Demand-Oriented Generation of Urban Parking Policies

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ABSTRACT
The parking problem is a common sub-topic of transportation planning and urban planning, and it is increasing its impact day by day as urbanization intensifies. The rapid increase in the number of private vehicles, coupled with the presence of borders and thresholds limiting capacity increases in cities render the demand-supply problem permanent. The parking problem is generally addressed by rapidly generating additional supply to meet the rising demand and is dealt by non-integrated, piecemeal methods. Such micro- and medium-sized solutions only focus on temporarily deferring the larger problem. Hence, there is a need for an approach in which the demand is determined at all scales, evaluated on the basis of sub-centers, and policies and strategies are produced accordingly.

In this study, a demand-oriented integrated parking lot planning approach has been generated for Trabzon, where supply is strongly limited due to topography. With the generated approach, policies and principle recommendations have been developed.
Keywords: Parking demand, parking policy, Trabzon, parking strategies.

1. INTRODUCTION
Parking lot planning and its applications are a significant part of transportation planning in the world. It is also an area of transportation and land use planning that is typically handled in combination with the parking policies determined in the land use plans (Molan and Simićević, 2018). With the increasing number of vehicles in the world and in Europe in particular, the importance of parking lot applications and planning, is increasingly recognized and applications that provoke demand are avoided. With this perspective, applications that draw vehicles to the city center are being abandoned to the past. Instead, practices that emphasize better management of the existing capacity are put on the agenda. The field is now leaning towards applications within the framework of park management, where parking demand in the city centers is calculated in advance and roadside parking is disallowed. Thus, the issue is handled more as a demand management issue. Examining parking policies in depth reveal three different approaches: the traditional approach, demand management and market-based (Barter, 2010).

The traditional approach can be divided into two, as automobile-centered layout and demand-centered layout. The automobile-centered layout emerges from associating the space usage functions with the demand and determining the minimum parking requirement for certain functions. The demand-centered approach, on the other hand, is one that proceeds from the number of vehicles that the activity will attract by associating the demand with the activity (Şenbil, 2012). The demand management approach is based on meeting the parking demand by developing transportation policies, land use policies and policies that will increase the efficiency of the current supply. In the market-oriented approach, the formation of the parking lot supply is left to the free market. In this approach, parking areas are perceived as rentable or sellable units rather than public spaces (Tozluoğlu, 2017).

Parking policies and planning are researched under many different fields. Especially in recent years, studies on Smart Parking Strategies have increased (Teodorovic, 2006). Parking strategies and shared parking policies are advancing (Krapivsky and Redner, 2019; Aldred and Jungnickel, 2013). Mingardo et al. (2022) investigated the relationship between

behavior and price by working on pricing strategies and generated strategies based on it. There are also simulation-based studies for determining compensation strategies (Mei et al., 2020). In larger scale assessments, McShane and Meyer (1982) examined parking policies in terms of urban targets and then generated strategies to meet the requirements. On the other hand, there are also researches emphasizing the significance of integrated planning in parking lot planning. Sandor and Siszar (2015) examined the role of an integrated parking data system in traffic management. Furthermore, integrated systems were researched in association with the Park&Ride system (Song et al., 2017). Parking demand, on the other hand, has generally been studied within the scope of forecast-development models and efficiency (Wilson, 1992; Wong et al., 2000; Yan et al., 2019; Tiexin et al., 2012). In the area of effective management of demand and supply simultaneously, there are Parking Management oriented researches (Litman, 2008). The management of parking areas involves searching for the optimal regulation of the use of parking spaces by examining current daily transportation habits (Yan et al. 2019).

Many studies emphasize that parking policies in Turkey are determined incompletely or insufficiently. In addition, it is known that arrangement and planning errors are combined with mistakes in the implementation phase. In general, expanding parking areas in terms of capacity and strategically increasing capacity in places that attract private vehicle traffic constitute the fundamental applications (Ağaoğlu and Daşdemir, 2019). Especially in Turkey, roadside parking is a significant factor in reducing urban traffic efficiency (Bingöl et al. 2010).

