Introduction of Smart Parking System for urban congested CBD Areas

(Case Study of Islamabad)

Final Year Project 2019-2023

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"In the name of Allah, the most beneficent and merciful".

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ABSTRACT

Pakistan is a country with a rapidly growing population and urbanization. The traffic in Pakistan is characterized by congestion, unsafe driving practices, and inadequate road infrastructure. The high population density and urbanization have resulted in severe traffic congestion in major cities, leading to longer travel times and increased fuel consumption.

The rapid urbanization and increasing vehicle ownership have resulted in severe parking problems in urban central business district (CBD) areas. The inefficiency of traditional parking systems contributes to traffic congestion, wasted fuel, and increased pollution. To address these challenges, this thesis presents the introduction of a smart parking system for urban congested CBD areas, with a specific focus on the case study of Islamabad.

The main objective of this research is to design and implement a smart parking system that optimizes parking space utilization, reduces traffic congestion, and enhances the overall parking experience for residents and visitors in Islamabad's CBD areas. The proposed system utilizes various technologies, including Internet of Things (IoT), real-time data collection, and advanced algorithms for parking space management.

The research methodology includes a comprehensive literature review, data collection through surveys and interviews, and analysis of existing parking infrastructure in Islamabad. Based on the findings, a smart parking system architecture is proposed, encompassing sensor-based parking detection, data aggregation, cloud computing, mobile applications, and an administrative dashboard.

The implementation of the smart parking system involves the deployment of sensors in parking spaces to detect their occupancy status. The collected data is then transmitted to a centralized server, where it is processed and made available to users through a mobile application. The application provides real-time parking availability information, navigation guidance, and payment options, thereby optimizing parking space utilization and minimizing the time spent searching for parking.

The evaluation of the proposed smart parking system includes performance analysis, user feedback, and comparison with traditional parking systems. The results demonstrate the system's effectiveness in reducing traffic congestion, improving parking efficiency, and enhancing the overall user experience in CBD areas. Furthermore, the economic and environmental benefits of the system are also highlighted.

In conclusion, this thesis presents a comprehensive study on the introduction of a smart parking system for urban congested CBD areas, with Islamabad as a case study. The proposed system offers a sustainable solution to alleviate parking problems, enhance urban mobility, and contribute to the development of smarter cities. It serves as a valuable reference for urban planners, policymakers, and researchers seeking to implement similar parking management strategies in other cities facing similar challenges.

CHAPTER 1

1. INTRODUCTION

1.1 Background

Traffic and transport infrastructure plays a crucial role in a country's economic and social development. A well-developed transportation network is essential for facilitating the movement of goods and people, providing access to markets and opportunities, and promoting trade and commerce.

Efficient and safe transport systems can improve productivity, reduce costs, and enhance competitiveness, which can contribute to economic growth and job creation. Additionally, access to reliable transportation can enhance social mobility and provide people with greater access to education, healthcare, and other essential services. In contrast, inadequate or poorly maintained transportation infrastructure can lead to traffic congestion, increased travel times, higher costs, and reduced accessibility, which can impede economic growth and limit social opportunities. Therefore, investing in traffic and transport infrastructure is critical for a country's development and is essential for meeting the needs of its growing population and economy.

For context, an example of a city with the best traffic/transport infrastructure is Tokyo, Japan. Tokyo has a well-connected and efficient transportation system that includes a combination of trains, buses, and subways, as well as an extensive network of pedestrian and cycling paths. The city's public transportation system is renowned for its punctuality, cleanliness, and safety, and it operates around the clock, providing residents with reliable and affordable transportation options.

In contrast, one example of a city with the worst traffic/transport infrastructure is Dhaka, Bangladesh. Dhaka's transportation system is plagued with numerous challenges, including chronic traffic congestion, inadequate public transportation options, and poor road infrastructure. The city's public buses and trains are often overcrowded and poorly maintained, making commuting a daily struggle for residents. Additionally, the lack of proper traffic management and parking facilities further exacerbate the problem, leading to longer travel times and increased road accidents.

The difference in traffic/transport infrastructure between Tokyo and Dhaka highlights the significant impact that transportation systems can have on a city's livability and economic growth. While Tokyo's efficient transportation system has helped the city to thrive economically and improve the quality of life for its residents, Dhaka's poor transportation infrastructure has had the opposite effect, hindered economic growth and negatively impacted the daily lives of its citizens.

Traffic and transport in Pakistan face numerous challenges due to rapid urbanization, population growth, inadequate infrastructure, and insufficient public transportation systems. Here is a brief overview of the key aspects of traffic and transport in Pakistan:

- Road Network: Pakistan has an extensive road network, but it struggles with issues such as congestion, poor road conditions, and limited capacity. Major cities often experience traffic jams during peak hours, leading to significant delays and increased travel times.

- Public Transportation: Public transportation systems, such as buses and trains, exist in major cities like Karachi, Lahore, and Islamabad. However, they face challenges of inadequate coverage, insufficient capacity, and substandard facilities. Private minivans and rickshaws also serve as popular modes of transport, especially in urban areas.
- Traffic Management: Traffic management in Pakistan faces several challenges, including ineffective traffic regulations, lack of traffic enforcement, and a high number of vehicles operating without proper documentation. These issues contribute to traffic congestion and road safety concerns.
- Urban Congestion: Major cities in Pakistan, particularly Karachi, Lahore, and Islamabad, experience severe traffic congestion. The influx of vehicles, limited road capacity, and a lack of efficient traffic management exacerbate congestion issues. This leads to increased travel times, fuel consumption, and pollution levels.
- Infrastructure Development: Pakistan has been investing in infrastructure development projects to improve transportation. This includes the construction of new roads, flyovers, underpasses, and highways to ease traffic flow and reduce congestion. Additionally, mass transit projects, such as metro systems, are being implemented in major cities.
- Road Safety: Pakistan faces challenges related to road safety, including a high number of road accidents. Factors contributing to this issue include reckless driving, inadequate driver training, poor road conditions, and non-compliance with traffic rules. Efforts are being made to raise awareness, enforce regulations, and improve road safety measures.
- Sustainable Transportation: With growing concerns about environmental impact and sustainability, there is a need to promote sustainable transportation options in Pakistan. Initiatives such as introducing electric vehicles, improving public transportation, and encouraging non-motorized transport modes like cycling are gaining attention.

While Pakistan faces significant challenges in traffic and transport, efforts are underway to address these issues. The government, along with various stakeholders, is working on improving infrastructure, enhancing public transportation systems, implementing traffic management measures, and promoting sustainable transport options to create a more efficient and sustainable transportation network.

1.2 Problem Statement

The problem this project seeks to address is the traffic congestion and parking issues faced by urban areas in Pakistan, particularly the Central Business District (CBD) of Islamabad.

The increasing population and urbanization in Pakistan have led to a significant rise in the number of vehicles on the road, especially in urban areas, resulting in traffic congestion and parking shortages. The Central Business District (CBD) of Islamabad, being the commercial hub of the city, experiences heavy traffic flow during peak hours, leading to increased travel times and delays. The current parking management system in Islamabad is inadequate, resulting in illegal parking, traffic disruptions, and safety hazards. Furthermore, the existing parking facilities are insufficient to cater to the needs of commuters, leading to parking shortages and congestion on the roads.

In addition to the parking issue, the lack of technology integration and smart parking systems further exacerbate the problem. The current parking system in Islamabad relies on manual ticketing and payment systems, which are time-consuming and prone to errors. There is no centralized parking management system, and drivers must rely on finding a suitable parking spot through trial and error, resulting in increased congestion on the roads.

The aim of this project Is to Introduce a Smart Parking System for the CBD areas of Islamabad to provide a reliable and efficient parking management system that can reduce traffic congestion and improve accessibility for commuters. The proposed system will leverage advanced technologies, such as sensors, cameras, and data analytics, to provide real-time information on parking availability, reduce parking search time, and enable online payment and booking of parking spots. The introduction of a Smart Parking System will not only alleviate the parking issue but also enhance the overall traffic flow, reduce travel time, and improve road safety in the CBD areas of Islamabad.

1.3 Study Scope

For this project, I-8 Markaz (CBD) was selected as the study area based on the fact that it is among the most commercially active area.

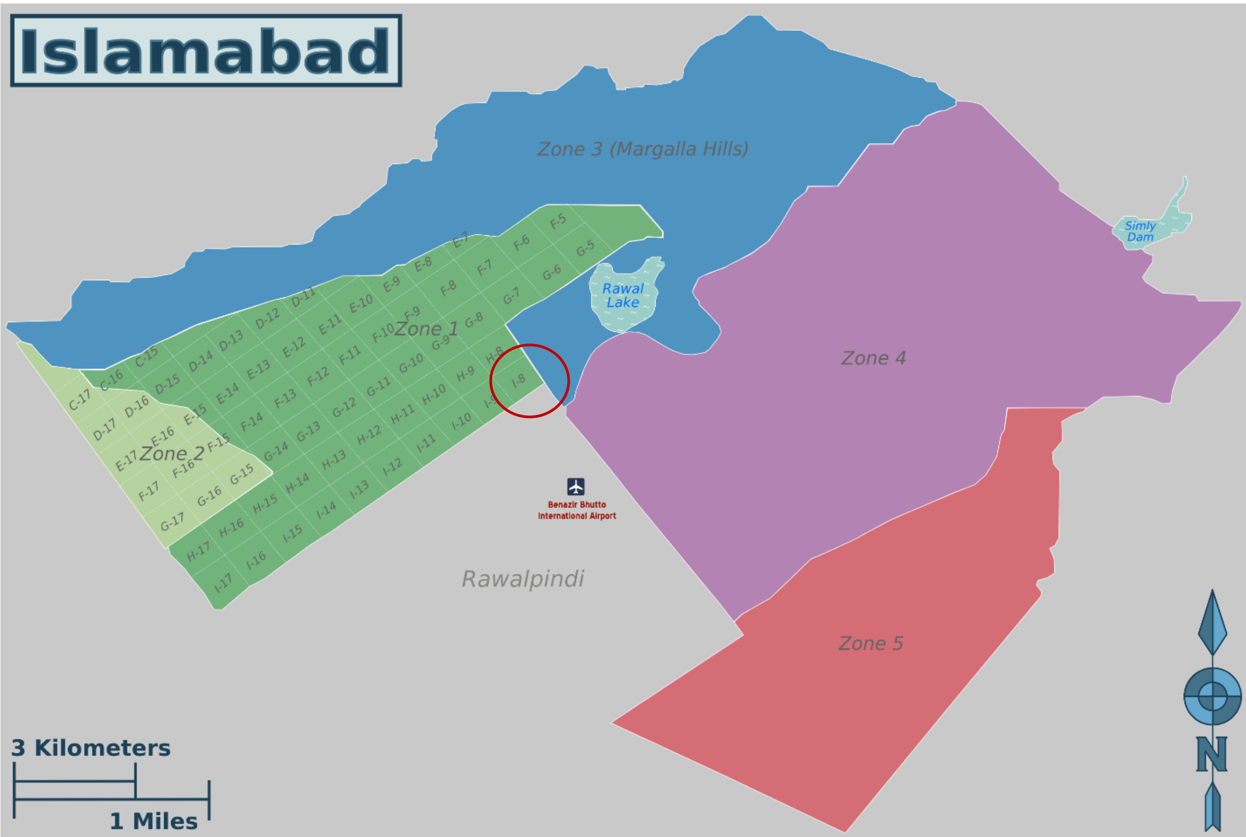


Figure 1.1: Zones and Sectors of ICT, with I-8 Sector Encircled

Located at the north tip of Rawalpindi, I-8 is right in the middle of Islamabad Capital Territory. Major part of incoming traffic is from 9th Ave Road on South-West, IJP Road on South-East, and Islamabad Expressway on North-East sides. The adjacent H-8 Sector is secondary main source.

Figure 1.2: Satellite image of I-8 Markaz, I-8 Sector

Before conducting our research, an initial survey of Traffic and Parking was conducted. Parking areas both on-street and off-street were identified and parking spots available were counted. Further, survey of Peak-Hour and Peak-Day of the week was conducted. The following results were concluded:

Peak-Day	Peak-Hour
Saturday	1830-2100 hrs.
Sunday	1830-2100 hrs.
Thursday	1600-1800 hrs.

