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Research Article

Parking Analysis for Hospitals: Atatürk University Research Hospital Example

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Abstract

Parking facilities have become an inevitable necessity today with the increasing use of motor vehicles and population mobility. Providing parking facilities for hospitals is a fundamental requirement for the operation of healthcare institutions, and the lack of parking spaces is a common problem faced by hospital administrators, designers, and planners. The aim of this study is to evaluate the parking capacity of Atatürk University Research Hospital in Erzurum and to analyze whether this capacity meets the current demand. Within the scope of the study, the current parking demand of Atatürk University Research Hospital, located in Erzurum, was calculated. Off-street parking studies were conducted in the parking areas identified as part of the study. Parking spaces were determined, and the occupancy-vacancy ratios were calculated through vehicle counts. As a result of the study, it was determined that the current parking capacity of Atatürk University Research Hospital is insufficient to meet the emerging demand. Solution proposals were presented to balance the gap between the current parking need and the parking demand.

Key Words

Research Hospital, Parking, Parking Forecasting, Vehicle Counting, Parking Capacity.

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1. Introduction

The unplanned growth of cities and the increase in individual vehicle usage lead to significant transportation issues, making these problems some of the most urgent urban challenges that need to be addressed (Atalay and Hurşit, 2024). The continuous increase in the number of vehicles makes it mandatory to provide adequate parking spaces, further increasing the need for parking lots. These parking lots not only ensure the safe parking of vehicles but also play a critical role in traffic management. While vehicles parked freely on streets can obstruct traffic flow and cause congestion, well-designed parking lots reduce traffic density, making urban transportation smoother.

Providing parking facilities for hospitals is a fundamental requirement in the operation of healthcare institutions, and the lack of parking spaces is a common issue faced by hospital managers, designers, and planners. Therefore, the efficient planning and management of hospital parking lots are crucial for the comfort and safety of both hospital staff and patients (Al-Jameel et al., 2020).

The planning and management of these parking lots are critically important not only for the comfort and safety of hospital staff and patients but also for regulating traffic around the hospital, reducing parking issues, and facilitating access for emergency interventions. Effective parking planning and management can reduce the stress of hospital visitors and staff, making access to the hospital easier and more efficient (Alfadhlani et al., 2019).

The aim of this study is to evaluate the adequacy of the parking capacity at Atatürk University Research Hospital in Erzurum and to determine the balance between capacity and demand. The study involves on-site observations and vehicle counts to analyze the utilization rates of the hospital's parking areas. The adequacy of the current parking capacity to meet the demand, as well as issues such as capacity shortages and overuse, have been identified through data analysis. Additionally, practical recommendations for optimizing parking management and balancing capacity with demand are proposed to enhance the efficient use of parking spaces.

1.1. Hospitals

Hospitals employ a wide range of healthcare professionals, including doctors, nurses, pharmacists, laboratory technicians, and radiologists. These professionals work together to assess patients' health conditions, develop appropriate treatment plans, and manage rehabilitation processes. Hospitals can also provide services in various specialties, such as surgical operations, maternity services, psychiatric treatment, and chronic disease management.

Modern hospitals not only provide treatment services but also take on roles in public health protection and improvement, health education, and medical research. In this context, hospitals develop and implement projects aimed at improving community health. Some hospitals collaborate with universities to offer practical training opportunities for medical students and specialists in training.

Additionally, hospitals contribute to the improvement of transportation infrastructure in their surrounding areas. Efficient and reliable transportation routes are essential for the smooth functioning of emergency services. Public transportation connections and parking arrangements play a critical role in facilitating access for patients, visitors, and staff. This can impact traffic flow around the hospital and thus emerge as a factor to be considered in urban planning.

The location of a hospital plays a critical role in the effectiveness and accessibility of healthcare services. The strategic placement of hospitals should ensure ease of access for both patients and healthcare workers. A good location enhances the rapid response capacity of emergency services while also facilitating daily transportation for patients and staff.

Additionally, the location should minimize the hospital's environmental impact and be planned in a way that can manage traffic density. Demographic changes, such as the increasing population and rural-to-urban migration, are driving up hospital demand and increasing the need for new healthcare facilities. This has highlighted the necessity of creating new spaces to meet the needs of the community.
When determining the location of a hospital, various factors are considered in terms of cost, competition, and sustainability. The cost here is not only borne by the investor; the costs associated with the investment's impact on society and the national economy are also evaluated. The more efficiently a facility operates, the lower its costs will be in the long term. The criteria considered in this regard are as follows (Karaağaç, 2017):

- Proximity to residential areas
- Capacity to adapt to heavy traffic
- Ease of access for staff and doctors
- Resistance to environmental factors (such as pollution, noise)
- Availability of suitable and sufficient parking spaces for vehicles

- Location in areas with growth potential and ability to contribute to the development of these areas
- Centrally located for easy and quick access
- Seamless connection to infrastructure systems
- Competitive positioning with nearby healthcare facilities

It has been stated that, in places like hospitals where individuals gather, large-capacity parking lots cannot be established within the parcel boundaries of regional parking areas, and decisions regarding this matter should be made in collaboration with the relevant authorities. Additionally, provisions regarding the construction and operational authority for these parking lots are outlined. It has also been ruled that no fees should be charged for parking lots constructed by the authorities (Karaağaç, 2017).

The parking area required for hospitals is divided into two separate categories: hospitals and primary health care institutions, and the required parking areas for each category are determined in (Table 1).