This study identifies the parking demands in the Trabzon city center and sub-centers. It reveals by which applications and recommendations the problems can be solved. The counting and observations were made in the central region. Solution principles and approaches have been produced concerning in which regions and with what kind of administrative practice can interventions be made in the parking lot problem. In this context, suggestions have been developed regarding the parking policies to be implemented, parking investment, pricing structure and business plans, basic decisions regarding on-road and off-road parking arrangements, and the preparation of parking standards and criteria. Furthermore, long term recommendations are provided regarding moving the focus of on-road and off-road parking areas away from the city center, the selection of parking areas in the immediate vicinity of the center to be organized in a way that will allow transfer by forms of public transportation, and suggestions are made for the long-term parking policies and pricing structure.

2. STUDY AREA & METHODOLGY

2.1. Study Area and Base Case

Parking lots were surveyed and counted to determine the parking capacity and information and habits of parking users in Trabzon. Parking lots were counted near streets, avenues and their surroundings where traffic is dense and related parking problems manifest. The daily capacity utilizations were determined by the observers with the prepared parking sheets, the roadside parking sheets were filled and the roadside parking lot observation charts were generated. Parking lots were counted in parallel with conducting the "Parking User Surveys". The counting process was carried out for each parking lot three times a day; at 09:00 in the morning, 12:00 in the afternoon and 17:00 in the evening. Counting and observations were made for both roadside parking and facility type parking lots. Within the scope of the study, a user survey was conducted with 510 citizens. Parking lot inventory surveys were conducted in 37 of the 57 parking lots in Ortahisar, Trabzon which were visited.

. 12 of these parking areas are roadside and 45 are in-house parking lots. However, during on-site observation and identification studies, it has been determined that 8 on-site parking lots are currently out of service. Within the scope of the study, "Car Park User Surveys" with parking users and "Car Park Inventory Surveys" with parking operators were carried out. The locations of private and municipal car parks are given in Figure 1.

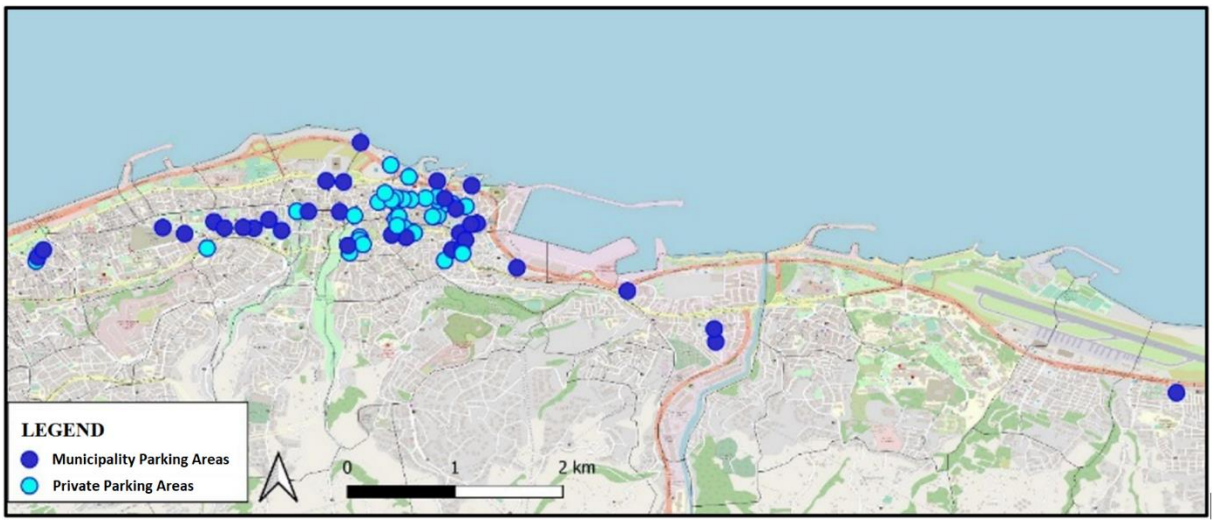

Figure 1. Locations of Ortahisar District Parking Areas (TMP,2022)

12 roadside parking lots in Trabzon-Ortahisar were counted. While roadside parking areas are more common in the city center, they are also located in and around Hagia Sophia Square, which is one of the busiest areas of the city. It has been determined that roadside parking in Trabzon is in the form of parallel parking. Roadside parking areas are given in Figure 2.