Table 1.1: Peak-Day and Peak-Hours

Parking Area	No. of Parking Spots
Off-street 1-0	100
Off-street 1-1	70
Off-street 2-0	110
Off-street 2-1	75
Off-street 3-0	120
Off-street 3-1	84
Off-street 4-0	105
Off-street 4-1	85
On-Street	215

Table 1.2: Number of available Parking Spots

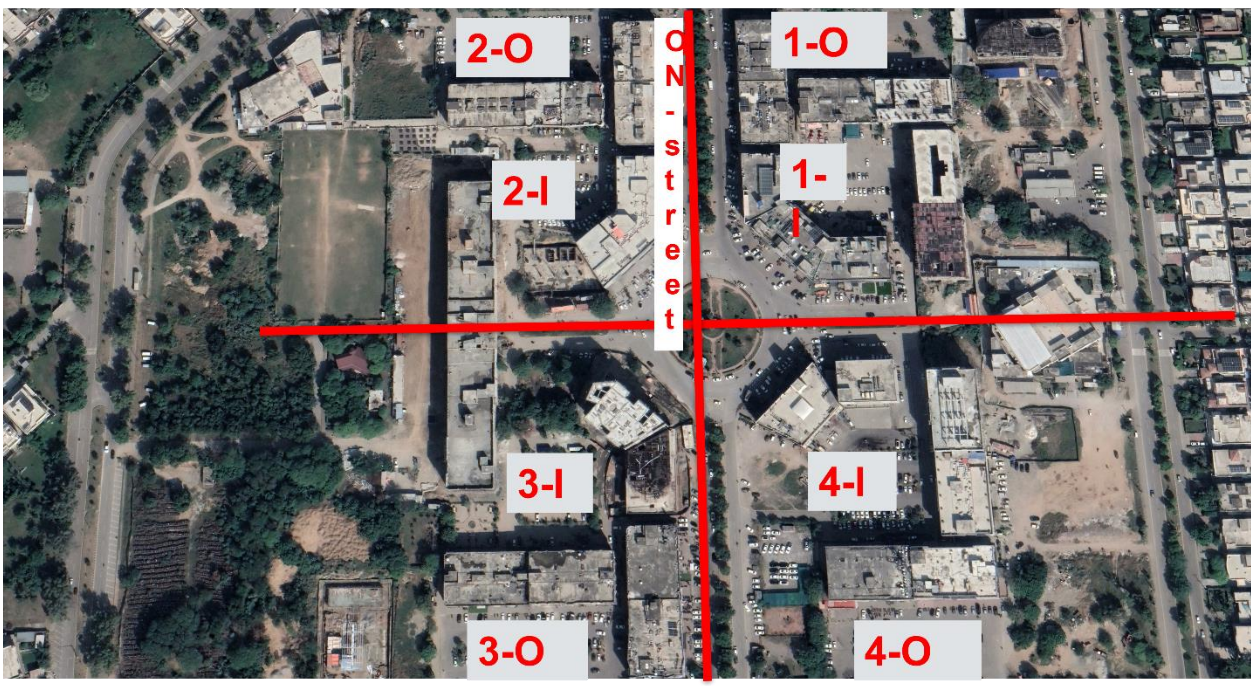


Figure 1.3: Off-Street Parking Areas Labeled

1.4 Research Objectives

The following were the main objective of this research:

- To design and implement a smart parking system for urban congested CBD areas in Islamabad.
- To optimize parking space utilization in Islamabad's CBD areas through the implementation of a smart parking system.
- To reduce traffic congestion in Islamabad's CBD areas by providing real-time parking availability information and navigation guidance to users.
- To enhance the overall parking experience for residents and visitors in Islamabad's CBD areas through the implementation of a smart parking system.
- To evaluate the effectiveness of the proposed smart parking system in reducing traffic congestion and improving parking efficiency in Islamabad's CBD areas.
- To compare the proposed smart parking system with traditional parking systems in terms of performance, user feedback, economic benefits, and environmental impact.
- To provide a valuable reference for urban planners, policymakers, and researchers seeking to implement similar parking management strategies in other cities facing similar challenges.

CHAPTER 2

2. LITERATURE REVIEW

Every journey starts and finishes with a person walking, except for instances where drive-through facilities are available at various locations such as banks and fast-food restaurants. When traveling by private vehicle, the pedestrian portion of the trip takes place when the individual parks the vehicle at a designated parking space.

At the destination end of a journey, private vehicles are accessed through private driveways, garages, on-street parking spaces, or nearby off-street lots or garages. The location and type of parking opportunities at the destination heavily depend on land-use function and density, as well as various public policy and planning factors. For land to be utilized effectively, it must be accessible.

Although public transportation plays a significant role in providing accessibility in densely populated urban areas, parking facilities remain crucial for most journeys. The availability, convenience, and cost of parking facilities determine the level of accessibility for private vehicles. Major activity centers, such as regional shopping malls, sports facilities, and airports, rely on a significant parking supply to ensure site accessibility. Without adequate parking facilities, such centers would be unable to operate profitably for an extended period.

2.1 Concept of Car Parking

Car parking is a crucial aspect of urban and suburban transportation infrastructure that is necessary for providing safe, secure, and convenient storage for private vehicles. It plays a significant role in the accessibility, livability, and economic vitality of urban areas. However, managing car parking can be a complex and challenging task due to its significant impact on land-use, transportation, and environmental policy.

The importance of car parking can be seen from the fact that most trips in urban areas are made by private vehicles, and parking facilities are essential for ensuring the accessibility of destinations. Without adequate parking, businesses, commercial centers, and residential areas may experience reduced foot traffic, decreased economic activity, and diminished quality of life. Therefore, the provision of parking facilities is necessary to ensure the efficient movement of people and goods and to support urban development.

The management of car parking involves several factors, such as the location, type, size, and design of parking facilities, pricing mechanisms, and enforcement strategies. Parking facilities can be managed by various entities, including governments, private companies, and individual property owners. Local governments typically regulate parking through zoning and land-use regulations, building codes, and parking ordinances. Parking management can also be carried out through various pricing mechanisms such as flat rate parking fees, metered parking, or dynamic pricing based on supply and demand.

Despite its importance, managing car parking can present various challenges and problems. One significant problem associated with car parking is the limited availability of space, particularly in densely populated urban areas. As urban areas continue to grow and densify, finding sufficient parking spaces for an increasing number of vehicles becomes increasingly difficult. Moreover, the construction of new parking facilities can be expensive, making it challenging for businesses and property owners to provide adequate parking.

Another problem with car parking is the negative impact on the environment. The construction and maintenance of parking facilities can result in land-use changes, including the destruction of green spaces and natural habitats. Additionally, car parking is a significant contributor to air and water pollution, as vehicles emit harmful pollutants and parking lots generate stormwater runoff.

Furthermore, managing car parking can be challenging from an enforcement perspective. Parking violations, such as parking in prohibited areas or overstaying a parking time limit, are widespread, leading to revenue loss and traffic congestion. To address these issues, many local governments have implemented strict enforcement policies, including parking tickets and towing, to deter illegal parking practices.

2.1.1 Parking Generation and Supply Needs

Parking generation and supply needs are essential concepts in urban planning and transportation engineering. These concepts refer to the estimation and provision of parking spaces necessary to accommodate the parking demand of vehicles in a particular area.

Parking generation refers to the estimation of the number of parking spaces required to accommodate the parking demand generated by a particular land use. The parking demand can be estimated by using parking generation rates, which are based on data collected from similar land uses. The parking generation rates are typically expressed as the number of parking spaces required per unit of floor area, number of employees, or number of customers. For instance, the parking demand generated by a retail store may be estimated as 4 parking spaces per 1,000 square feet of retail space.

Once the parking demand is estimated, the next step is to determine the parking supply needed to meet the demand. Parking supply needs refer to the number of parking spaces that need to be provided to meet the estimated parking demand. The parking supply needs can be determined by subtracting the existing parking supply from the estimated parking demand. The existing parking supply can be determined by counting the number of parking spaces available in the study area.

The provision of parking spaces can have significant impacts on the surrounding area. The location, design, and management of parking facilities can affect traffic flow, pedestrian safety, and the environment. Therefore, it is essential to carefully consider the parking supply needs and provide parking facilities that meet the demand while minimizing negative impacts.

There are various types of parking facilities that can be provided to meet the parking supply needs, including on-street parking, off-street parking, and structured parking. On-street parking refers to parking spaces provided along the street. Off-street parking refers to parking spaces provided on private property, such as parking lots and garages. Structured parking refers to multi-level parking facilities that can accommodate many vehicles.

The provision of parking facilities can be challenging in urban areas with limited available space. The construction of new parking facilities can be expensive, and the loss of open space can have negative impacts on the environment and community. Therefore, it is important to consider alternative transportation options, such as public transportation, biking, and walking, to reduce the parking demand and alleviate parking supply needs.

In conclusion, parking generation and supply needs are critical concepts in urban planning and transportation engineering. The estimation of parking demand and the provision of parking supply are necessary to ensure the accessibility, livability, and economic vitality of urban areas. The location, design, and management of parking facilities can have significant impacts on the surrounding area, and it is essential to carefully consider the parking supply needs and provide parking facilities that meet the demand while minimizing negative impacts.

2.1.2 Parking Studies and Features

Parking studies are conducted to analyze the parking situation in a particular area and determine the parking demand and supply needs. These studies are typically conducted by transportation planners, engineers, or consultants and involve collecting data on parking occupancy, duration, and turnover rates.

One of the main characteristics of parking studies is the collection of parking data. The data collection methods typically include manual counts, automated counts, surveys, and interviews. Manual counts involve physically counting the number of parked vehicles at various times of the day. Automated counts involve using sensors or cameras to count the number of parked vehicles automatically. Surveys and interviews involve asking drivers about their parking behavior and preferences.

Another characteristic of parking studies is the analysis of the parking data. The analysis typically involves identifying the peak parking demand periods, the parking duration, and turnover rates. The peak parking demand periods can be used to estimate the parking demand and determine the parking supply needs. The parking duration can be used to estimate the number of parking spaces required and the turnover rates can be used to estimate the amount of parking time available.

Parking studies also involve the evaluation of the parking facilities in terms of their location, design, and management. The location of parking facilities can have a significant impact on the surrounding area in terms of traffic flow, pedestrian safety, and the environment. The design of parking facilities can affect the accessibility, convenience, and safety of the facility. The management of parking facilities can affect the efficiency, effectiveness, and user satisfaction of the facility.

One of the challenges of parking studies is the variability of parking demand and supply needs over time and location. The parking demand and supply needs can vary based on the land use, time of day, day of the week, and season. Therefore, it is important to conduct parking studies periodically to ensure that the parking facilities continue to meet the changing parking demand and supply needs.

In conclusion, parking studies are critical to understanding the parking situation in a particular area and determining the parking demand and supply needs. These studies involve collecting parking data, analyzing the data, and evaluating the parking facilities. The variability of parking demand and supply needs over time and location is a challenge that requires periodic parking studies to ensure that the parking facilities continue to meet the changing needs of the area.

2.1.3 Parking Terms

2.1.3.1 Accumulation and Duration

Parking accumulation and duration refer to the amount of time a vehicle spends parked in a particular location. This information is important for parking management and planning purposes.

Parking accumulation refers to the number of vehicles that occupy a parking space over a period. Parking accumulation can be measured in terms of occupancy rate, which is the percentage of time that a parking space is occupied over a given period. For example, if a parking space is occupied for 12 hours out of a 24-hour period, the occupancy rate would be 50%. Parking accumulation can also be measured in terms of turnover rate, which is the number of vehicles that occupy a parking space over a given period. For example, if a parking space is occupied by 12 different vehicles over a 24-hour period, the turnover rate would be 12.

Parking duration refers to the length of time that a vehicle spends parked in a particular location. Parking duration can be measured in terms of average length of stay, which is the average amount of time that a vehicle spends parked in a particular location. For example, if the average length of stay for a parking lot is 2 hours, this means that on average, vehicles spend 2 hours parked in that lot. Parking duration can also be measured in terms of maximum stay, which is the maximum amount of time that a vehicle is allowed to park in a particular location. For example, if the maximum stay for a parking lot is 4 hours, this means that vehicles are not allowed to park in that lot for more than 4 hours.

Parking accumulation and duration are important considerations for parking management and planning. By measuring these factors, parking managers can determine the level of demand for parking in a particular area, and make decisions about how to allocate parking resources. For example, if parking accumulation is high but parking duration is short, it may be more effective to implement a pricing system that encourages turnover rather than increasing the number of parking spaces. Conversely, if parking accumulation is low but parking duration is long, it may be more effective to increase the number of parking spaces rather than implementing a pricing system. Understanding parking accumulation and duration can help parking managers make more informed decisions about how to allocate parking resources and meet the needs of drivers in a particular area.