Table 1. Parking Capacity for Healthcare Institutions in the General Parking Regulation

Type of organization	Settlements with a population between 10,000 and 50,000	Settlements with a population between 50,001 and 200,000	Settlements with a population of over 200,000
Hospital	1 parking space for 125 m²	1 parking space for 100 m²	1 parking space for 75 m²
Primary healthcare institutions	1 parking space for 125 m²	1 parking space for 125 m²	1 parking space for 125 m²

The connection between hospitals and public transportation is of great importance for increasing access to healthcare services and ensuring that patients receive timely treatment. The effectiveness of transportation infrastructure is a critical factor in the location of hospitals; well-planned public transportation systems facilitate patient access to hospitals, minimizing time loss in emergencies. Additionally, the presence of public transportation allows for regular and sustainable hospital visits. Therefore, integrating public transportation routes with hospitals is an element that enhances the quality of healthcare services and positively affects public health. There are both positive and negative interactions between transportation systems and public health. In areas with heavy traffic, increased noise and air pollution have been found to have adverse effects on public health. Moreover, it has been observed that this situation leads to social divisions based on income levels. In areas with high vehicle density, low-income populations tend to live in greater numbers, deepening social inequalities. The impact of public transportation systems in reducing private vehicle use can alleviate the effects of these problems. Additionally, in cities where both bus and rail systems coexist, public transportation usage tends to be higher compared to cities with only bus-based systems. The primary reason for this difference is that rail systems are considered more reliable (Cohen et al., 2014)

In many cities in our country, rail transportation systems have limited usage due to high costs and the inadequacy of the existing traffic infrastructure. Therefore, bus and minibus transportation plays a significant role in accessing hospitals. Since access to hospitals is required at all hours of the day, public transportation services should be organized in a way that reduces congestion. In this context, factors such as frequency of services, route planning, stop locations, and the structure of the stops play a critical role (Tansel, 2013).

Hospitals face significant parking problems due to high visitor traffic. In large-scale healthcare facilities, the insufficiency of existing parking capacity makes it difficult for patients and visitors to find parking spaces, leading to traffic congestion around the hospital. To ensure efficient use of hospital parking lots, it is essential to regularly analyze user habits, vehicle parking durations, and parking occupancy rates. Additionally, parking management systems and technological solutions can help address these issues. Furthermore, raising awareness among patients and visitors about parking usage can contribute to a more efficient utilization of parking spaces.

1.2 Parking concepts and types

Parking areas are defined as spaces where vehicles traveling on the road can stop for short or long durations. Different types of parking facilities exist based on various factors such as parking duration (short, medium, long), parking area size (small, medium, large), and location (urban, suburban). In city centers, the most common transportation issue is typically finding and organizing parking spaces. One of the main reasons for this problem is the repurposing of designated parking areas for other uses or the inadequate planning of parking facilities. Parking areas are generally classified into three main categories: on-street parking, off-street parking, and multi-story parking (Gençkal, 2022).

1.2.1. Off-Street parking

Off-street parking refers to parking areas located outside a designated roadway. Unlike on-street parking, off-street parking facilities may face various challenges. When determining the location of a parking facility, factors such as demand and proximity to service areas should be considered. Off-street parking should be situated in areas planned to support surrounding traffic flow and various

functions. The main traffic flow is usually concentrated near business centers; therefore, off-street parking should be located at the periphery of commercial areas and at points providing good pedestrian connectivity. Ensuring sufficient off-street parking in business districts can be challenging; however, this issue is addressed through the construction of multi-story parking structures and mandatory parking allocations in newly constructed buildings. The occupancy limit for off-street parking is set at 90%, and exceeding this threshold indicates insufficient parking capacity. (İskender, 2010).

1.2.2. Off-Street parking design rules

One of the most preferred types of parking areas in places like hospitals is off-street parking. Having the parking area located near the hospital's main entrance and in an easily accessible position provides convenience for patients and visitors. Additionally, the proximity of the parking area to main roads and public transportation lines makes transportation more efficient and regulates traffic flow. A sufficiently large area should offer enough parking space to meet both current and future needs. Environmental conditions, security, lighting, and accessibility for disabled individuals should also be considered, and the parking design must be planned to ensure user safety and comfort. On the other hand, analyzing environmental conditions can enhance the efficiency of the parking lot. In this context, some basic principles for site selection have been established.

- A traffic study should be conducted for the area where the parking facility will be planned. This process should examine factors such as traffic counts, changes in traffic density, and traffic flow directions.
- The service status of the parking facilities in the area should be thoroughly investigated.
- Based on the land characteristics of the area, high-efficiency service areas should be identified.

Other conditions to consider in off-street parking design include:

- As the parking angle decreases, it becomes easier for vehicles to park. However, due to the maneuvering space and the required corridor width for vehicle movement within the parking lot, this results in a loss of unit parking space. Therefore, in areas with boundary angles of 90 degrees, it is recommended that the parking angle should not be less than 45 degrees.
- For off-street parking planning, an initial value of 25-28 m²/vehicle can be used as the unit parking space measurement.
- Backup spaces should be arranged as tracks extending from the parking area entrance toward the corridor (similar to ramps in garages). This arrangement ensures that vehicles entering the parking area first enter these backup spaces and transition into the corridor where they will park. Backup spaces are considered part of the parking area entrance and should be equipped with the necessary markings, a good drainage system, sufficient lighting, cleanliness, and safety measures for pedestrian movements. The backup space at the exit can be smaller compared to the entrance area, but to prevent delays caused by passenger loading and to facilitate the movement of other vehicles, it should preferably have at least two tracks.
- Necessary precautions should be taken for pedestrian safety in the vehicle corridors within the parking area and at entrance/exit points, and pedestrian pathways and markings should be provided.
- One-way corridors should be preferred as much as possible for safe and orderly vehicle movement. If two-way corridors must be used, the width of these corridors should be at least 6 meters.
- The designated unit parking spaces for vehicles should be equipped with necessary safety measures (e.g., tire chocks, raised curbs) to prevent vehicles from accidentally leaving the parking area.
- The perimeter of the parking area should be enclosed with the necessary protective elements (e.g., fences, walls, etc.).
- In newly constructed regional and general parking areas, at least 10% of the parking area should be designated for electric vehicles (including charging units) in accordance with the relevant standards (Çakmak and Çiçek, 2024).