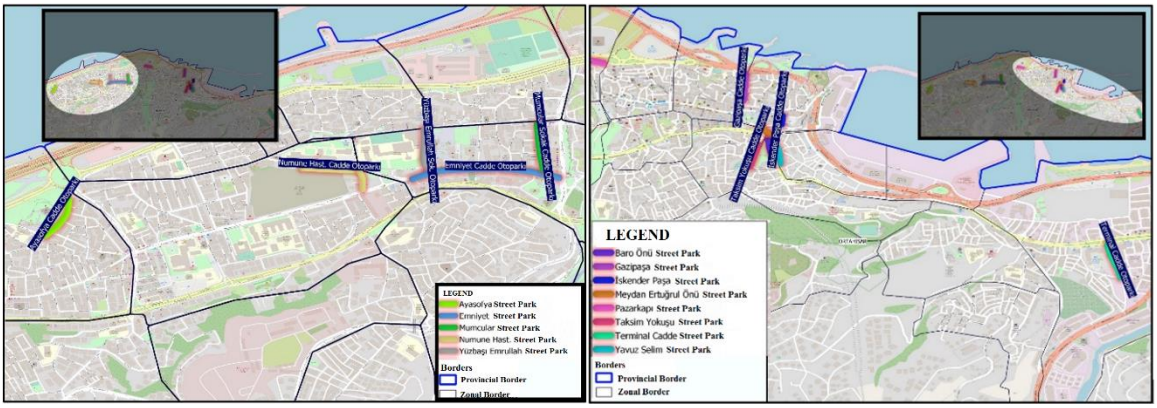

Figure 2. Roadside Parking Areas (TMP, 2022)

The general average of the daily average occupancy rates in the roadside car parks in the city center is 26%. While the highest occupancy rate was 87%, the lowest was calculated as 5%. The average occupancy rate was calculated as 64% as a result of the car park counting carried out in the car park areas in the city center. While the highest occupancy rate was 100%, the lowest was calculated as 18%.

According to the results obtained from the surveys, when the technical infrastructure in the parking areas are examined, no problem was found in 42% of the parking lots. Traffic problems in 17% and high demand in 11% of the parking areas were encountered. These problems are followed by physical problems such as low demand, road superstructure deficiencies, safety issues and water accumulation. The problems identified are presented in Figure 3.

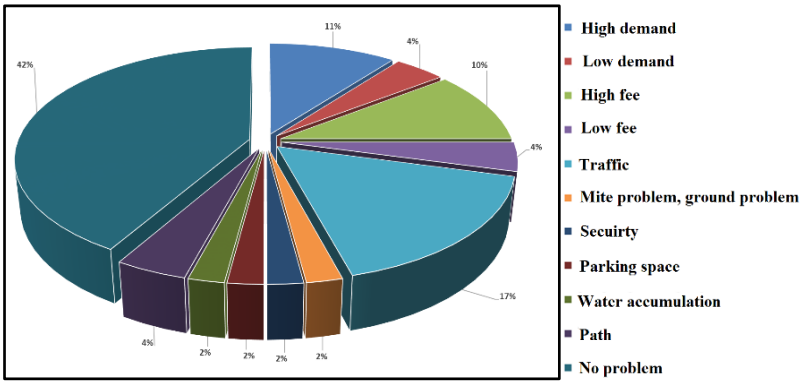

Figure 3. Identified Problems (TMP, 2022)

2.2. Planning Approach and Method

In order to achieve and implement the aforementioned goals, a 4-stage planning approach has been developed and a flow chart has been created. The flow chart created is given in Figure 4.

In step 1; infrastructure researches were carried out for the city center where problem clusters reside and infrastructure is concentrated. At this stage, on- and off-road paid parking capacities, daily utilization rates of these parking lots, transportation habits, policies and the current logic for parking lot planning and other infrastructure data were investigated.