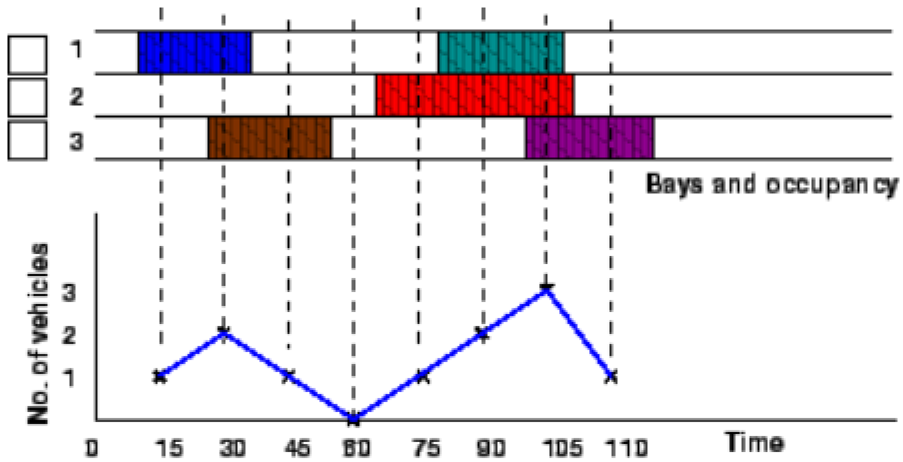


Figure 2.1: Parking Accumulation Curve

2.1.3.2 Parking Volume

Parking volume refers to the total number of vehicles that can be accommodated in a parking facility, typically expressed as a maximum number of vehicles at any given time. It is determined by the total number of parking spaces available in the facility, as well as the size and layout of the parking area.

2.1.3.4 Parking Load

Parking load refers to the number of vehicles parked in a parking facility at a given time, usually expressed as a percentage of the total parking capacity. It is a measure of how well a parking facility is utilized, and is influenced by factors such as parking demand, availability, and pricing. Parking load can also vary depending on the time of day or day of the week, with peak demand periods resulting in higher parking loads.

2.1.3.5 Parking Turnover

Parking turnover is the number of times that a parking space is occupied and vacated over a given time period, usually expressed as the average number of vehicles that use the space in a day. It is an important measure of the efficiency and effectiveness of a parking facility, as high turnover rates indicate that parking spaces are being utilized efficiently and are meeting the needs of users. Parking turnover can be influenced by a variety of factors, including the availability of parking spaces, parking pricing and policies, and the overall demand for parking in each area.

$$parkingturnover = \frac{parkingvolume}{No.ofbaysavailable}$$

2.1.3.6 Parking Index

Parking index measures the efficiency or utilization of parking spaces by comparing the number of occupied parking bays to the total number of parking spaces available over a given time period. Parking index is useful for evaluating the efficiency of parking operations and identifying areas where improvements can be made to optimize parking utilization.

$$\text{parking index} = \frac{\text{parking load}}{\text{parking capacity}} \times 100$$

2.1.4 Design of Parking Facilities

Parking design is an essential part of urban planning and transportation engineering. It involves the planning, design, and management of parking facilities, including surface parking lots, parking structures, and underground parking garages. A well-designed parking facility should provide safe, convenient, and accessible parking for all users, including pedestrians, bicyclists, and motorists.

One of the primary considerations in parking design is the amount of parking that is needed. This is typically determined by analyzing the parking demand of a particular area or land use, such as a commercial district, residential neighborhood, or event venue. Once the parking demand is established, parking designers can determine the appropriate number of parking spaces required to meet that demand.

Another important aspect of parking design is accessibility. Parking facilities should be located within a reasonable distance of the land use they serve, and should be easily accessible by all modes of transportation, including walking, bicycling, public transportation, and private vehicles. This requires careful consideration of the surrounding transportation network, as well as the layout and design of the parking facility itself.

Parking designers must also consider the safety and security of parking facilities. This includes designing facilities with adequate lighting, clear signage, and appropriate landscaping. In addition, parking facilities must be designed to accommodate emergency vehicles and provide safe pedestrian and bicycle access.

Another important consideration in parking design is sustainability. Parking facilities can have a significant impact on the environment, and designers must take steps to minimize that impact. This includes using environmentally-friendly materials, designing facilities to maximize natural ventilation and lighting, and providing space for alternative transportation modes, such as bicycles and electric vehicles.

Finally, parking design must also consider the needs and preferences of the users. This includes providing adequate space for different types of vehicles, such as large trucks and buses, as well as providing amenities such as restrooms, charging stations, and bicycle storage.

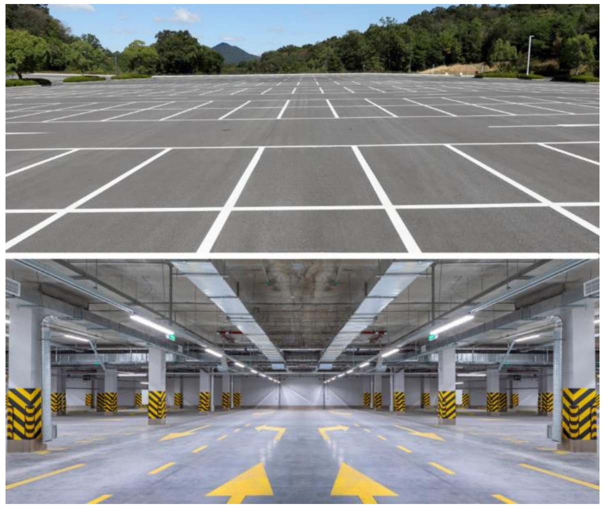


Figure 2.2: Unstructured and Structured Parking

2.1.5 Parking Layout and Dimensions

Parking design involves determining the layout and dimensions of parking spaces and traffic flow patterns in parking areas. Parking design must cater to the dimensions required for different types of parking spaces. The following are some standard parking dimensions commonly used in parking design:

For parallel parking spaces, the standard length is 22 feet (6.7 meters) and the standard width is 8.5 feet (2.6 meters). For perpendicular parking spaces, the standard length is 18 feet (5.5 meters) and the standard width is 9 feet (2.7 meters). For angled parking spaces at a 45-degree angle, the standard length is 18 feet (5.5 meters) and the standard width is 8.5 feet (2.6 meters).

Compact car parking spaces typically have a length of 16 feet (4.9 meters) and a width of 7.5 feet (2.3 meters). Handicap accessible parking spaces have a length of 18 feet (5.5 meters) and a width of 8 feet (2.4 meters).

Additionally, drive aisle widths are crucial for smooth traffic flow. Aisle widths between parking rows should be at least 24 feet for two-way traffic, with a recommended width of 30 feet. For one-way traffic, minimum widths are 12 feet, while a recommended range is 14 to 16 feet. Drive aisle widths for two-way traffic should be a minimum of 24 feet, with a recommended width of 26 to 30 feet.

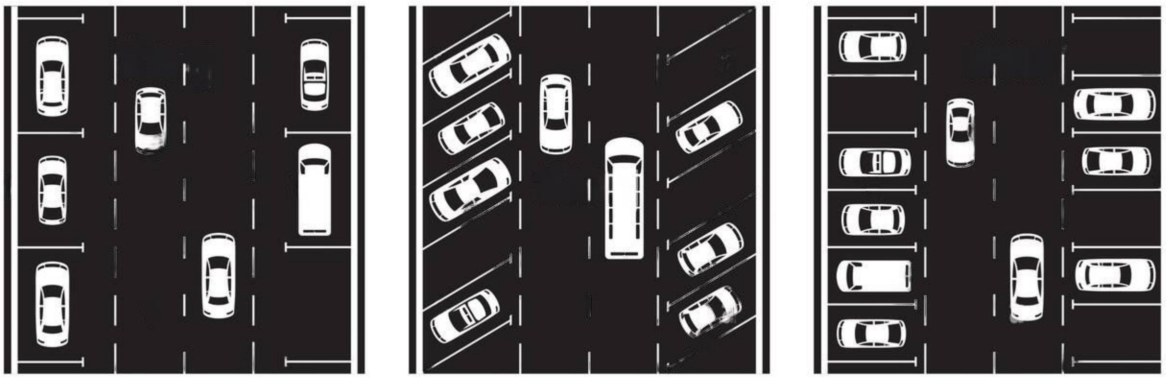


Figure 2.3: Different types of Parking Layout

2.1.6 Parking Surveys

There are several different types of parking surveys that can be conducted, including:

1. In-Out Survey:

The in-out survey is a type of parking survey where the count of occupied parking spaces is taken at the start of the survey. Then, the number of vehicles entering and leaving the parking lot during a particular time interval is recorded. Finally, the count of occupied parking spaces at the end of the survey is taken. This survey requires minimal labor and can be conducted by a single person. However, it does not provide any information on the duration of parking or the turnover rate of the parking lot. Therefore, it is not possible to estimate the parking fee based on this survey.

2. Fixed Period Sampling:

Fixed period sampling is a parking survey technique that is like the in-out survey. The survey starts by counting all the vehicles at the beginning. After a fixed interval of time ranging from 15 minutes to an hour, the count is taken again. However, there is a risk of not recording the number of vehicles parked for a short duration.

3. License plate method of survey:

To obtain the most accurate data, the license plate method of survey is used. This involves monitoring each parking space continuously at intervals of around 15 minutes and recording the license plate number. This provides information on the length of time a vehicle has been parked in a specific space. This helps in calculating the fare for parking, which is based on the duration of the vehicle's stay. If the time interval is shorter, there are fewer chances of missing short-term parkers. However, this method is very labor-intensive.

4. User Survey:

These surveys gather feedback from parking facility users on their experiences and satisfaction levels. This information can be used to identify areas for improvement and to inform decisions related to pricing, amenities, and other factors that affect user experience.

2.1.7 Parking Statistics

1. According to a study by INRIX, an analytics company, the average driver spends 17 hours a year searching for parking spots.
2. A survey by the National Parking Association found that more than 50% of drivers avoid going to certain destinations due to parking difficulties.
3. In urban areas, the average parking space size is 7.5 feet by 16.5 feet, while the average vehicle size is 6 feet by 15 feet.
4. In a study by the University of California, Los Angeles, it was found that up to 30% of traffic congestion in cities is caused by drivers searching for parking spots.
5. The International Parking Institute reports that parking spaces can range from $10,000 to $80,000 per space to construct in a structured parking facility.
6. A study by the Institute of Transportation Engineers found that parking spaces per 1,000 square feet of gross leasable area in shopping centers ranged from 3.3 to 8.2, depending on the type of store.
7. In the United States, there are an estimated 2 billion parking spots, which is more than the total number of cars (approximately 280 million) on the road.
8. The parking industry is estimated to generate $100 billion in annual revenue worldwide.
9. In a study by the City of Los Angeles, it was found that parking meters that accept credit cards generate 23% more revenue than those that only accept coins.
10. In a survey by the National Parking Association, it was found that 90% of Americans have experienced parking difficulties, with 56% citing lack of available parking as the main issue.

Although above statistics are not gathered from Islamabad, Pakistan as per speaking, they still are a great reference when parking studies and designs are considered.

2.2 Research Papers

2.2.1 Agent-Based Modelling and Simulation to Assess the Impact of Parking Reservation System

2.2.1.1 Introduction

The article titled "Agent-Based Modelling and Simulation to Assess the Impact of Parking Reservation System" by Xun-You Ni and Daniel (Jian) Sun aims to explore the impact of a parking reservation system on parking operations and overall transportation network performance. The study is motivated by the growing concern over the inefficiencies of traditional parking management systems and the need for more sustainable and efficient alternatives. The authors propose a simulation-based approach to assess the effectiveness of parking reservation systems and provide insights into their potential benefits for reducing congestion, enhancing mobility, and improving sustainability.

2.2.1.2 Research Objectives

The objective of this research is to evaluate the impact of a parking reservation system on parking demand, parking occupancy, and overall transportation network performance. The authors aim to develop an agent-based model that simulates the parking reservation system's operation and evaluates its effectiveness in reducing congestion and enhancing mobility. They also seek to examine the system's impact on sustainability, such as reducing greenhouse gas emissions and energy consumption.

2.2.1.3 Research Conclusion

The study's findings suggest that a parking reservation system can significantly reduce congestion and enhance mobility by improving the efficiency of parking operations. The authors found that the system can reduce the parking demand and occupancy rates, leading to less time spent searching for parking spaces and reducing traffic congestion. Additionally, the reservation system can help reduce greenhouse gas emissions and energy consumption, making it an environmentally sustainable solution. The research also suggests that the system's effectiveness depends on several factors, such as the parking demand and supply, reservation fees, and user behavior. The authors conclude that the agent-based modelling approach is a useful tool for evaluating the impact of parking reservation systems and can inform policymakers and stakeholders about their potential benefits.