1.2.3. On-Street parking

These types of parking areas are referred to in various ways in the literature: roadside, on-street, or in-street parking. They are located on streets where vehicles park in designated areas. Compared to other parking options, on-street parking is the easiest and least expensive to implement (Güngör, 2006). While it offers advantages in terms of saving drivers time and distance, it also has disadvantages for vehicles in motion on the road. These include a reduction in the usable width of the road, thus decreasing its capacity, and other vehicles slowing down as they attempt to navigate the narrowed road (Gençkal, 2022). Another downside is that vehicle owners visiting workplaces often park along the sidewalk for the entire day, preventing other drivers from using the space for short-term parking. Although not very common in our country, its use has increased in recent years. Additionally, the occupancy limit for on-street parking has been set at 85%; exceeding this threshold indicates parking shortages and negatively impacts traffic flow (Güngör, 2006).

On-street parking situations can be divided into three categories:

- Parallel Parking
- Angle Parking

- Perpendicular Parking

Parallel parking

Parallel parking is a type of parking where vehicles are positioned parallel to the roadside. In this case, since the maneuvering space required for entering and exiting a parking spot is smaller compared to angle parking, the number of parking spaces available along the road will decrease. Therefore, parallel parking should be preferred considering the condition and needs of the road.

Angle parking

Angle parking is a method where vehicles are parked at a specific angle to the roadside. As the parking angle increases, the maneuvering space required for entering and exiting the parking spot decreases. If there is sufficient width for a vehicle to maneuver without obstructing traffic, angle parking should be preferred. Angle parking is usually implemented at 30, 45, or 60 degrees. When parking at 30 or 45 degrees, there is a risk of the vehicle doors hitting other cars, so parking at a 45-degree angle may be a better choice (Aslan, 2022).

Perpendicular parking

Perpendicular parking, where vehicles are parked at a 90-degree angle to the roadside, provides higher capacity compared to other angled parking methods. However, it narrows the road area more, so it is generally not considered suitable from a traffic perspective. Nonetheless, if the roads are wide enough not to affect traffic flow, this type of parking can be preferred (Aslan, 2022).

Perpendicular roadside parking should be used for specific purposes in certain areas. For example, its perpendicular orientation is often used for commercial vehicles to approach buildings for loading purposes (Hızıroğlu, 2023).

As the parking angle increases, more vehicles can be parked along the road. However, the negative impact of angle parking on traffic is greater compared to parallel parking. While fewer parking spaces are provided along a road in parallel parking, the area it occupies on the road is smaller than angle parking. Considering this, priorities should be determined regarding how to plan parking along the road, and it should be decided which factor is more important (Aslan, 2022).

Based on the specified parameters, an appropriate parking angle should be chosen in line with the physical dimensions of the road and traffic volume analysis. Due to the insufficient width of road sections in our country, parallel parking, which occupies less space compared to other angled parking methods, is more commonly preferred for maneuvering space (Filizfidan, 2019).

1.2.4. Multilevel parking structures

Multilevel parking structures are modern buildings designed to effectively address the increasing number of vehicles and limited space in cities, aiming to meet parking demand and reduce urban traffic.

The basic design principle of multilevel parking structures is to efficiently use volume by stacking vehicles vertically, rather than spreading them out horizontally over large areas. These smart parking systems effectively "stack" vehicles in a sense. It is clear that multilevel parking structures are more functional compared to off-street and on-street parking. To use land more efficiently and provide greater capacity, multilevel parking structures are frequently preferred (Mazlum, 2019).

Types of Multilevel Parking Structures can be listed as follows:

- Ramp-based Multilevel Parking Types
  - Straight ramp
  - Spiral ramp
  - Sloped multilevel ramp
- Vehicle Lift (Mechanical) Parking Types
  - Rotary or non-rotary fixed lift
  - Lift allowing both horizontal and vertical movement
  - Fully automated lift (Karaağaç, 2017).

Ramp Parking

Known as the classic model of multilevel parking, ramp parking structures are designed with ramps that allow vehicles to move between floors. In these parking structures, drivers are directed to different levels using ramps. Ramp-based parking can have various design shapes, such as parallel, opposite, staggered, and circular (Mazlum, 2019).

Mechanical System Parking

Mechanical system parking structures are systems that allow vehicles to be automatically parked. These systems offer vertical placement possibilities using less space compared to traditional parking. Vehicles are placed through automated mechanisms without the driver's intervention. Drivers complete the parking process by leaving their vehicles in the system, and they can use a control panel or application to retrieve the vehicle.

1.3. Parking Pricing

Looking at studies abroad, it is observed that free parking is quite rare. Parking is generally approached as an investment, and it is stated that pricing provides benefits for various purposes. These benefits are as follows:

- It increases the turnover of available parking spaces, shortening the time users spend finding parking and reducing the replenishment and transportation times for facilities, thereby improving the user experience.
- It reduces the number of parking spaces needed to meet demand, lowers total parking costs, and ensures that facilities are used more intensively and efficiently.
- It encourages long-term parking to shift to less preferred areas, helping to reduce congestion in the most used areas. This situation can especially encourage drivers to use different modes of transportation (such as public transit).
- It reduces the total number of parked vehicles and, consequently, traffic congestion, accidents, energy consumption, and emissions.
- By generating income, it provides financial support for projects such as road and parking area construction (Litman, 2016).

Another important aspect of pricing is how the fees are collected. If parking is paid, it is important that the collection occurs upon exit from the parking area. This fee should be collected at a time appropriate for the patients' conditions, as patients may be experiencing pain, stress, or sadness when they arrive at the hospital. Inappropriate vehicle fees or incorrect fee collection can decrease the quality of healthcare services. Additionally, parking fees should be aligned with the durations required for healthcare services, considering both patients and staff. Specifically, hourly fees for short patient-doctor appointments may negatively affect people (Kale, 2012).