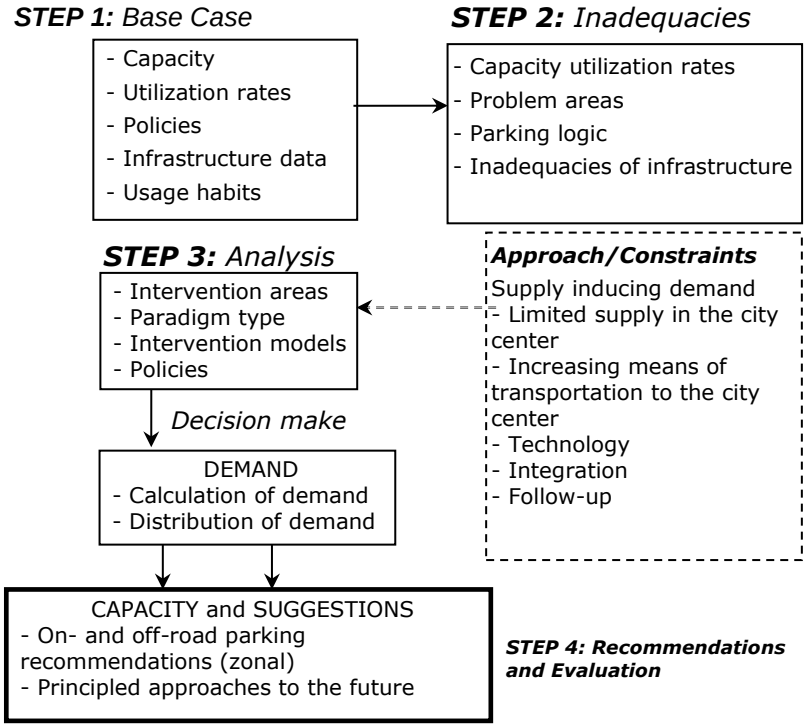

Figure 4. Planning Approach Flow Chart

In step 2; The capacity utilization rates of the existing parking lots in the daily flow were determined. The points where the capacity was exceeded and the clusters of these points were identified. Infrastructure deficiencies in the regions were determined by questioning the problem areas and the logic of the parking policies that constitute the problems. ***In step 3***; The regions that will be intervened in at the city center, the kind of logic that will be modified, and the intervention methods and policies were put forward. ***In step 4***; capacities were determined and recommendations made. At this stage, suggestions and

evaluations were made about the centers and regions where on- and off-road parking facilities should be built.

3. ANALYSIS

3.1. Deficiencies and Problem Areas

As a result of the parking surveys and censuses made in the Trabzon-Ortahisar region, the parking capacity, inadequacies, problem points and bottlenecks in the region were determined. Habits were obtained by car park user surveys, and data on capacity inadequacies were obtained by counting. Problem points in the region were determined as a result of field observations and consultations with the administration. The locations and capacities of the roadside and off-road paid parking areas with capacity problems are determined and given in Table 1 and Figure 5.

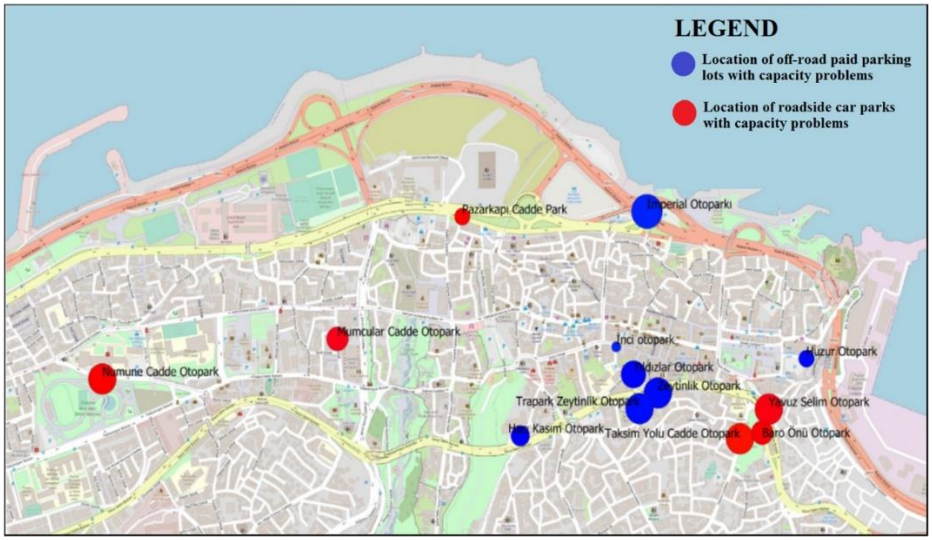

Figure 5. Locations of Off-Road and Roadside Car Parks with Capacity Problems

Table 1. Problem Points of Over-Capacity Roadside Car Parks

Roadside Parking Areas					
Carpark Name	**Morning**	**Afternoon**	**Evening**	**Capacity**	**Location**
Yavuz Selim	+	+		30	Main Artery
Pazarkapı			+	10	Main Artery
Numune	+	+		30	Collector Road
Mumcular		+		20	Collector Road
Taksim Yokuşu	+	+		30	Main Artery
Baro Önü		+		20	Collector Road
Off Road Parking Areas					
Carpark Name	**Morning**	**Afternoon**	**Evening**	**Capacity**	**Location**
Imperial			+	200	Main Artery
İnci		+	+	15	Collector Road
Trapark Zeytinlik		+		65	Collector Road
Yıldızlar		+		50	Collector Road
Zağnos Vadi içi			+	40	Main Artery
Zeytinlik		+		65	Collector Road
Huzur		+	+	30	Collector Road
Pelitli	+	+		25	Collector Road
Hacıkasım		+		35	Collector Road