2.2.2 Smart Parking System Using Image Processing and AI

2.2.2.1 Introduction

The research article "Smart Parking System Using Image Processing and AI" by Jiang Ruili, Wang Haocong, Wang Han, and Dr Eoin O'Connell introduces the concept of a smart parking system that utilizes image processing and artificial intelligence (AI) techniques to efficiently manage parking spaces. The authors highlight the problem of traffic congestion caused by inadequate parking spaces and the need for a solution that can optimize parking management.

2.2.2.2 Research Objectives

The main objective of the research is to design and implement a smart parking system that can accurately detect available parking spaces and provide real-time information to drivers. The system is based on the integration of image processing techniques and AI algorithms, including machine learning and deep learning models, to identify and classify parking spaces. The research also aims to evaluate the effectiveness of the proposed system in terms of accuracy, speed, and reliability.

2.2.2.3 Research Conclusion

The research demonstrates that the proposed smart parking system can effectively detect and classify parking spaces using image processing and AI algorithms. The system achieved a high accuracy rate of 98% in detecting available parking spaces and provided real-time information to drivers through a mobile application. The authors concluded that the system can significantly reduce the time spent searching for parking spaces and alleviate traffic congestion in urban areas. They also suggested that future research could focus on improving the scalability and robustness of the system for large-scale deployment.

2.2.3 The Study and Optimization of Parking Facilities in Central Business District: A Case Study of Saddar Peshawar, Pakistan

2.2.3.1 Introduction

The research titled "The Study and Optimization of Parking Facilities in Central Business District: A Case Study of Saddar Peshawar, Pakistan" by Shah Faisal and Rawid Khan was conducted to analyze the parking situation in Saddar, Peshawar, Pakistan's central business district. The study aimed to identify the parking problems faced by the public, assess the parking supply and demand, and suggest possible solutions to optimize parking facilities in the area.

2.2.3.2 Research Objectives

The main objective of this study was to provide an effective solution to the parking issues faced by the public in Saddar, Peshawar. The study aimed to identify the problems associated with parking and to propose possible solutions that could be implemented to optimize parking facilities in the area.

2.2.3.3 Research Conclusion

The study concluded that the parking facilities in Saddar, Peshawar were inadequate to meet the parking demand of the area. The researchers identified the major parking problems in the area, including illegal parking, insufficient parking capacity, and poor parking management. The researchers also suggested a few solutions to these problems, such as implementing an efficient parking management system, increasing the parking supply, and improving the public transportation system. The study recommended that a proper parking plan should be developed for the area, which should include the construction of new parking lots and the improvement of existing parking facilities. The research concluded that by adopting these solutions, the parking situation in Saddar, Peshawar could be significantly improved, resulting in a more efficient traffic flow and reduced congestion in the area.

2.3 Smart Parking System

2.3.1 Introduction

Smart Parking System is a technologically advanced solution to the longstanding issue of parking management. The conventional parking system has long been a source of frustration for drivers and parking facility operators alike. Inefficient parking management leads to congestion, environmental pollution, and lost time and revenue for businesses. To address these issues, smart parking systems leverage advanced technologies such as sensors, IoT, big data analytics, and mobile applications to optimize parking utilization, reduce traffic congestion, and improve user experience.

The integration of smart technologies allows parking operators to monitor parking spaces in real-time, provide real-time parking availability information to drivers, and automate payment and ticketing processes. With the increasing adoption of smart parking systems, urban planners and facility operators can make better decisions regarding parking infrastructure and optimize parking demand to reduce traffic congestion, carbon footprint, and enhance sustainability. The implementation of smart parking solutions also benefits businesses by increasing revenue, improving customer satisfaction, and reducing the operational costs associated with parking management.

2.3.2 Importance

Smart parking systems have gained significant attention in recent years due to the increasing demand for efficient and convenient parking facilities. These systems utilize advanced technologies such as Internet of Things (IoT), Artificial Intelligence (AI), and cloud computing to offer a seamless parking experience to drivers. The importance of smart parking systems lies in their ability to optimize parking resources, reduce congestion and air pollution, enhance safety and security, and provide real-time information to drivers.

Optimizing parking resources is one of the primary benefits of smart parking systems. By utilizing real-time data on parking availability and demand, these systems can guide drivers to the nearest available parking spot, reducing the time and effort required to find a parking spot. This leads to reduced congestion and air pollution, as drivers spend less time driving around in search of a parking spot.

Smart parking systems also enhance safety and security by providing better visibility into parking facilities. With the use of sensors and cameras, these systems can detect and report any suspicious activity, reducing the risk of theft and vandalism. Additionally, real-time monitoring of parking facilities ensures that any accidents or emergencies are quickly identified and responded to.

Furthermore, smart parking systems provide real-time information to drivers, enabling them to make informed decisions about parking. This information includes the availability of parking spots, the location of parking facilities, and the cost of parking, among others. This enhances the overall parking experience for drivers, as they can easily find parking and make informed decisions about parking options.

In summary, the importance of smart parking systems lies in their ability to optimize parking resources, reduce congestion and air pollution, enhance safety and security, and provide real-time information to drivers. These benefits make smart parking systems a crucial component of modern urban transportation systems.

2.3.3 Application

Smart Parking System is a technology-driven solution that optimizes parking operations, reduces traffic congestion, and improves the overall parking experience for users. Its applications are numerous, and they have the potential to transform how we park our vehicles.

One of the primary applications of Smart Parking System is its ability to improve the efficiency of parking operations. With real-time data, parking operators can monitor parking spaces and optimize parking management, ensuring that available spaces are utilized to their fullest potential. This can help reduce traffic congestion in busy urban areas, minimize the time and effort required to find a parking space, and increase the revenue generated by parking facilities.

Another application of Smart Parking System is in the development of smart cities. By integrating Smart Parking System into a city's infrastructure, city planners can create a more efficient and sustainable urban environment. With the ability to monitor and manage parking resources, cities can optimize their transportation systems and reduce carbon emissions by minimizing the time vehicles spend on the road looking for parking spaces.

In addition to the above, Smart Parking System can also improve the parking experience for users. With features such as real-time parking space availability information, mobile payment options, and automated parking assistance, parking becomes faster, more convenient, and less stressful. Users can avoid the frustration of searching for a parking space, and can easily locate and pay for a space with the touch of a button.

Overall, the applications of Smart Parking System are vast, and the technology has the potential to revolutionize parking operations and transportation in cities around the world. By improving the efficiency of parking operations, reducing traffic congestion, and enhancing the user experience, Smart Parking System can make parking easier, faster, and more convenient for everyone.

2.3.4 Market Areas

Smart Parking Systems have wide-ranging applications across various market areas. The system has been widely implemented in public and private parking facilities, including commercial buildings, shopping centers, airports, hospitals, and sports venues. The smart parking system has the potential to revolutionize the parking experience by providing convenience and reducing time and effort required for finding a parking spot. The market areas of smart parking systems include both developed and developing countries.

The demand for Smart Parking Systems is increasing due to the rising number of vehicles, traffic congestion, and the need for efficient parking management. In developed countries, where traffic congestion is a significant issue, the Smart Parking System has become a necessary tool for cities and municipalities to manage their parking facilities effectively. Furthermore, the increasing adoption of advanced technologies such as the Internet of Things (IoT) and cloud computing has created opportunities for smart parking systems.

In developing countries, the Smart Parking System is still in its early stages of development. However, with the rapid urbanization and increasing vehicle ownership, the demand for parking management solutions is expected to rise in the coming years. The adoption of Smart Parking Systems in developing countries can help improve traffic flow, reduce pollution, and increase parking revenue.

Overall, the market areas of Smart Parking Systems are vast and diverse, and the system's potential to improve parking management and enhance the parking experience makes it an attractive solution for both public and private parking facilities.

2.3.5 Brief History

Smart Parking System is a recent advancement in the parking industry, which has become a popular solution to the growing parking problems in urban areas. The idea of automated parking systems dates to the early 1900s, where simple mechanical lifts were used to stack cars on top of each other. However, the modern concept of Smart Parking System emerged in the 1990s with the development of advanced technologies such as sensors, mobile applications, and data analytics.

The first Smart Parking System was implemented in the United States in 1992 in the city of Pasadena, California. It utilized sensors embedded in the ground to detect the presence of vehicles and communicate the information to a central control system. The system provided real-time parking information to drivers, reducing traffic congestion and saving time.

Since then, Smart Parking Systems have been implemented in many cities across the world, including London, Tokyo, and Singapore, to name a few. With the increasing demand for parking spaces and the need for efficient management, the Smart Parking System has become an important technology in the parking industry.

The history of Smart Parking System shows a continuous evolution of technology and innovation, leading to the development of more advanced and efficient systems. The integration of IoT, machine learning, and AI technologies has further enhanced the capabilities of Smart Parking Systems, making them more user-friendly, cost-effective, and environmentally friendly.

2.3.6 Processes

Smart parking systems involve several processes, each of which is critical for ensuring the smooth operation of the system. The processes involved in smart parking systems are as follows:

- **Vehicle Detection**

The first step in a smart parking system is the detection of the presence of a vehicle. This is done using sensors that are installed at each parking space.

- **Data Transmission**

Once a vehicle is detected, the data is transmitted to a central server, where it is processed and analyzed. The data includes information such as the location of the parking space, the time of arrival, and the duration of stay.

- **Parking Space Reservation (optional)**

If a user wants to reserve a parking space in advance, they can do so through a mobile app or a web portal. This helps to ensure that the user has a guaranteed parking space when they arrive at the parking lot.

- **Payment Processing (optional)**

Once a user has parked their vehicle, the system calculates the parking fee based on the duration of stay and any other relevant factors. The user can then make the payment through a mobile app or a payment kiosk.

- **Navigation**

In large parking lots, it can be difficult for users to find an available parking space. Smart parking systems provide navigation services that guide users to the nearest available parking space.

- **Maintenance and Monitoring**

Smart parking systems require regular maintenance to ensure that the sensors and other components are working properly. The system also needs to be monitored to detect any issues and resolve them quickly.

Overall, smart parking systems involve a range of processes that work together to provide a convenient and efficient parking experience for users while also helping to reduce traffic congestion and improve the utilization of parking spaces.

2.3.7 Components

A Smart Parking System consists of various components that work together to ensure efficient and convenient parking. These components include sensors, communication networks, data analytics software, mobile applications, and parking guidance systems.

- **Sensors**

Sensors are a crucial component of the system as they detect the presence of vehicles in parking spots and transmit this data to the system. Communication networks such as Wi-Fi, Bluetooth, or cellular networks allow the sensors to communicate with the central server and transmit data in real-time.

- **Data Analytics Software**

Data analytics software processes the data received from sensors to provide insights into parking patterns, parking usage, and other relevant information. This information can be used to optimize parking operations, improve parking facilities, and provide better services to customers.

- **Mobile Application**

Mobile applications enable drivers to find available parking spots in real-time, reserve parking spots in advance, and make payments for parking. These applications can also provide directions to the nearest available parking spots, reducing the time and effort required to find a parking spot.

- **Guidance Systems**

Parking guidance systems use digital displays or mobile applications to guide drivers to available parking spots. This not only improves the parking experience for drivers but also reduces the time and energy required to find a parking spot, leading to reduced traffic congestion and carbon emissions.

In conclusion, a Smart Parking System is composed of multiple components that work together to improve parking operations, provide a better parking experience for customers, and reduce traffic congestion and carbon emissions.

2.3.8 Need

Smart Parking Systems have emerged as a solution to address the increasing problem of limited parking space and traffic congestion in urban areas. The need for a Smart Parking System arises from the growing number of vehicles on the road, leading to the scarcity of parking space, and resulting in time wastage and increased traffic congestion. The current manual system of parking management is inefficient, time-consuming, and prone to errors. The implementation of a Smart Parking System can help in efficient utilization of parking spaces, reduce traffic congestion, and provide a seamless parking experience to the users.

Moreover, the Smart Parking System can also help in reducing the environmental impact of vehicles, as less time spent searching for parking spaces leads to a reduction in carbon emissions. The system can also contribute to the development of smart cities, which is one of the key objectives of urban planning in today's world. The Smart Parking System can be integrated with other smart city technologies, such as traffic management systems, public transportation systems, and energy management systems, to provide a holistic solution to the urban planning challenges. Therefore, the need for a Smart Parking System is crucial to ensure sustainable and efficient urban mobility.