1.4. Analysis of parking types in terms of hospitals

Hospital parking areas, especially in large healthcare facilities located in city centers, are critical infrastructure elements that directly impact traffic regulation and user experience. Roadside parking areas are typically suitable for patients' relatives or patients who need to park for short periods, but due to limited parking spaces and the need for regular monitoring, they may fall short in terms of capacity. These parking types, while offering direct access, often have drawbacks, such as the obstruction of traffic flow by vehicles parked along the road and the creation of security risks. Additionally, when the duration of roadside parking is limited, extra parking spaces are required to meet the long-term parking needs of patients and visitors.

Off-street parking areas are preferred in regions surrounding hospitals where there is more available space and high vehicle density. These parking spaces are effective in reducing roadside congestion, but if they are located far from the hospital building, additional infrastructure solutions, such as pedestrian paths, bus services, or small vehicle transport, may be needed to facilitate access. While these parking types generally offer lower construction costs, they may affect users' access to hospital areas.

Multilevel parking systems, on the other hand, offer significant advantages in areas with limited land. These systems allow for a vertical increase in capacity, enabling more vehicles to be accommodated in a smaller space. However, the construction and maintenance of multilevel parking can be costly, presenting operational challenges. These structures require advanced parking management systems and effective guidance systems to regulate vehicle movement within the hospital. The advantages of multilevel parking are particularly significant in high-density areas, where efficient space utilization and optimized parking durations are crucial.

1.5. Parking study and demand determination

The purpose of parking studies is to gather data such as how long parking occurs, how much it is utilized by business owners and citizens, and how services can be provided with greater capacity. These studies are generally conducted in central streets, where business centers are densely located.
Parking studies are divided into two categories: off-street parking studies and on-street parking studies (Yarbaşı, 2002).
In parking studies conducted in the field of transportation and traffic engineering, the research generally includes the following steps:

- **Identification of the Study Area:** The study area should include traffic producers and pedestrian-accessible zones.
- **Counting of Parking Spaces:** Off-street and on-street parking areas are counted according to their spatial characteristics. Areas where parking is allowed, as well as areas with time restrictions and parking payment devices, are defined, and the counts are carried out in these regions.
- **Determining Parking Occupancy Levels:** The occupancy levels at the busiest hours and times of the day are determined. Throughout the day, the number of vehicles parked illegally or without permission is counted at regular intervals in both on-street and off-street parking areas, as well as loading zones.
- **Vehicle Dwell Time and Usage Cycle:** In order to determine the turnover rate used in setting parking fees and time limits, it is necessary to identify the dwell times of vehicles within the same parking unit and how frequently different vehicles use the same unit throughout the day. This analysis is carried out using license plate numbers.
- **Determining the Profile of Parking Users:** To collect information about parking users, verbal interviews and surveys are conducted. Data such as travel purpose, frequency, origin and destination points, parking duration, amount paid, arrival and departure times, and distance to the parking area are collected.
- **Evaluating Existing Parking Areas to Meet Demand:** Comparing parking demand with the available parking areas is carried out on a parcel or regional scale, depending on the scope of the study. For on-street parking, an occupancy rate of 85% and for off-street parking, 90% is important. It should be noted that in fully occupied parking areas, users may experience difficulty finding parking spaces.
- **Developing a Parking Strategy:** This involves the decision-making process regarding parking based on the identified data (Cinkiş, 2022).

Study Area

Atatürk University Research Hospital began its service as a state hospital in 1966 and was transformed into a university hospital in 1978. In response to increasing demands, a new facility opened in 1997 under the name Aziziye Research Hospital. In 2009, a new service building was added next to the university hospital. After the renovation of the old building, in 2011, Aziziye Research Hospital, located in the city center, was relocated to the university campus. The hospital covers an area of 181,000 m² and has 1,419 beds (Ataş, 2024).

Atatürk University Research Hospital's current location is 3 km away from Erzurum city center. It is approximately a 6-minute drive and 40 minutes on foot. The hospital is situated north of Erzurum City Hospital, on the north side of the main road. Access to the hospital can be provided via side roads. Public transportation and private vehicles can also be used to reach the hospital. The distance to Erzurum City Hospital is 2.3 km (Ataş, 2024).

Erzurum Atatürk University Research Hospital is the study area selected for this research. The hospital is one of the largest healthcare institutions in the city and stands out with its services and ease of access. As shown in Figure 1, the hospital is located close to Erzurum's main transportation routes. This provides a significant advantage for both hospital staff and patients in terms of accessibility but also increases traffic congestion in the surrounding area. Particularly, the high number of parked vehicles on the streets around the hospital and in the designated parking areas leads to traffic jams, making it difficult to access the hospital. Atatürk University Research Hospital is shown in (Figure 1) below.

Figure 1. Atatürk University Research Hospital

For the hospital parking study, an off-street parking survey was conducted in five of the most frequently used parking lots designated exclusively for patients, patient relatives, and visitors. The selected parking lots are as follows: Inpatient Visitor Parking Lot 1 (1), Inpatient Visitor Parking Lot 2 (2), Emergency Parking Lot (3), Outpatient Parking Lot 1 (4), and Outpatient Parking Lot 2 (5), as indicated below. The study area is shown in (Figure 2).

Figure 2. Study Area

2. Materials and Methods

2.1. Hospital Data

In this study, the material used to determine the parking demand includes the number of staff, bed count, daily patient count, number of attendants and visitors, and parking surveys conducted at Atatürk University Research Hospital. These data were obtained from the Turkish Statistical Institute (TÜİK) and the University Hospital (Table 2).