When the data on supply and capacity problems are examined, it is evident that there are capacity inadequacies in the regions where parking lots are concentrated. It is clear that the demand for parking in these areas has not been fully responded to. The sloping geographical structure and the land use types that are confined to a narrow area do not reserve the necessary space for roadside parking on the streets. Demands for parking cannot be met because the relevant methods to solve the parking demand within residential or commercial areas are not used. General and regional parking problems caused by insufficient capacity for parking demand are given in Table 2.

Table 2. General and Regional Problem Points

General Problems	**Regional Problems**
Capacity inadequacies in recreation areas	Tangent-Bar Circle
High parking fees	Kahramanmaraş Street
Insufficient capacity in residential areas	Inadequate Parking Area in Beşirli Beach Area
Parking demand generated by home-work trips	Capacity problem in and around the university area
Inadequate parking capacities in public institutions	Demand to increase due to the City Hospital
High costs of capacity increases	Capacity insufficiency in Değirmendere Bus Station Area
Stressing the capacity of parking lots	Capacity inadequacies in the School and Its Surroundings
	Demand for parking in front of the Imperial Hospital
	Airport area parking issues
	Boztepe Tea gardens and touristic areas

The main problem issues and the regional problem points have developed in a similar framework. The roadside and off-road parking areas cannot meet the demand, especially the parking areas around the urban reinforcement areas are insufficient. The distribution and schematic representation of regional problem points are given in Figure 6.

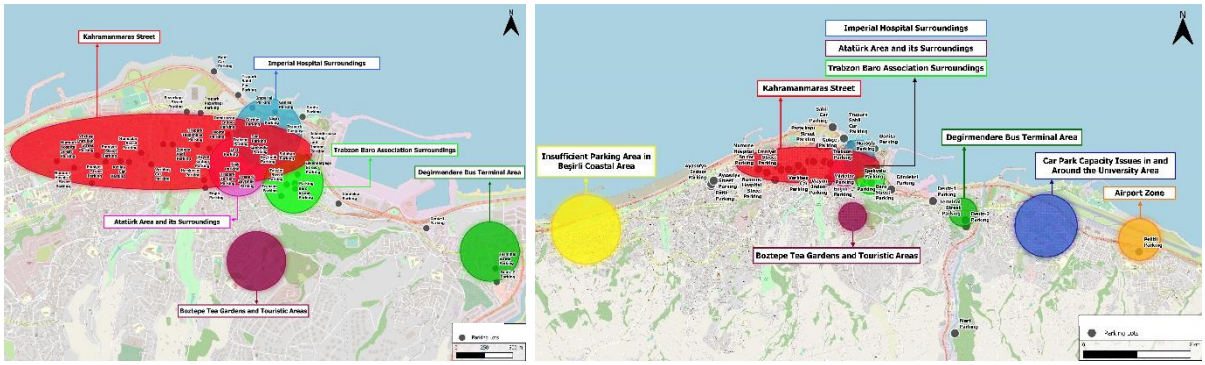

Figure 6. Distribution of Regional Problem Points-1 (Center) (General)

Regional problem points are clustered in the same location as the region where capacity inadequacies are concentrated. In addition, it is seen that they extend towards the west along the axis of Kahramanmaraş Street. This shows that parking problems and capacity inadequacies are clustered in the area between Yavuz Selim Boulevard and Kahramanmaraş Street and intensify as they converge predominantly towards the coast in the eastern part of the region.

In summary, the parking infrastructure in the city center is insufficient and there are capacity problems. There are technical problems such as the irregularity of the entrances

and exits of the parking facilities. Roadside parking has negative effects on traffic. Roadside parking occurs due to the inadequacy of the public areas and the parcels of the enterprises themselves. The addition of roadside parking on top of narrow streets and sloping structures in residential areas creates negative effects on traffic. Smart parking systems and technological applications are not sufficiently utilized. It is also understood that there are problems with the standards in private parking lots. The parking problems experienced especially in the Çarşı District, Gazipaşa and the Kemeraltı Region are at a remarkable level.