2.4 SUMO (Simulation of Urban MObility)

SUMO (Simulation of Urban MObility) is an open-source microscopic traffic simulator for road vehicles, public transportation, bicycles, and pedestrians. It is a widely used simulation platform for research and development of Intelligent Transportation Systems (ITS) and traffic management strategies. SUMO allows researchers to test and evaluate various traffic scenarios in a safe and controlled virtual environment. With its modular architecture and the ability to import real-world road network data, SUMO has become a powerful tool for simulating complex transportation scenarios and evaluating their impact on traffic flow, emissions, and safety.

SUMO was developed by the German Aerospace Center (DLR) in the early 2000s and is now maintained and developed by a growing community of researchers and developers worldwide. It has a user-friendly graphical user interface (GUI) and supports various programming languages such as Python, Java, and C++. SUMO is also integrated with other tools such as TraCI (Traffic Control Interface) and Veins (Vehicles in Network Simulation) for enhanced simulation capabilities. Overall, SUMO provides a comprehensive and flexible platform for transportation researchers and practitioners to explore and develop innovative solutions for traffic management and ITS.

2.4.1 SUMO's Strengths

Some of the major strengths/advantages of SUMO are:

1. **Open-source**

SUMO is a free and open-source software tool that can be downloaded, modified, and distributed under the GPL (GNU General Public License) agreement. This makes it accessible to many users and encourages collaboration and innovation.

2. **High degree of customization**

SUMO allows users to customize almost every aspect of their simulations, from the traffic demand to the road network topology and traffic control systems. This makes it suitable for a wide range of applications and research questions.

3. **Realistic traffic behavior**

SUMO uses advanced traffic flow models and behavior rules to simulate realistic traffic behavior, including lane changing, car following, and intersection behavior. This makes it suitable for studying complex traffic phenomena and evaluating traffic management strategies.

4. **Large user community**

SUMO has a large and active user community that provides support, documentation, and tutorials. This makes it easier for users to get started with the tool and find solutions to their problems.

5. **Integration with other tools**

SUMO can be easily integrated with other software tools, such as network analysis tools, visualization tools, and microscopic simulators. This allows users to combine SUMO with other tools to create more powerful simulations and analysis.

Overall, SUMO offers a powerful and flexible platform for simulating urban traffic networks and studying a wide range of traffic-related issues. Its open-source nature, customizability, realistic traffic behavior, large user community, and integration capabilities make it a valuable tool for researchers and practitioners in the field of transportation.

2.4.2 SUMO's Limitations

SUMO, being a simulation tool, has some limitations that researchers and users should be aware of. Some of the limitations of SUMO are:

1. **Computation time**

SUMO is a complex simulation tool that requires significant computing power to run. Running large-scale simulations with many vehicles and detailed models can take a long time and require powerful computers or servers.

2. **Accuracy**

While SUMO strives to be as accurate as possible in its simulation results, it is important to note that there are limitations to how accurate simulations can be. Factors such as driver behavior, weather conditions, and road construction can all affect traffic patterns and cannot always be accurately modeled.

3. **Complexity**

SUMO has a steep learning curve and requires a significant amount of time and effort to become proficient in using the software. Users need to have a good understanding of traffic flow theory and modeling techniques to create effective simulations.

4. **Data requirements**

SUMO requires a significant amount of input data to run simulations, such as road networks, traffic demand, and vehicle parameters. Gathering and processing this data can be time-consuming and require additional resources.

5. **Model limitations**

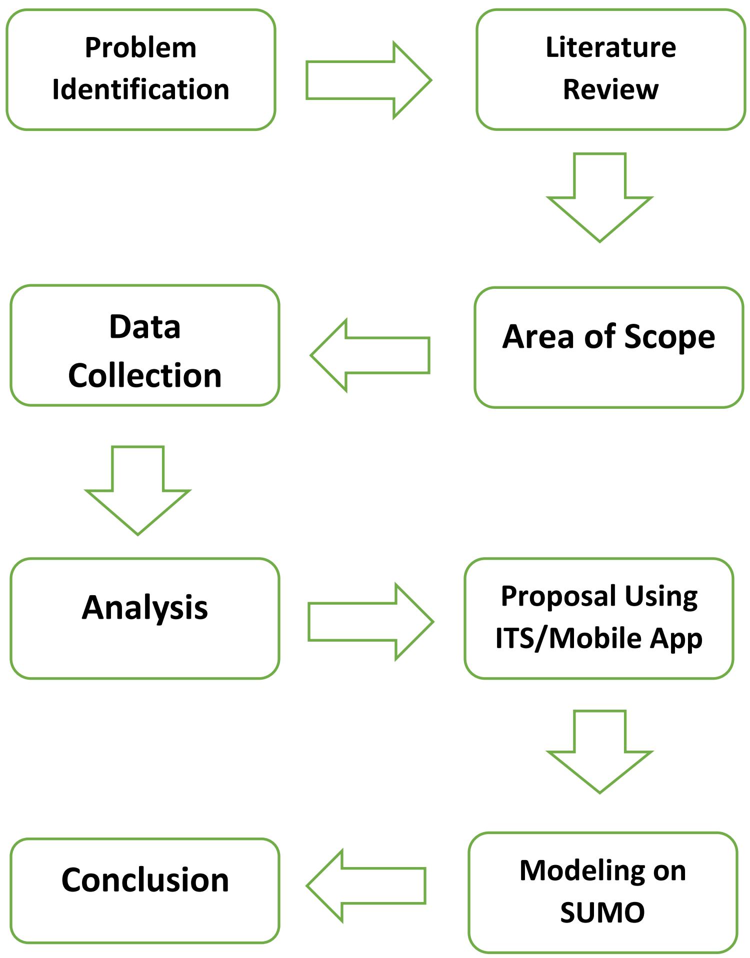
SUMO uses models to represent various aspects of the transportation system, such as vehicles, traffic flow, and traffic signals. While these models are generally accurate, they have some limitations and may not accurately represent real-world conditions.

Despite these limitations, SUMO remains a valuable tool for transportation researchers and professionals. By simulating traffic flow in a virtual environment, it can provide insights into traffic patterns and help identify potential solutions for improving transportation systems.

CHAPTER 3

3. RESEARCH METHODOLOGY

3.1 Hierarchy



The parking analysis in this research employed a hierarchical approach, wherein the initial focus was on identifying parking-related issues specific to the Area of Study. This was followed by the collection of relevant data through a Preliminary Study, enabling a thorough and accurate analysis based on real-world information. The utilization of real-world data validated the identified problems and facilitated a comprehensive assessment.

Subsequently, proposed solutions were individually implemented and simulated using the SUMO software. This simulation-based approach allowed for evaluating the effectiveness of each solution and assessing its impact on the identified problems. Detailed conclusions were then drawn based on the outcomes of these simulations, encompassing the extent of improvement achieved by each specific solution, as well as an examination of their respective advantages and disadvantages.

By employing this systematic and comprehensive methodology, the research successfully addressed the parking challenges specific to the Area of Study, providing valuable insights and recommendations for enhancing the parking situation. The combination of empirical data analysis and simulation modeling using SUMO contributed to the rigor and reliability of the research findings, thereby adding significant value to the field of parking management and urban mobility.

3.2 Procedure

3.2.1 Sampling Strategy

The study used a fixed period sampling strategy where all on-street and off-street parking spots in the I-8 CBD were counted and observed over a period of 3 and a half hours. The off-street parking areas were divided into quadrants and named accordingly.

3.2.2 Data Collection

The number of occupied parking spots and their registration numbers were noted down during the initial count. Subsequently, the parking spots were revisited after 30 minutes to check for any changes in occupancy status. The changes noted included cars leaving the spot, new cars occupying previously unoccupied spots or cars being replaced by other cars.