Table 2. Atatürk University Research Hospital Healthcare Professionals and Bed Count

Year	Bed count	Total physicians	Nurses	Midwives	Pharmacists	Other healthcare personnel	Total healthcare personnel
2012	1188	545	377	3	17	136	1078
2013	1188	639	450	2	18	132	1241
2014	1188	663	526	4	20	148	1361
2015	1330	706	491	8	20	138	1363
2016	1188	722	458	6	23	128	1337
2017	1418	613	455	6	22	113	1209
2018	1418	582	674	8	27	240	1531
2019	1418	625	818	17	31	284	1775
2020	1418	619	792	17	32	275	1735
2021	1418	656	889	20	34	421	2020
2022	1419	748	953	21	36	426	2184

When examining the Atatürk University Research Hospital's personnel structure, it is evident that it includes not only healthcare workers but also staff working in various fields outside of the healthcare sector. According to the information obtained from the Atatürk University Research Hospital, when personnel outside the healthcare sector are included, the total number of employees is determined to be 3,633.

Considering that there has been no significant change in the hospital's bed count and based on the latest information from the hospital, the current bed capacity is accepted to be 1,419.

According to the data obtained from Atatürk University Research Hospital, the average number of patients per day is accepted to be 3,288.

The hospital has two parking areas designated for staff and six parking areas for patients and their relatives. The total capacity of these parking areas is 1,642 vehicles. These data are organized in (Table 3).

Table 3. Atatürk University Research Hospital Parking Spaces and Capacities

Parking type	Number	Capacity
Hospital staff	2	324
Patient and relatives	6	1318
Total	8	1642

The percentage distribution of parking lot usage is presented in Figure 3 below.

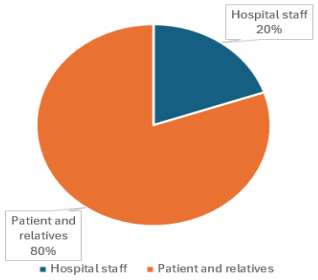

Figure 3. Parking Lot Usage Percentages

2.2. Survey Data

2.2.1. Data Collection

One of the fundamental stages of a research study is the collection of appropriate data according to the type of research and the data requirements. In this study, data collected from the parking areas of Erzurum Atatürk University Research Hospital were used for parking surveys. The survey studies were conducted in the five busiest parking areas used by patients and their relatives between 20.05.2024 and 24.05.2024, from 08:00-12:00 in the morning and 13:00-17:00 in the afternoon. To collect the data, survey forms were first prepared. The columns in the survey forms represented the observation hours (08:00, 09:00, etc.), and the rows were numbered from 1 to 30. A starting point was determined in the parking area, and every 60 minutes, the license plates were recorded sequentially from this starting point. By repeating the same license plate numbers in the columns corresponding to different time intervals, the duration of the vehicle's parking could be determined. Vehicles parked overnight were not directly observed, but the vehicle count in the parking areas was recorded with the first observation at 08:00 in the morning. The data between 08:00 and 17:00 were selected because these are the peak hours of parking lot usage. However, it is recommended that future studies examine parking occupancy and usage patterns outside of these hours, particularly during nighttime and weekend periods.

2.2.2. Data Analysis

In this study, the peak demand day was identified to determine the highest occupancy rate for each parking lot during the observation period. The occupancy rate was calculated as the ratio of the number of vehicles present in the parking lot at a given time to the total parking capacity. For the calculation of occupancy rates, vehicle counts recorded at hourly intervals between 08:00 and 17:00 were analyzed for each parking lot. First, the day with the highest occupancy rate over the five-day observation period was determined. Then, the highest recorded occupancy value within that specific day was selected as the maximum occupancy rate for the corresponding parking lot.

With the collected data, the occupancy rates, parking durations, and entry-exit numbers for each parking lot were numerically analyzed according to the observation hours. Additionally, the daily usage trends and peak hours of the parking lots were determined. These data were visualized by creating graphs. Graphs showing the changes in the occupancy rates of each parking lot over time were used to determine the hours of higher parking demand. Graphs analyzing parking durations revealed how long users stayed in the parking areas and their preferences for short-term or long-term use. Through these graphs, peak hours of parking lot usage were identified, and necessary data were provided for effective demand management and optimal evaluation of parking capacity.

3. Findings

Hospitals, unlike other facilities, are not completely empty; they are spaces that host continuous human circulation. This makes it quite difficult to determine an exact capacity figure for hospitals. The term capacity not only refers to the number of beds but also includes individuals benefiting from outpatient clinic services, employees, and visitors, all of whom should be considered in capacity calculations.

The assumptions made for the estimation are as follows:

- The Atatürk University Research Hospital's bed count is indicated as 1,419. However, instead of assuming all beds are occupied, a 58% occupancy rate is assumed based on 2022 Health Statistics. Therefore, 823 beds are considered to be occupied. The number of inpatient beds is found to be 823. • The visitor-to-patient ratio is estimated to be 1.5. The number of companions and visitors is taken as 1,235.
- According to the data obtained from the Atatürk University Research Hospital, the average number of daily patients is assumed to be 3,288.Based on these assumptions, the average daily number of patients, 823 inpatient beds, 1,235 companions and visitors, and 3,633 employees can be estimated. It is predicted that a total of 8,979 people will be present at the Atatürk University Research Hospital.

In the Atatürk University Research Hospital parking study, the most heavily used parking lots, which are open only to patients, patient relatives, and visitors, were selected to analyze the efficient use of off-street parking areas. These parking lots were chosen because they are located in areas with intense Atatürk University Research Hospital activities and play a significant role in visitor traffic. Therefore, five parking lots were designated for the study: Inpatient Visitor Parking Lot 1, Inpatient Visitor Parking Lot 2, Emergency Parking Lot, Outpatient Parking Lot 1, and Outpatient Parking Lot 2. These parking lots represent the busiest areas that meet the parking needs of visitors to the Atatürk University Research Hospital, making them suitable samples for providing data on occupancy rates and usage intensity.