3.2. Calculation of Parking Demand and Projections

3.2.1. *Accounting Methodology and Principles*

There are many methods in the relevant literature for calculating appropriate parking lot capacities. Among the approaches and techniques in this regard, it is considered that the approaches that take into account the West German criteria will be most compatible with the cities in Turkey. It is assumed that 12% of all vehicles in cities will park in the center during peak hours in major US cities. In small cities, it is taken into account that 18% of the vehicles will be parked in the center. According to West German criteria, one parking lot in the city center is considered for every 5-8 cars in the city. The need for urban parking *P* can be calculated by the following Equation: (Özdirim, 1994)

$$P = \frac{E}{k.D} \qquad (1)$$

Here, *E* represents the population of the whole city, *D* represents the number of inhabitants per vehicle, and *k* is the local coefficient (range 3-5). A parking lot requirement is calculated for 7-9% of the vehicles entering the city center every day. The future increase in the parking lots to be built in the city centers is also estimated. West German criteria foresee a projection of 30-35 years in this regard.

3.2.2. *Determination of Ortahisar District Parking Demand by Years*

Ortahisar district is the center of the Trabzon province in terms of social, economic and spatial aspects. This centrality leads to intense transportation, accessibility and parking problems in the aforementioned district. The population of the district and the population projections based on the development areas in the master development plans for 2040 are given in Table 3.

Table 3. Ortahisar District Base Case and 2040 Population Projections

Population of Base Case	328,509
Additional Population in 2040	322,899
Total Population in 2040	651,408

The population of the district in 2021 was determined to be 328,509. The additional population expected in 2040 is calculated as 322,809. Thus, it is predicted that the population of the district in 2040 will reach 651,408 in total. Various approaches produced according to the calculated number of vehicles that will demand parking are given below.

Within the scope of the transportation master plan, the rate of vehicle ownership per 1,000 people is determined to be 194, i.e. a rate of 0.194. With that being the case, when the aforementioned rate is multiplied by the population figure, it is revealed that there are presently 63,730 vehicles in the district. Considering that this ratio will increase to 0.25 (TMP, 2022) in 2040, 162,852 vehicles will be reached.

Areas with the characteristics of city centers were determined to include different sub-centers, core regions and interaction areas by evaluating commercial mobility, functional identity, spatial interaction and social characteristics. Ortahisar Square and the

surrounding area where commercial functions are concentrated has been taken as the main city center-core region. This is because its built urban area is a region with increasing parking related activity and density as well as social, cultural and spatial interactions and specialization. Although this area is strengthened in terms of central feature towards the CBD (Central Business District), it is on a scale between the entire urban residential area and the CBD. In addition, parking problems are already known to be concentrated in this region. There are 3 sub-centers, a core region, two CBD areas and a central interaction region in the district center. The CBD, interaction areas and sub-center boundaries are given in Figure 7.

Figure 7. CBD, Interaction Areas and Sub-Centers

It is assumed that there is one vehicle in the city center for every 5-8 cars in the city. The total number of vehicles is entered into the calculation with the coefficients of 5 and 8, and both the current and projected parking demand for the year 2040 have been determined. In Table 4, the Ortahisar District city center parking demand calculation is presented according to the first method.

Table 4. Ortahisar City Center Parking Lot Demand According to the First Method (Coefficients of 5-8)

Coefficient	**Base Case** (vehicle)	**Year 2040** (vehicle)
5	12,746	32,570
8	7,966	20,356

According to the second method, the big city coefficient is 12% and the small city coefficient is 18%. According to this approach, the parking demand calculated is given in Table 5.

Table 5. Ortahisar City Center Parking Lot Demand According to the Second Method (12-18%)

Ratio (%)	**Base Case** (vehicle)	**Year 2040** (vehicle)
12	7,647	19,542
18	11,471	29,313

Ortahisar does not have metropolitan features at the Turkish or world level. Meanwhile, projection values for 2040 are at relatively high levels. For these reasons, the method in which it is assumed that 1 vehicle looks for parking space in the city center for every 8 vehicles in total was deemed appropriate. According to these calculations, 7,966 vehicles demand parking space in the current situation and 20,356 vehicles will demand parking space in 2040. The demand for paid parking, which is made up of 3,716 vehicles in the central region of Trabzon is met by paid parking lots and free roadside parking.

