comprehensive perspective facilitated the identification of context-specific strategies that are not only technically sound but also behaviorally and administratively feasible. The prioritization of strategies through expert-driven AHP analysis reflected both on-ground realities and stakeholder expectations, thus enhancing the operational applicability of the final recommendations.

Parking management enhances user service quality and choice, fosters flexibility, and contributes to the creation of more functional communities. It also adapts to new demands and uses. Essential criteria for successful parking management include providing convenient parking options and effectively informing users about the parking system.

This study integrates traditional methods with user opinions and demand calculations to propose parking strategies for Trabzon Ortahisar. Traditional approaches alone were insufficient for strategy selection, as they did not adequately address user profiles and habits. Consequently, traditional methods, such as calculations of parking capacities and utilization rates, were compared with user and parking surveys. The AHP method was employed to refine the strategy selection and provide optimal recommendations for the city. Population growth projections indicate that Ortahisar's population will rise from 328,509 in 2021 to approximately 651,408 by 2040. Demand calculations using both West German and U.S. city criteria led to a preference for the German approach, given Ortahisar's non-metropolitan status. This approach estimated a parking demand of 7,966 vehicles currently, rising to 20,356 by 2040. This demand is addressed by both paid parking and free roadside options.

Traditional methods suggest that strategies aimed at increasing parking space efficiency, such as shared parking strategies and setting parking maximums, are ideal for the city. Other strategies include parking pricing and improving pricing methods to encourage alternative modes of transport. User survey data was collected to assess preferences and demands for various strategies, including:

- Strategies to Increase Parking Space Efficiency
- Setting Parking Maximums
- Parking Pricing Strategies
- Improving Pricing Methods and Providing Financial Incentives

The survey provided insights into vehicle ownership, trip purposes, and transportation mode preferences. Based on the results, seven criteria were identified as ideal for parking management:

- Sensitivity to Pedestrian Transportation
- Fee Sensitivity
- Reserved Parking Spaces
- Shared Parking Spaces
- Integration with Mobile Applications
- Proximity to Destinations
- Security

These criteria were prioritized using the AHP method, with input from 12 experts. The final prioritization was as follows:

- Security
- Proximity to Destinations
- Sensitivity to Pedestrian Transportation
- Fee Sensitivity
- Reserved Parking Spaces
- Shared Parking Spaces
- Integration with Mobile Applications

The study demonstrates a hybrid approach, combining traditional methods with user feedback to inform strategy selection. This approach is expected to provide more realistic and actionable solutions for parking management. Future research should explore the impacts of these strategies on urban planning scenarios and investigate their roles in shaping urban mobility and accessibility plans. This thesis, with its hybrid approach, is anticipated to serve as a foundational contribution to future studies.

5.1. Compatibility of Ortahisar's Central District Characteristics with Parking Data

Ortahisar, as the central business and administrative district of Trabzon, is characterized by narrow street layouts, insufficient off-street parking capacity, and high daily visitor traffic. The parking inventory revealed that 8 of the 45 off-street parking lots are out of service and only 12 roadside parking zones exist, which are inadequate to meet the local demand. These findings clearly reflect a mismatch between parking supply and demand in this high-density central area.

5.2. Discrepancy Between User-Prioritized Strategies and the Existing Parking System

Strategies such as time limitation and pricing were strongly favored by users; however, they are either minimally implemented or entirely absent in the current parking system. Especially in the city center, uncontrolled long-term parking reduces turnover and impairs access for other potential users. This highlights a significant gap between user expectations and the current operational framework.

5.3. Balance and Tension Between Expert and User Opinions in the Local Context

The AHP analysis indicated that while users prioritize practical benefits (e.g., time and fee control), experts emphasize system-oriented solutions (e.g., access management and technological integration). Nonetheless, commonly supported strategies such as time restrictions suggest not a contradiction but rather differing hierarchies of importance. This implies that the integration of both perspectives is feasible and meaningful.

5.4. Applicability of the Ranked Strategies in the Context of Ortahisar

Most of the proposed strategies—such as time restrictions, dynamic pricing, and user prioritization—are applicable in Ortahisar's compact and historically constrained urban fabric without requiring significant physical infrastructure changes. However, strategies involving technological systems demand both adequate municipal digital capacity and a cultural adaptation by users. Therefore, in the short term, low-cost and regulation-based strategies appear to be the most viable.

5.5. Practical Implications for the Ortahisar Case

The findings of the study highlight several practical implications that can guide parking policy development in Ortahisar. As the central district of Trabzon, Ortahisar experiences significant pressure on its limited parking infrastructure, especially around commercial and historical centers such as Atatürk Square and Hagia Sophia Square. The integration of user preferences, expert evaluations, and parking inventory analysis led to a prioritized strategy list that emphasizes time-restricted parking and dynamic pricing as feasible and impactful interventions. These strategies directly respond to the short-term, high-turnover demand structure typical of the district. Moreover, the participatory approach adopted in the study provides a replicable model for other urban areas in Turkey where user behaviors and institutional expertise must be aligned to enhance the efficiency of parking management. The consistency observed between expert priorities and user demands in the final strategy hierarchy further supports the legitimacy and implement ability of the proposed solutions within the unique spatial, social, and economic context of Ortahisar.

In doing so, the study fulfills its initial objective of bridging methodological gaps in parking strategy selection for mid-sized urban areas like Trabzon.

Beyond identifying context-specific parking strategies, the study demonstrates the applicability of an AHP-based participatory planning model in urban mobility decision-making. By combining demand estimation, user surveys, and expert evaluations, this model offers a replicable and scalable framework for integrated parking management, particularly in complex urban settings.

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CRediT Authorship Contribution Statement

Ecenur Sarıca Karakulak: Writing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. Görkem Gülhan: Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data Availability

The data that support the findings of this study are not publicly available because they are not solely owned by the authors. Access to the data may be subject to restrictions imposed by third parties.

Ethics Committee Approval

No ethics committee approval was required for this study since all datasets and survey instruments used are already published and properly cited in the references.

Resume

Ecenur Sarıca Karakulak is an urban and regional planner with a strong academic and professional background in sustainable urban mobility and parking management. She earned her undergraduate degree in Urban and Regional Planning from Pamukkale University-Faculty of Architecture and Design, Denizli, Turkey, where she also completed her master's degree in the same department. Her thesis focused on parking management strategies and integrated both quantitative modeling and stakeholder-based approaches, highlighting her expertise in contemporary urban transportation challenges. Currently, she works as a Urban Planner at the Denizli Metropolitan Municipality, where she contributes to urban planning initiatives with an emphasis on mobility, accessibility, and sustainable development. Her professional interests include transport planning, public space design, and the integration of smart solutions into urban policy.

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