The study was conducted in two main time periods, morning and afternoon, to observe the usage dynamics of each parking lot more closely. During the specified time frames, from 08:00-12:00 and 13:00-17:00, the occupancy rates, occupied spaces, and parking durations of each parking lot were monitored at one-hour intervals. To collect detailed data on the usage of off-street parking, specially prepared counting sheets were used. The counting sheets recorded the number of parked vehicles and their parking durations in specific categories for each parking lot. This approach allowed for a comprehensive analysis of the capacity utilization, congestion levels, and potential parking space requirements of the Atatürk University Research Hospital parking lots.

The parking studies were conducted between May 20, 2024, and May 24, 2024. Inpatient Visitor Parking Lot 1 is the most frequently used parking lot among patients and their visitors. Located at the central position of the Atatürk University Research Hospital, the parking lot is also very close to the Faculty of Medicine and the Faculty of Dentistry at Atatürk University. Capacity and highest occupancy rates for all parking types, including open ones, are shown in (Table 4).

Table 4. Information about the surveyed parking lots

Parking lot name	Capacity	Highest occupancy rate %
Inpatient Visitor Parking Lot 1	210	98
Inpatient Visitor Parking Lot 2	53	92
Emergency Parking Lot	50	96
Outpatient Parking Lot 1	120	92
Outpatient Parking Lot 2	220	91

The capacity occupancy rates of hospital parking lots are an important indicator for determining the hospital's daily vehicle traffic and the efficient use of parking spaces. In this study, the highest occupancy rates of different Atatürk University Research Hospital parking areas were examined. The results revealed that the occupancy rates of different parking areas at Atatürk University Research Hospital vary significantly. The highest capacity utilization was observed in Inpatient Visitor Parking Lot 1, with an occupancy rate of 98%, followed by Inpatient Visitor Parking Lot 2, with an occupancy rate of 92%. This indicates a high demand from visitors of hospitalized patients, suggesting that the parking needs in these areas are higher compared to other sections.

The Emergency Parking Lot had an occupancy rate of 96%, making it one of the highly utilized areas. Since patients and their companions arriving at the emergency department are generally expected to park for shorter durations, this high occupancy rate suggests that the usage dynamics of this parking area require further examination.

The occupancy rates of Outpatient Parking Lot 1 and Outpatient Parking Lot 2 were measured at 92% and 91%, respectively. These figures indicate that outpatient visitors actively use these parking areas. Overall, these findings highlight the need for an evaluation of hospital parking capacity, considering regional variations in usage patterns.

Figure 4 illustrates the highest recorded occupancy rates for each parking lot on each day during the five-day observation period. This graph visualizes the variations in parking lot occupancy across different days, allowing for a comparison of the peak usage levels.

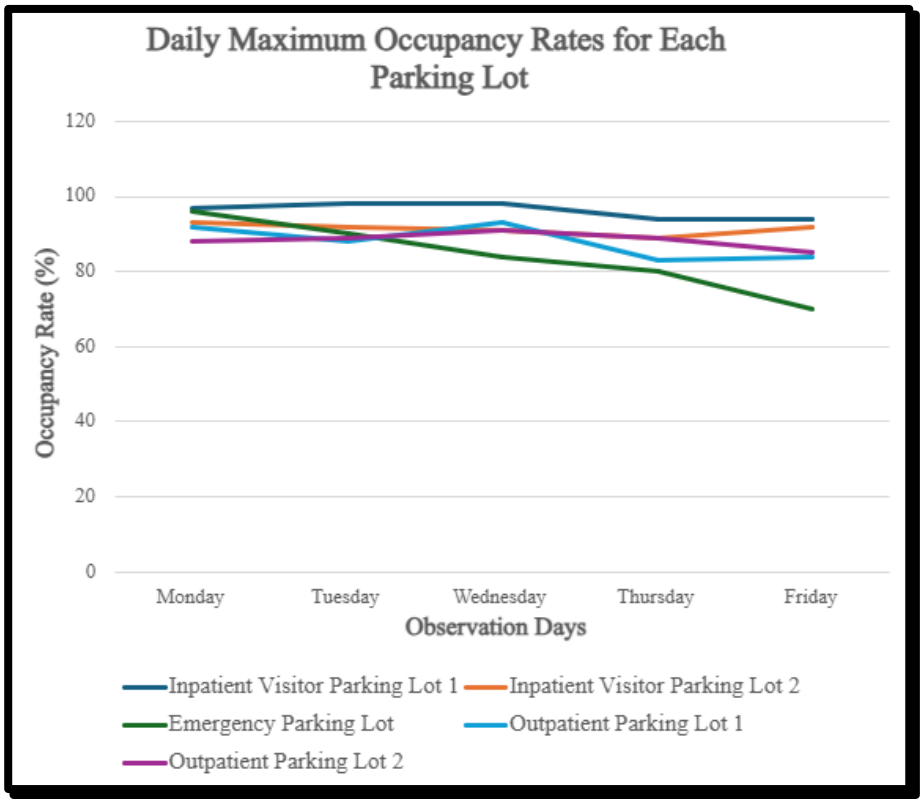

Figure 4. Daily Maximum Occupancy Rates for Each Parking Lot

This figure presents the highest recorded occupancy rates for each parking lot during the five-day observation period. According to the data presented in the graph, occupancy rates in hospital parking lots fluctuate throughout the weekdays. In the interpretation of Figure 4, the days with the highest occupancy rates differ by parking area. Specifically, Inpatient Visitor Parking Lot 1 and Inpatient Visitor Parking Lot 2 reached their peak occupancy on Tuesday. The Emergency Parking Lot and Outpatient Parking Lot 1 had the highest occupancy rates on Monday, while Outpatient Parking Lot 2 peaked on Wednesday. This suggests that the hospital experiences a higher influx of patients and visitors at the beginning of the week, leading to increased parking demand, which decreases as the weekend approaches. Additionally, while some parking lots show a steady decline in occupancy rates, others exhibit a fluctuating trend, with periods of both increase and decrease. This indicates that the utilization of hospital parking lots varies independently across different time periods, and the usage intensities of different parking lots differ from one another.