3.2.2.1 Demand vs. Available parking space

Off-Street Parking

Sunday

Figure 3.1: Sunday off-street 1-O Demand vs. Available Parking

Figure 3.2: Sunday off-street 1-I Demand vs. Available Parking

Figure 3.3: Sunday off-street 2-O Demand vs. Available Parking

Figure 3.4: Sunday off-street 2-I Demand vs. Available Parking

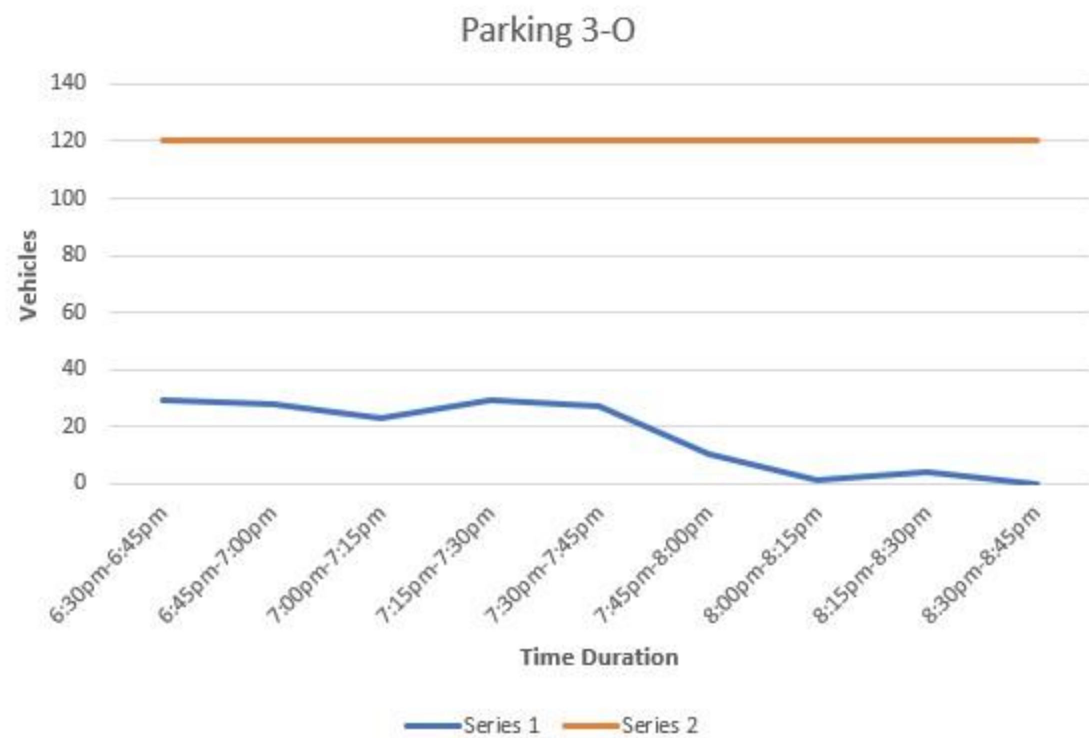


Figure 3.5: Sunday off-street 3-O Demand vs. Available Parking

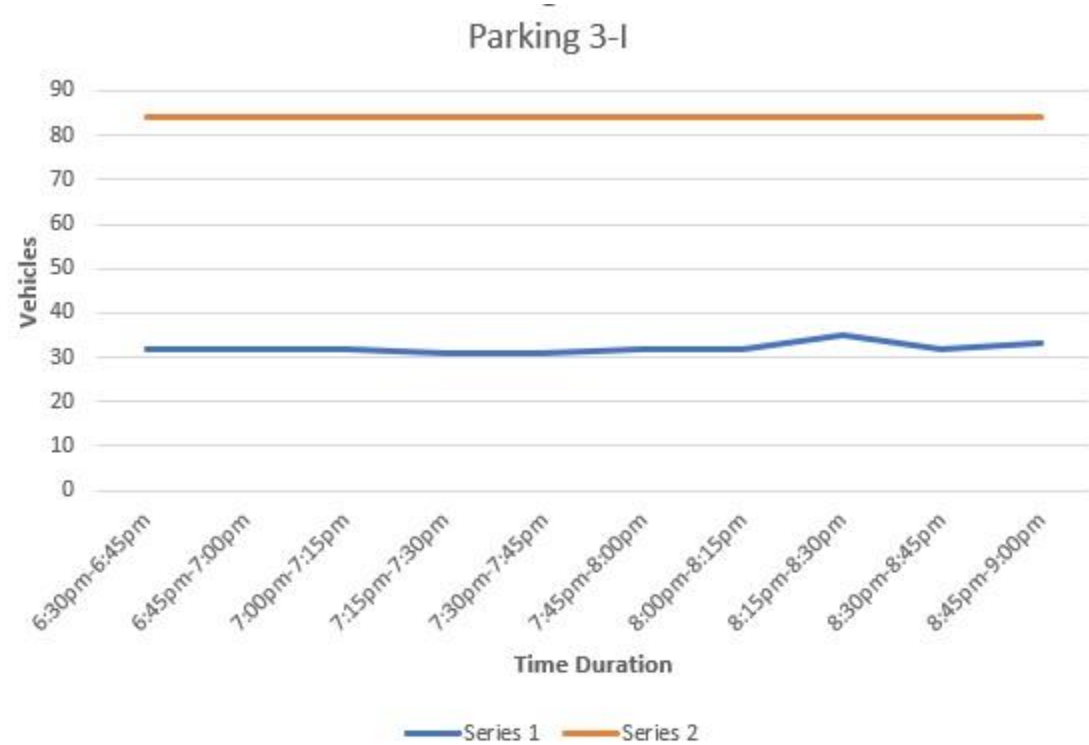


Figure 3.6: Sunday off-street 3-I Demand vs. Available Parking

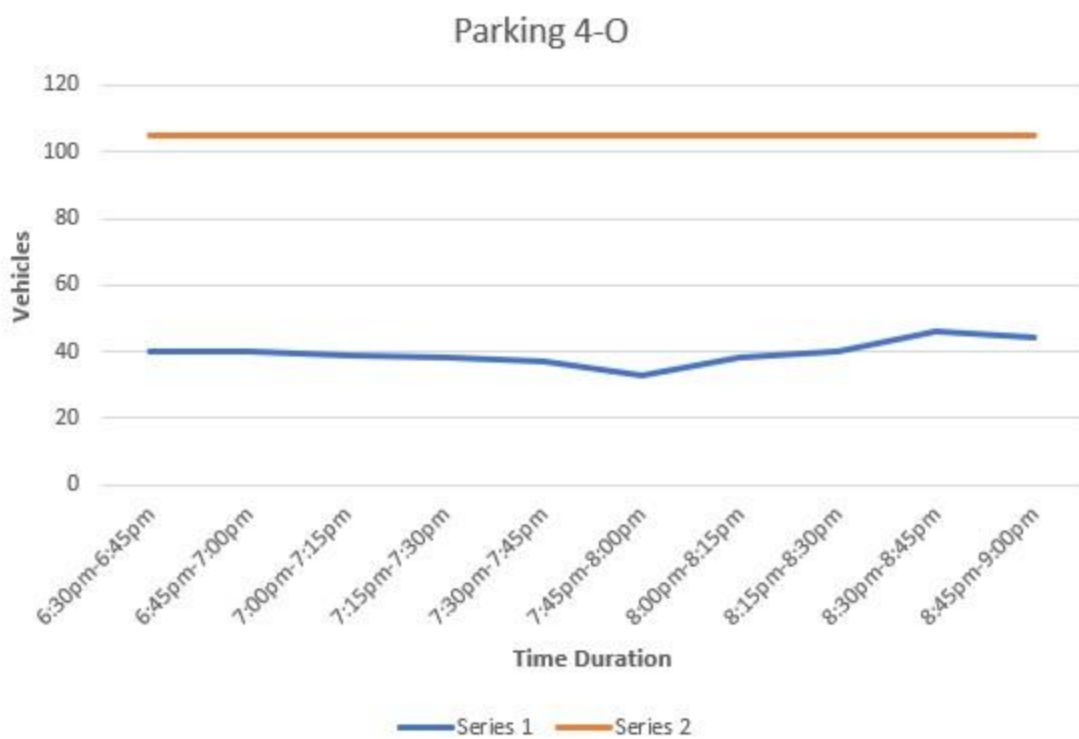


Figure 3.7: Sunday off-street 4-O Demand vs. Available Parking

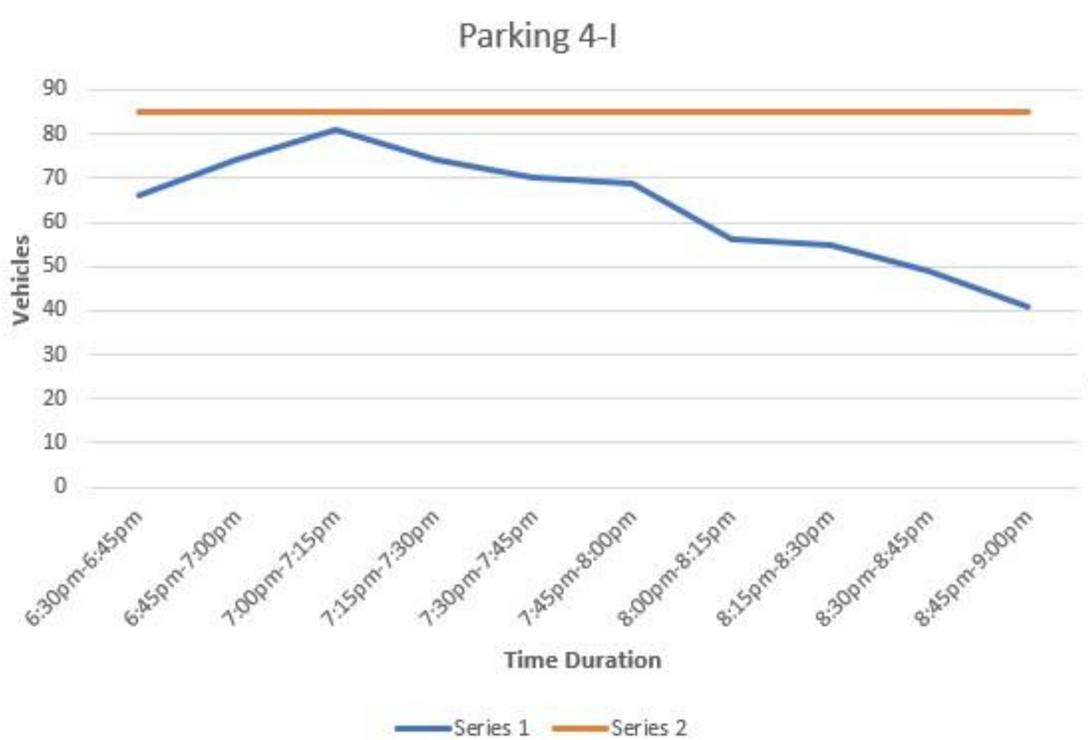


Figure 3.8: Sunday off-street 4-I Demand vs. Available Parking

Saturday

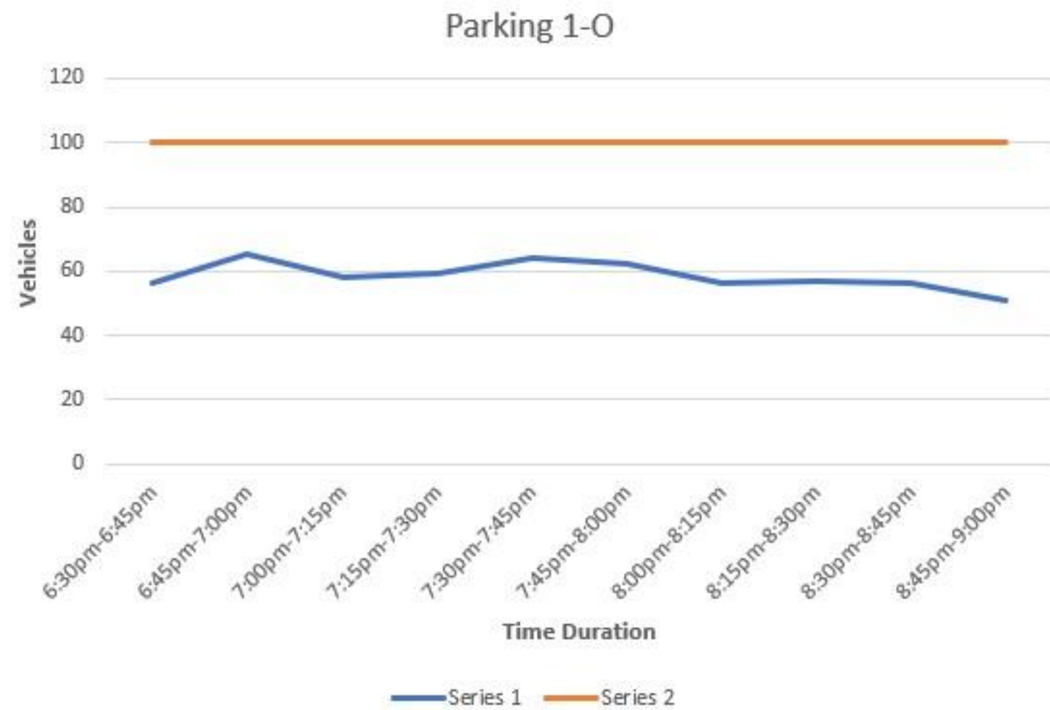