The Ortahisar city center does not have the capacity to meet all parking demand with paid parking lots. As in other cities in Turkey, a certain part of the demand is met by off-road and roadside paid parking lots. The other part is mainly provided by uncontrolled parking on the roadsides on collector roads.

All of the mentioned capacity is in the region defined as the city center. This ratio decreases towards the outer edges of the city center. Considering that there is parking demand for 7,966 vehicles in the city center in the present situation, it is assumed that proportionally, the demand which is met by paid parking lots is at the level of 45% within the borders of the district. It can be deduced from this that the core region, the central interaction area and the 1st degree CBD region, which is the region where the demand is presently concentrated produces the majority of the demand. It is known that increasing parking lot capacity through additional facilities will accelerate the increase in demand. It will also attract more private vehicles to the city center. In light of these facts, instead of increasing the parking lot supply in direct proportion to the demand, it is deemed more appropriate to meet a certain part of the need with Park Management Strategies and Practices.

3.2.3. Calculation of Parking Demand by Centers

Calculating the distribution of the demand in the centers and regions with central characteristics cannot be done simply according to population proportions. Because there are no or few residential areas in the zones in the city centers, the population may seem low in these land use types. However, during business hours, the highest demand for vehicles is experienced in these neighborhoods. The distribution of demand in city centers is related to the concentration of commerce and job opportunities in the zones. While weighting this distribution, the weights of commercial uses and the force of attraction for the year 2040 specified in the Master Zoning Plan were taken into account. In line with this, the commercial densities of the centers were calculated. Then, the parking demand, which is estimated to be 20,356 for 2040 according to the distribution of commercial areas, was distributed among the centers by weighting. The rate of commercial units on the ground floor of residential buildings was assumed as "1/8". This was added to the commercial use ratio when determining the weighting. The Distribution of Additional Parking Demand Expected to Occur in 2040 by Centers is given in Table 5.

Table 5. 2040 Distribution of Additional Parking Demand Expected in 2040 by Centers

CENTERS	Commercial (ha)	Residential business (ha)	Residential business / 8 (ha)	Commercial + (Residential business/ 8) ha	Weighting Ratio	Parking demand 2040 (Vehicle)
Core region	7.85	4.6	0.58	8.42	0.14	2,930
Central interaction area	7.81	4.87	0.61	8.41	0.14	2,927
1.Sub-Center	9.7	51.9	6.49	16.18	0.28	5,630
2.Sub-Center	1.88	10.09	1.26	3.1	0.05	1,080
3.Sub-Center	8.84	39.04	4.88	13.72	0.23	4,773
1st degree CBD	0.67	26.64	3.33	4	0.07	1,393
2st degree CBD	0.61	32.43	4.05	4.66	0.08	1,623
TOTAL	**37.36**	**169.57**	**21.20**	**58.55**	1.00	20,356

When the parking demand and production rates of central regions are analyzed (center-core region, central interaction area and 1st Degree CBD region), it is seen that demand for 7,250 vehicles will be generated. Especially the 1st and 3rd sub-centers will create high levels of parking demand in the future and their center features will be strengthened. The parking demand to be produced by the centers over the years has been calculated as a

linear increase. In Table 6, the parking demand to be produced by the centers by years is given.

Table 6. Parking Demand to be Generated by Centers by Years

Year	Core region	Center Interaction Area	1st Sub Center	2nd Sub Center	3rd Sub Center	1st degree CBD	1st degre e CBD	TOTAL
2022	1,216	1,216	2,419	436	1,996	604	692	**8,579**
2023	1,311	1,311	2,597	472	2,150	648	744	**9,233**
2024	1,406	1,406	2,776	508	2,305	692	795	**9,888**
2025	1,502	1,501	2,954	543	2,459	736	847	**10,542**
2026	***1,597***	***1,596***	***3,133***	***579***	***2,613***	***779***	***899***	***11,196***
2027	1,692	1,691	3,311	615	2,767	823	951	**11,850**
2028	1,787	1,786	3,489	651	2,922	867	1,002	**12,505**
2029	1,883	1,881	3,668	686	3,076	911	1,054	**13,159**
2030	1,978	1,976	3,846	722	3,230	955	1,106	**13,813**
2031	2,073	2,072	4,025	758	3,385	999	1,158	**14,468**
2032	2,168	2,167	4,203	794	3,539	1,042	1,209	**15,122**
2033	2,263	2,262	4,381	830	3,693	1,086	1,261	**15,776**
2034	2,359	2,357	4,560	865	3,847	1,130	1,313	**16,430**
2035	2,454	2,452	4,738	901	4,002	1,174	1,364	**17,085**
2036	2,549	2,547	4,916	937	4,156	1,218	1,416	**17,739**
2037	2,644	2,642	5,095	973	4,310	1,262	1,468	**18,393**
2038	2,740	2,737	5,273	1,008	4,464	1,305	1,520	**19,047**
2039	2,835	2,832	5,452	1,044	4,619	1,349	1,571	**19,702**
2040	***2,930***	***2,927***	***5,630***	***1,080***	***4,773***	***1,393***	***1,623***	***20,356***