Figure 5 illustrates the variation in hourly occupancy rates for each parking lot on its peak demand day. This graph helps identify the time periods during which each parking lot experiences the highest demand.

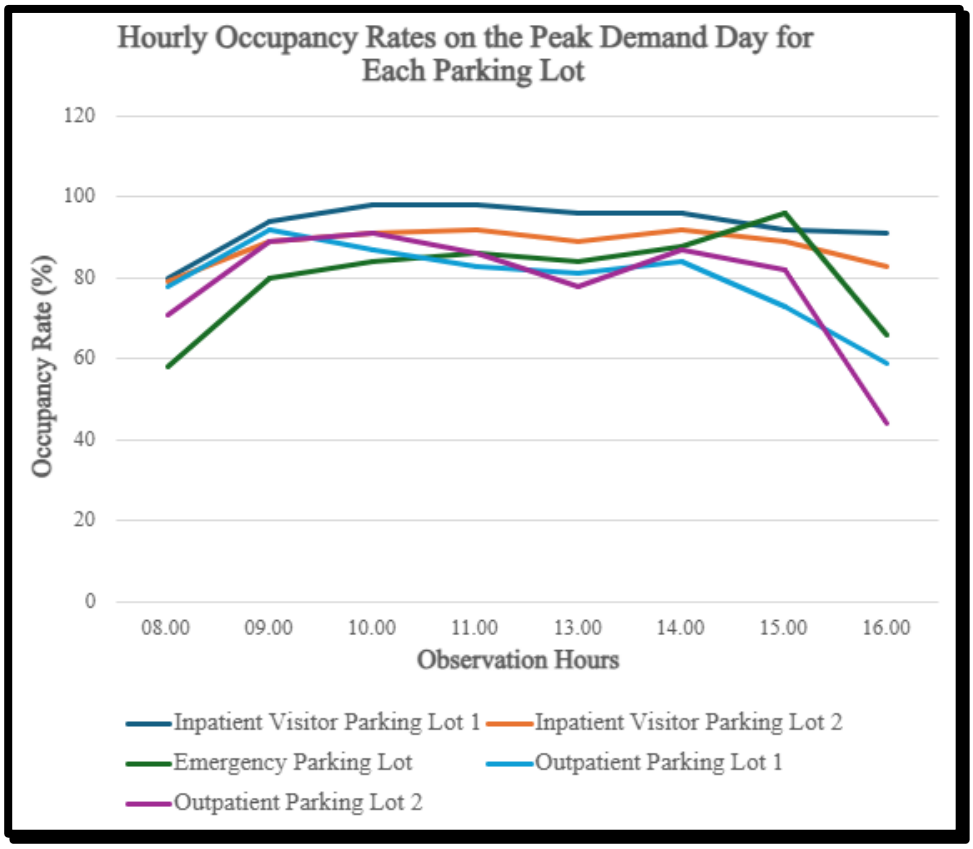

Figure 5. Hourly Occupancy Rates on the Peak Demand Day for Each Parking Lot

This figure illustrates the hourly occupancy rates for each parking lot on their respective peak demand days. The data reveals that, with the exception of the "Emergency Parking Lot," other parking lots exhibit relatively parallel occupancy rates throughout the day, indicating a stable usage pattern. In contrast, the "Emergency Parking Lot" shows a pronounced fluctuation in occupancy, suggesting that its usage varies significantly, with demand exhibiting noticeable peaks and valleys. The other parking lots display more predictable occupancy trends, with their usage remaining relatively consistent across similar time intervals. These findings suggest that the utilization of each parking lot differs at various times, highlighting the distinct usage patterns and varying demand levels across the hospital's parking facilities. The duration of these vehicles' stay in the parking lot is shown in Table 5.

Table 5. Parking Duration and Percentages

Parking Lot Name	1 Hour or Less	2 Hours	3 Hours	4 Hours	5 Hours	6 Hours or More
Inpatient Visitor Parking Lot 1	59.62	10.69	7.62	6.32	5.32	10.43
Inpatient Visitor Parking Lot 2	54.19	10.19	8.35	6.31	6.60	13.64
Emergency Parking Lot	74.47	12.98	5.55	2.52	2.48	3.31
Outpatient Parking Lot 1	50.90	13.59	8.86	7.18	8.51	10.25
Outpatient Parking Lot 2	51.94	11.15	9.01	9.56	10.26	8.11

The study conducted on the Inpatient Visitor Parking Lot 1 revealed different occupancy rates based on parking durations. The percentage of parking for 1 hour or less was found to be 59.62%, while the percentage of parking for 6 hours or more was 10.43%. This indicates that the majority of visitors park for short durations, but there is also a demand for long-term parking for patients. The high occupancy rate of Inpatient Visitor Parking Lot 1 suggests that patients tend to park for extended periods, while short-term visitor traffic is redirected to other parking lots.

Similarly, in the analysis of Inpatient Visitor Parking Lot 2, the percentage of parking for 1 hour or less was 54.19%, while the percentage of parking for 6 hours or more was 13.64%. Like Inpatient Visitor Parking Lot 1, this parking lot is predominantly used

for short-term parking, but the long-term parking rate still reaches 13.64%. This reflects the extended visits of patients and their relatives spending more time in the Atatürk University Research Hospital. Inpatient Visitor Parking Lot 2 is one of the areas with increased visitor density, indicating the need to increase capacity to accommodate long-term parking requirements.