Figure 3.9: Saturday off-street 1-O Demand vs. Available Parking

Figure 3.10: Saturday off-street 1-I Demand vs. Available Parking

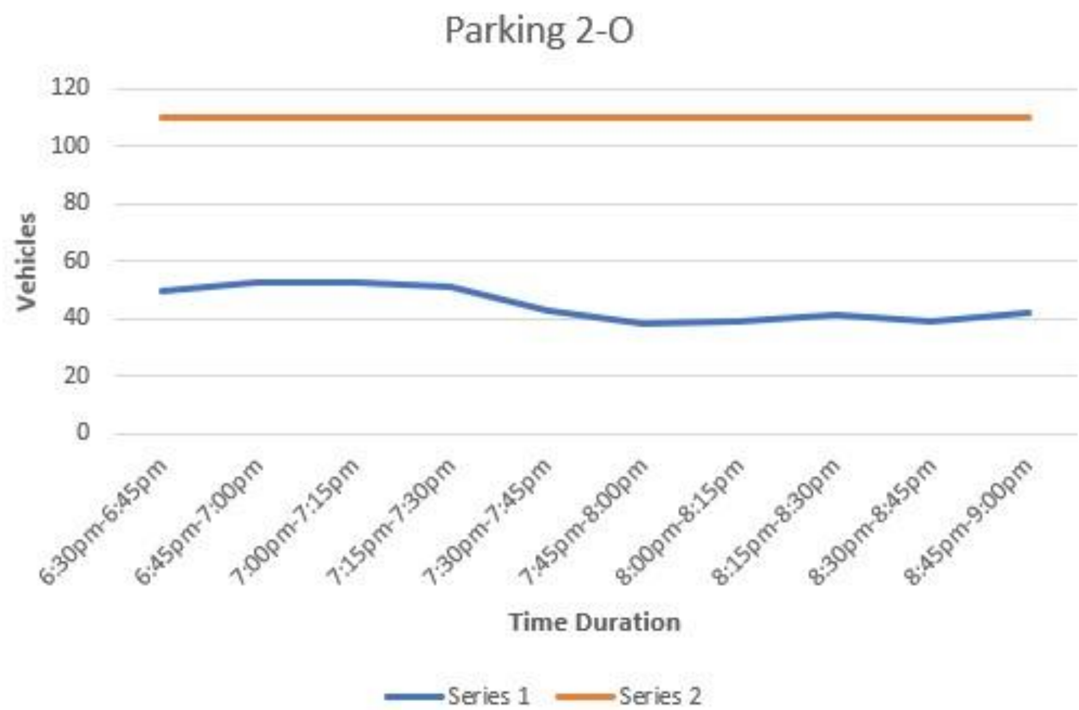


Figure 3.11: Saturday off-street 2-O Demand vs. Available Parking

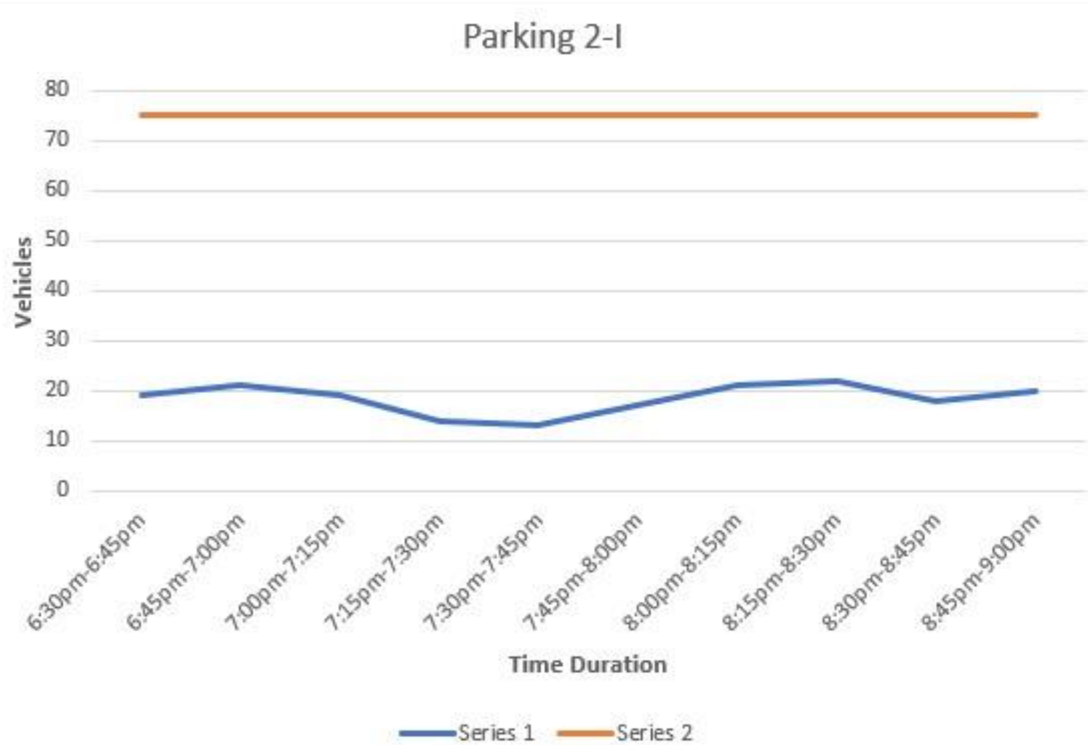


Figure 3.12: Saturday off-street 2-I Demand vs. Available Parking

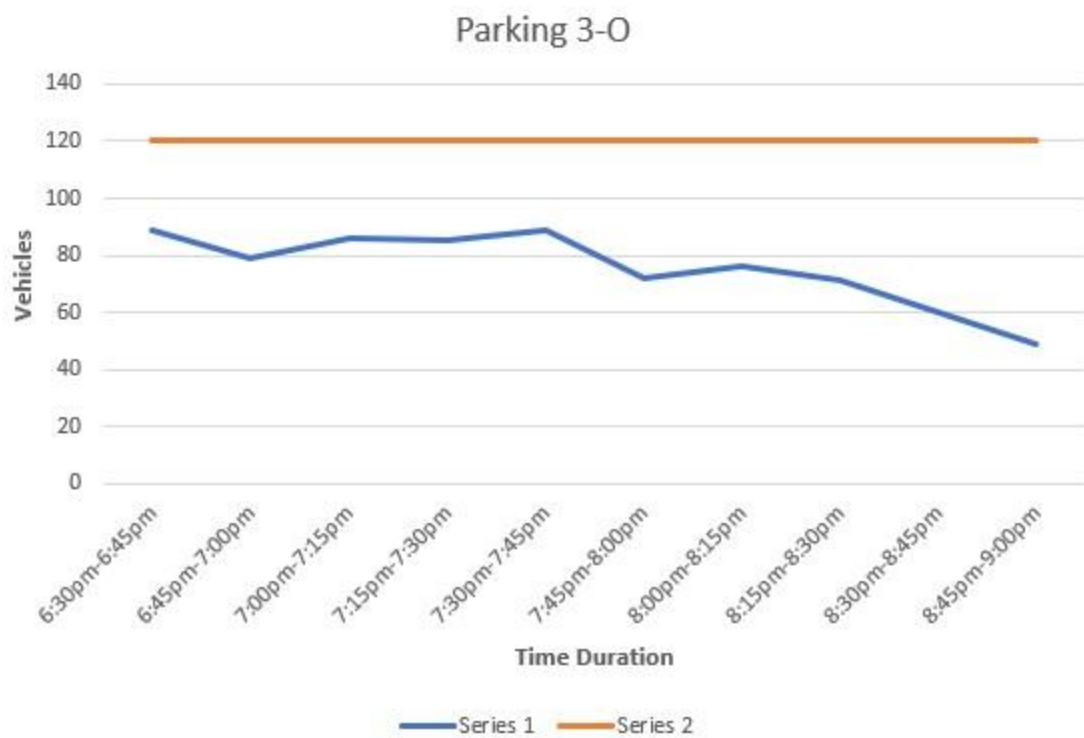


Figure 3.13: Saturday off-street 3-O Demand vs. Available Parking

Figure 3.14: Saturday off-street 3-I Demand vs. Available Parking

Figure 3.15: Saturday off-street 4-O Demand vs. Available Parking

Figure 3.16: Saturday off-street 4-I Demand vs. Available Parking

Thursday

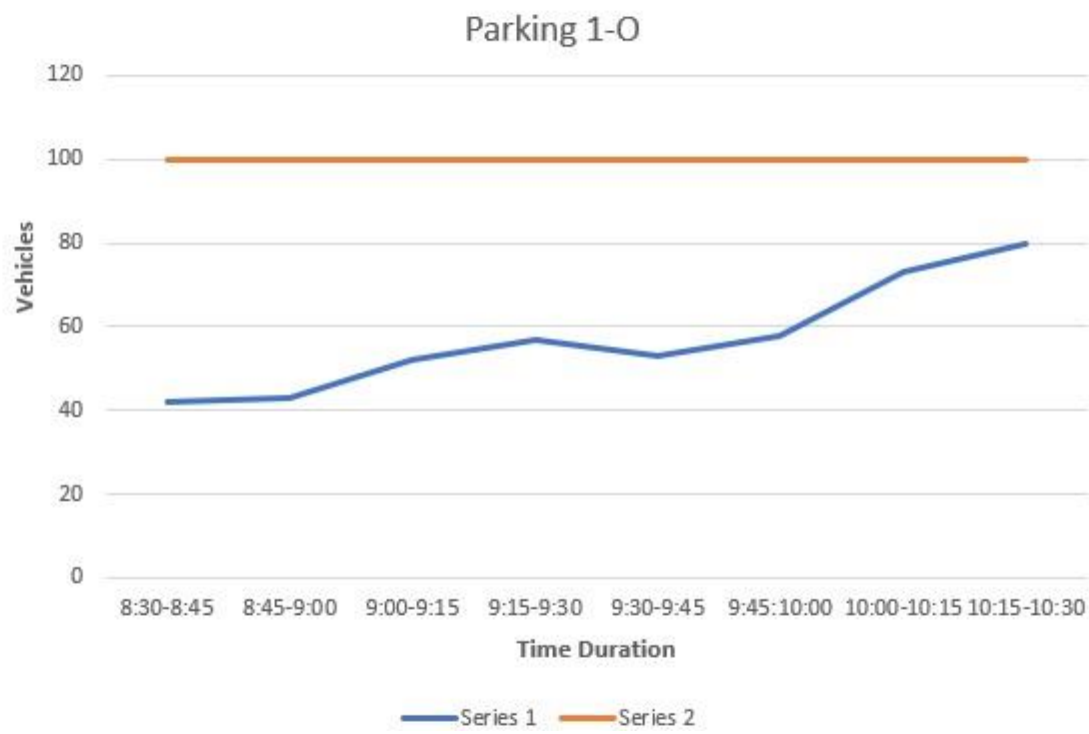


Figure 3.17: Thursday off-street 1-O Demand vs. Available Parking

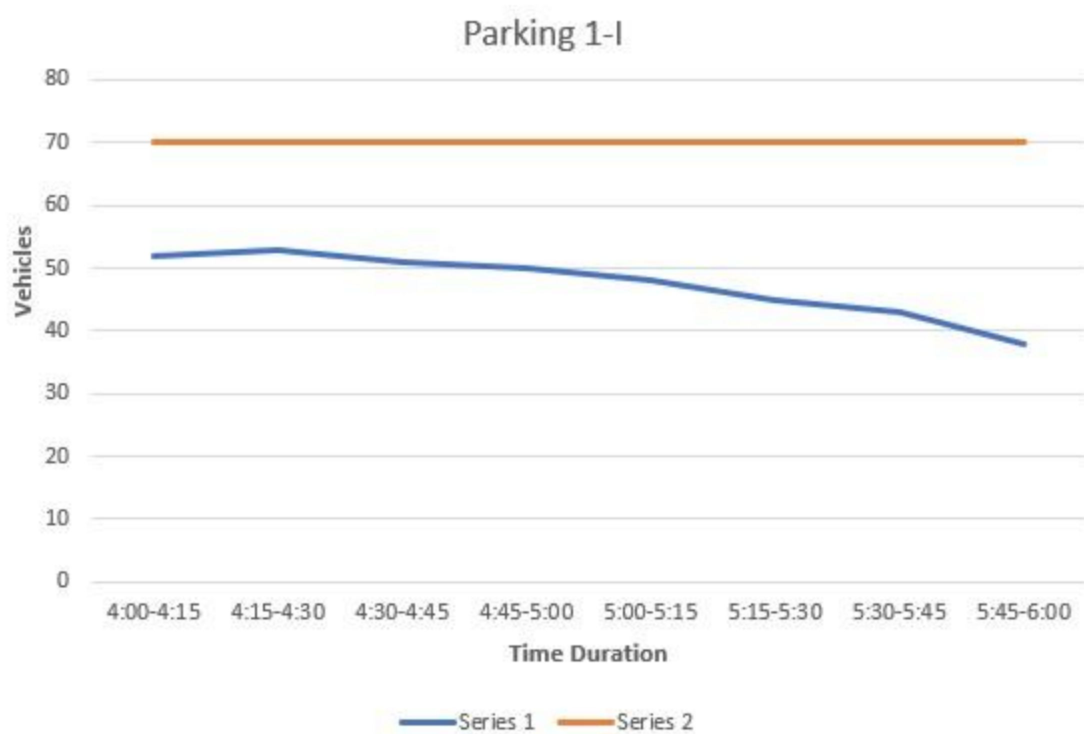