For the 1st stage, which is defined as the short and medium term, the parking demand for 2026 is calculated by taking into account the 0-5 years range. Since the effect of the increase in vehicle ownership rate on the result is minimal, it is not included in the calculation.

3.3. Determination of Parking Policies

The following policies have been developed to increase the efficiency of the parking lot infrastructure for Ortahisar district, which is the city center of Trabzon. These policies were primarily designed in accordance with the objectives in the Eleventh Development Plan and were created by utilizing the objectives and strategies obtained from the stakeholders within the scope of the Trabzon Transportation Master Plan workshops. General parking policies were evaluated together with the suggestions obtained from the stakeholders at the Trabzon Transportation Master Plan Workshops, and the policies for the short and medium term within the scope of Stage-1 are given below.

- Limiting or not increasing roadside parking, which prevents vehicle traffic flow, especially in the core area and central interaction area.
- Regulating roadside parking mainly for temporary waiting, service vehicles and public needs.
- Establishment of high price enforcement zones within the core region to limit access by private vehicles
- Determining the standards regarding parking and parking types within the framework of the regulations to which they are bound.
- Reaching an agreement with commercial enterprises on keeping parking areas in front of the shops unoccupied during the day, making arrangements and inspections that prioritize needs such as goods deliveries and loading/unloading.
- Development of technological parking systems in the central interaction area and core area (sliding, elevators, multi-storey etc.)
- Expanding Park & Ride applications and integrating them with public transportation systems

- Roadside parking via parking pockets for short-term stops, which otherwise reduces the traffic capacity
- Identification and implementation of park management strategies (Parking Management Strategies)
- Utilizing Intelligent Transportation Systems (ITS) and Smart Parking applications in fare collection methods
- Developing standards for licensing off-road parking lots, raising quality and operational requirements
- Instead of parallel parking, which reduces parking capacity, identifying suitable points in terms of traffic safety and road capacity and transforming these points into angled parking types
- Constructing high-capacity multi-storey car parks and putting them into operation especially at the outer edges of the central interaction area.
- Planning the locations and capacities of underground car parks in a way that will not induce demand in the center
- Providing applications, smart applications and internet support where the car park capacity and volume can be monitored by motorists.
- Establishment of a camera monitoring and control system in the city center at the roadside and off-road parking areas
- Carrying out awareness raising activities for the public on issues of transportation and parking (especially conveying the drawbacks of traveling to the center by private vehicle for the city)
- Taking steps to solve the parking problem in newly developed areas by creating regional car parks within the parcels or in the determined common areas.

4. CONCLUSION

In this study, an integrated car park planning model has been produced for the center of Trabzon. This model is a demand-oriented urban parking model. First, the current situation was identified in terms of capacity and utilization rates. To this end, counting and surveys were used. Afterwards, deficiencies were identified and problem areas were outlined. After the identification of the problems, the demand for urban parking was determined and associated with the problems. Later, policies were developed to eliminate the aforementioned problems and to meet the demand produced. The problem of induced demand, supply problems in the city center, the importance of increasing alternative means of transportation, technological developments, and integration opportunities have been taken into consideration in developing said policies. The main parking policies considered suitable for Trabzon; restriction of roadside parking, temporary waiting and service areas, limitation of private vehicle access, improvement of standards, practices for commercial enterprises, technological advances, short stops, parking management strategies, licensing of off-road parking, development of parking types habits, multi-storey and regional parking lots, smart applications and monitoring techniques have been determined within a framework of raising social awareness and dissemination of regional parking lots.

It is recommended for the future to develop an integrated approach in determining parking strategies and policies based on demand management and to associate these with more variables. In particular, algorithms should be created to ensure the balance of demand and supply, and approaches that can detect parking problems on the basis of these algorithms should be developed.

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