The Emergency Parking Lot, in contrast to the other parking lots, has a different usage dynamic, with the percentage of parking for 1 hour or less being 74.47%, while the percentage of parking for 6 hours or more is 3.31%. This reflects the nature of emergency services, where users typically need to park quickly and enter the hospital, resulting in largely short parking durations. The low percentage of long-term parking (3.31%) in the Emergency Parking Lot indicates that this parking area is primarily for temporary use, with parking spaces turning over quickly.

For the Outpatient Parking Lot 1, the percentage of parking for 1 hour or less is 50.90%, while the percentage of parking for 6 hours or more is 10.25%. These results indicate that visitor traffic at the polyclinics is mixed, with both short-term and long-term parking durations observed.

For the Outpatient Parking Lot 2, the percentage of parking for 1 hour or less is 51.94%, while the percentage of parking for 6 hours or more is 8.11%. The diversity in parking durations points to the dynamic nature of visitor and patient traffic at the polyclinics, suggesting that these parking areas need to be managed more efficiently.

These findings demonstrate that parking durations and intensities vary significantly across different sections of the Atatürk University Research Hospital, and that each parking lot exhibits distinct parking habits and durations based on its intended use.

The graphs showing the occupancy rates have clearly revealed the peak hours of usage for the parking lots. For example, it was observed that the occupancy rate in the Inpatient Visitor Parking Lot 1 reaches nearly 90% in the morning hours. The graphs analyzing parking durations show that the majority of users park for 1 hour or less, which leads to parking availability issues during peak hours.

This study addresses parking occupancy rates and demand analysis methods, similar to the study conducted by Al-Jameel et al. (2020) on Al-Sadar Hospital. However, the research conducted on Atatürk University Research Hospital makes a significant contribution to the literature by providing a more detailed analysis of daily parking trends and peak hours. Specifically, the graphical analysis of entry and exit data has enabled the identification of short-term and long-term trends in parking usage and provided concrete data for demand management.

In Alfadhlani's (2019) study at Dr. M. Djamil Hospital in Padang, the parking usage trends on weekdays were analyzed, and it was found that the highest occupancy occurred on Mondays due to the start of the workweek. Similarly, in our study on the Atatürk University Research Hospital parking lots, the busiest days were identified as Monday and Tuesday. Both studies show that the beginning of the workweek brings an increase in hospital visits, which results in insufficient parking capacity and creates significant demand pressure.

4. Conclusion and Recommendations

This study addresses the parking problem, which is one of the transportation issues at Atatürk University Research Hospital, located in Erzurum. During the research, studies were conducted on the parking areas that are frequently used by patients and their relatives over a period of five days, and data was collected through observations. Additionally, the number of hospital staff, bed capacity, and daily patient numbers were obtained from the Turkish Statistical Institute (TÜİK) and Atatürk University Research Hospital.

As shown in Table 4, the critical threshold of 90% is exceeded for off-street parking, indicating insufficient capacity. This necessitates either expanding parking facilities or implementing more efficient usage strategies. With future increases in population and visitors, the issue may become more severe.

Furthermore, this study is based on a 5-day observation period. To assess the effects of seasonal or weekly changes, longer-term data collection studies are necessary. Additionally, since the data obtained is specific to certain parking areas, it is recommended that parking lots of different types of hospital parking be studied as well.

The higher occupancy rates of Inpatient Visitor Parking Lot 1 and Inpatient Visitor Parking Lot 2 compared to other parking areas are due to the proximity of these two parking lots to other faculties within the campus. This situation is interpreted as drivers who cannot find parking spaces in other areas of the campus being directed to these parking lots.

The high occupancy rate of the Emergency Parking Lot is associated with the 24/7 operation of the emergency department and the continuous patient influx. Although short-term parking is expected, some vehicles remain for extended periods, increasing capacity utilization. Additionally, the use of this area by healthcare personnel and service vehicles contributes to the high occupancy. The high occupancy rates of the outpatient parking lots result from the heavy patient and visitor traffic. Increased appointment density during certain hours makes these areas more preferred. However, since outpatient visits typically require shorter parking durations, vehicle turnover remains high, helping to maintain a relatively balanced occupancy level.

The highest short-term parking rate, 74.47%, was observed in the Emergency Parking Lot, as patients receive quick treatment and leave. The lowest rate, 50.9%, was recorded in Outpatient Parking Lot 1, as patients prefer closer parking areas.

Inpatient Visitor Parking Lot 2 has the highest rate of parking for six hours or more at 13.64%, mainly due to kiosk employees and campus staff using this area. The lowest rate, 3.31%, was observed in the Emergency Parking Lot, as patients leave shortly after treatment.

The high rate of short-term parking is due to the generally brief duration of hospital visits. Especially during peak hours, this increases parking load, leading to traffic congestion at parking lot entrances and exits, as well as difficulties in finding available spaces. Therefore, implementing wayfinding signs and digital information systems to balance the parking turnover rate and optimize parking capacity usage is recommended.

The current parking capacity needs to be increased, especially for the most frequently used Inpatient Visitor Parking Lot 1. To achieve this, solutions such as evaluating existing spaces within the campus and creating new parking areas or constructing multi-story parking lots are recommended.

To optimize the existing parking capacity, implementing wayfinding signs and digital information systems is recommended. For instance, real-time information systems that direct drivers to less-used parking lots instead of overcrowded ones can help balance the parking load. Additionally, parking fee strategies based on duration could be applied to regulate the average parking time and enhance the parking turnover rate.

The tendency for roadside parking around the hospital should be reduced, and these areas should only be used for emergencies or short-term needs. Moreover, alternative transportation solutions (such as promoting public transportation or shuttle services) could be considered to regulate traffic.

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