Figure 3.18: Thursday off-street 1-I Demand vs. Available Parking

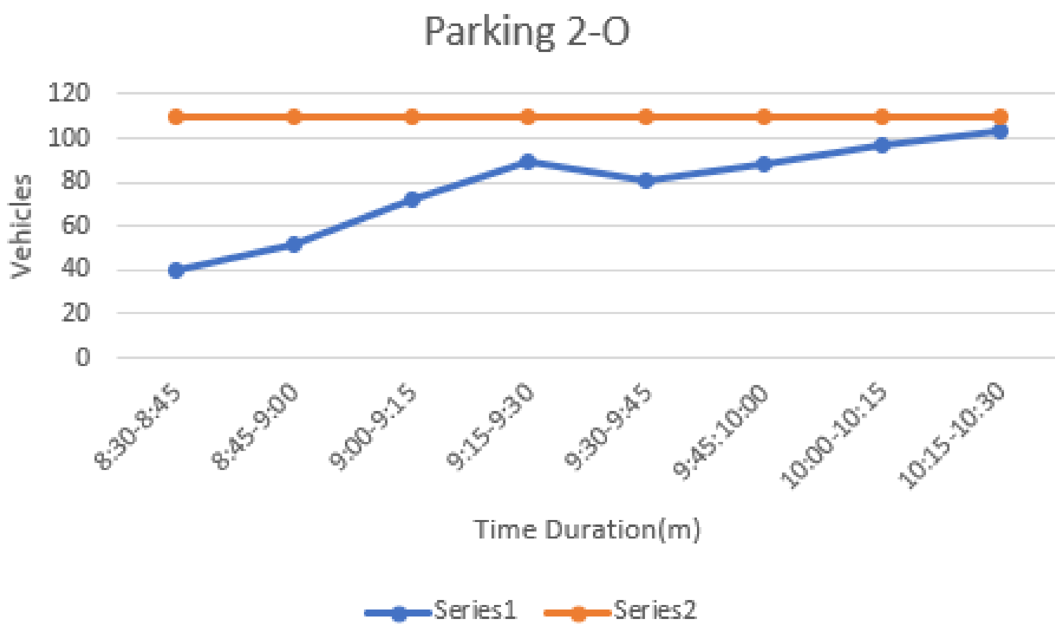


Figure 3.19: Thursday off-street 2-O Demand vs. Available Parking

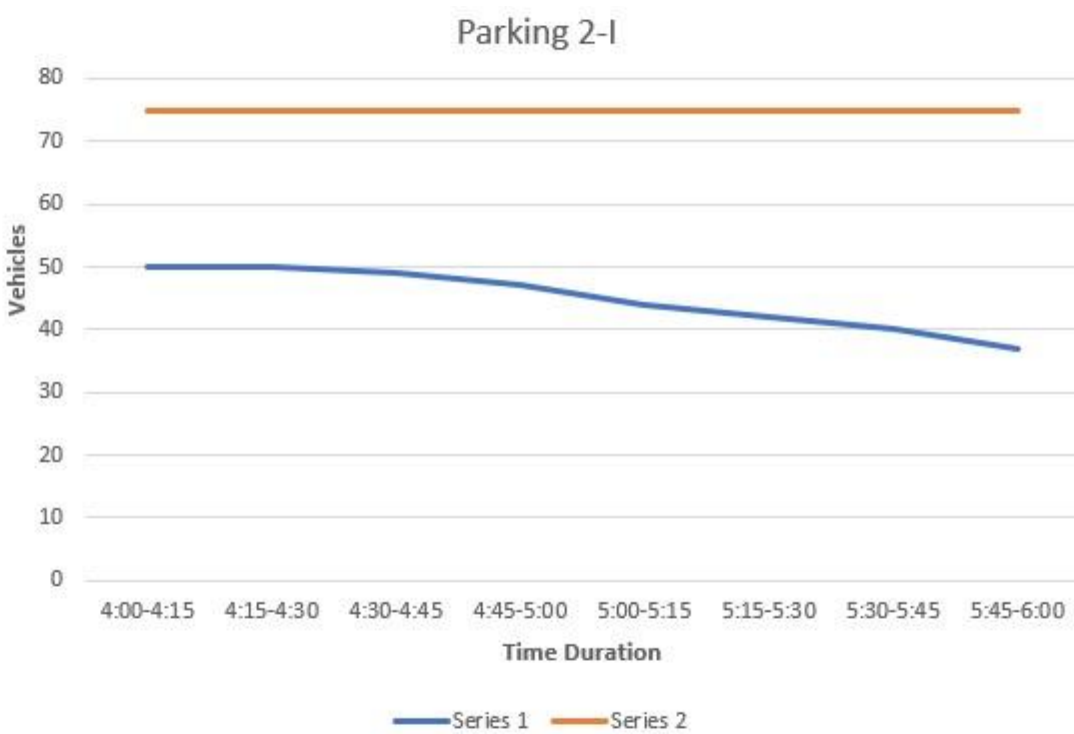


Figure 3.20: Thursday off-street 2-I Demand vs. Available Parking

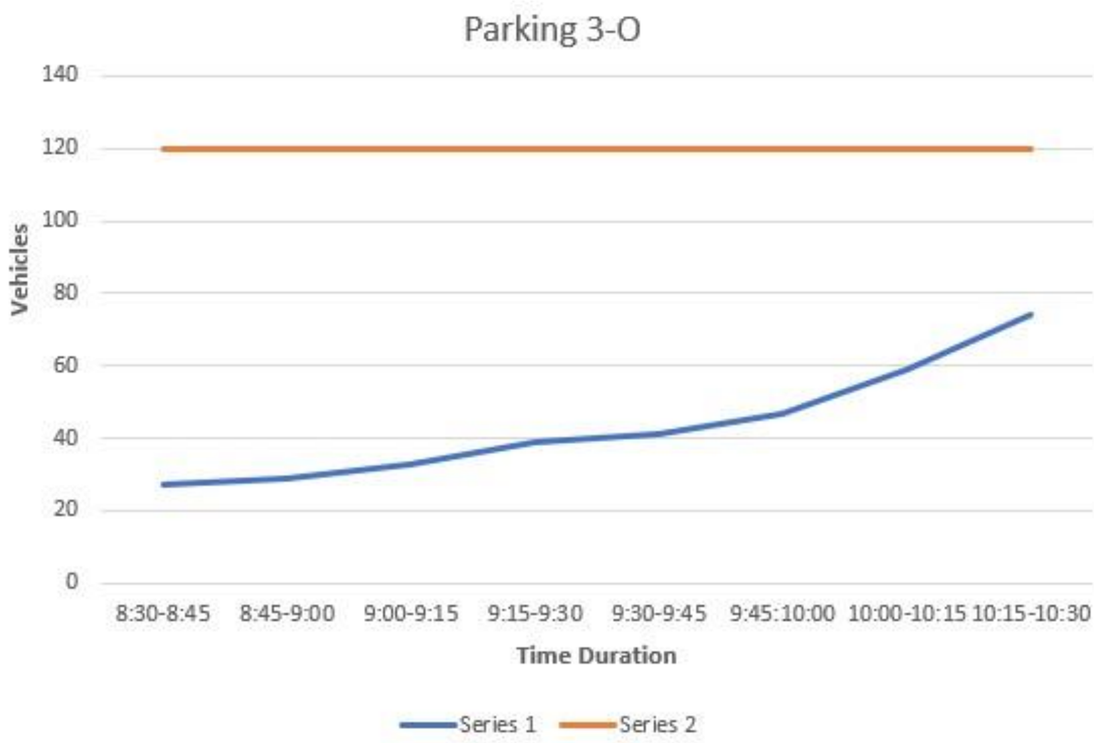


Figure 3.21: Thursday off-street 3-O Demand vs. Available Parking

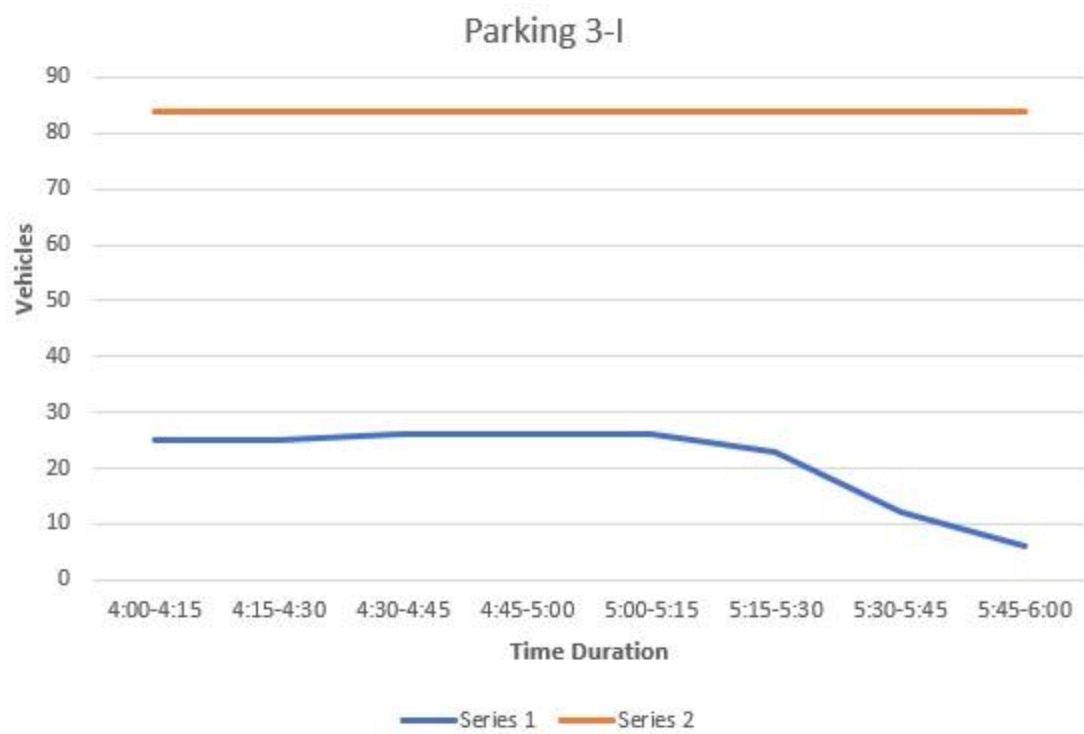


Figure 3.22: Thursday off-street 3-I Demand vs. Available Parking

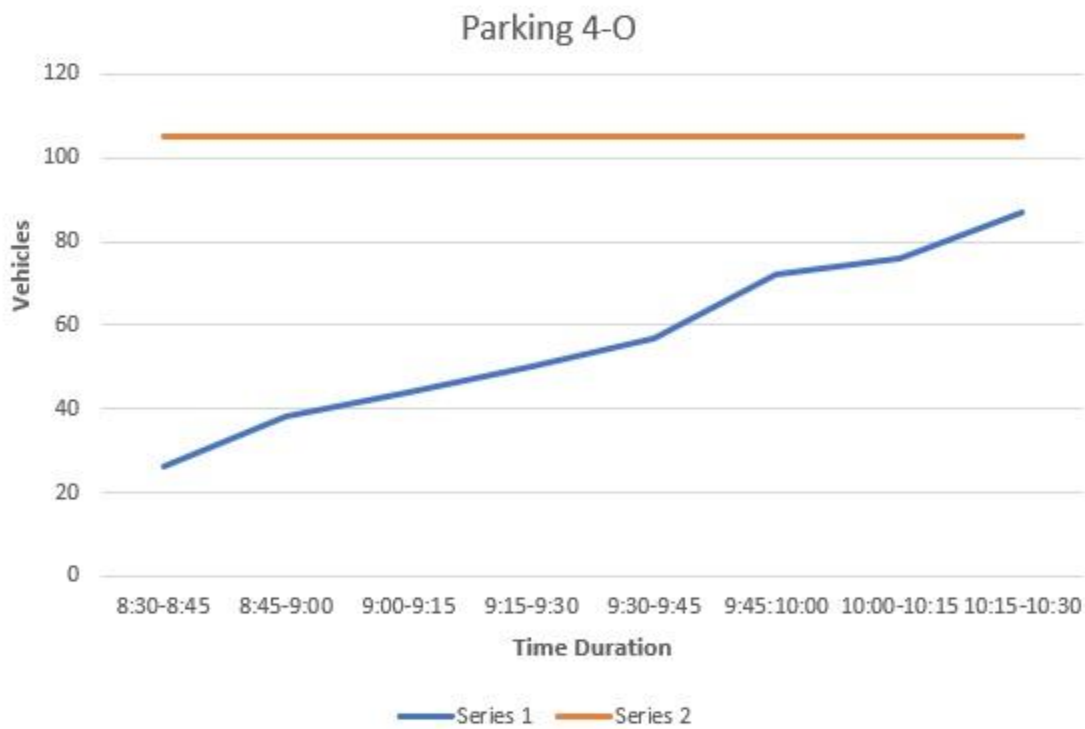


Figure 3.23: Thursday off-street 4-O Demand vs. Available Parking

Figure 3.24: Thursday off-street 4-I Demand vs. Available Parking

On-Street Parking

Saturday

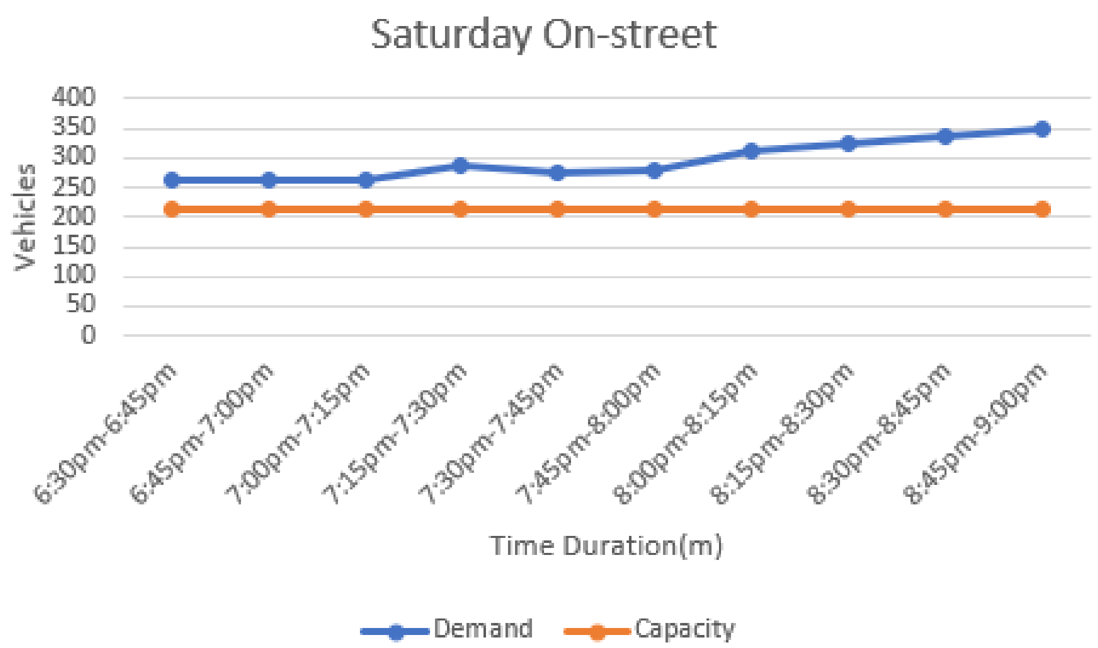


Figure 3.25: Saturday on-street Demand vs. Available Parking

Sunday

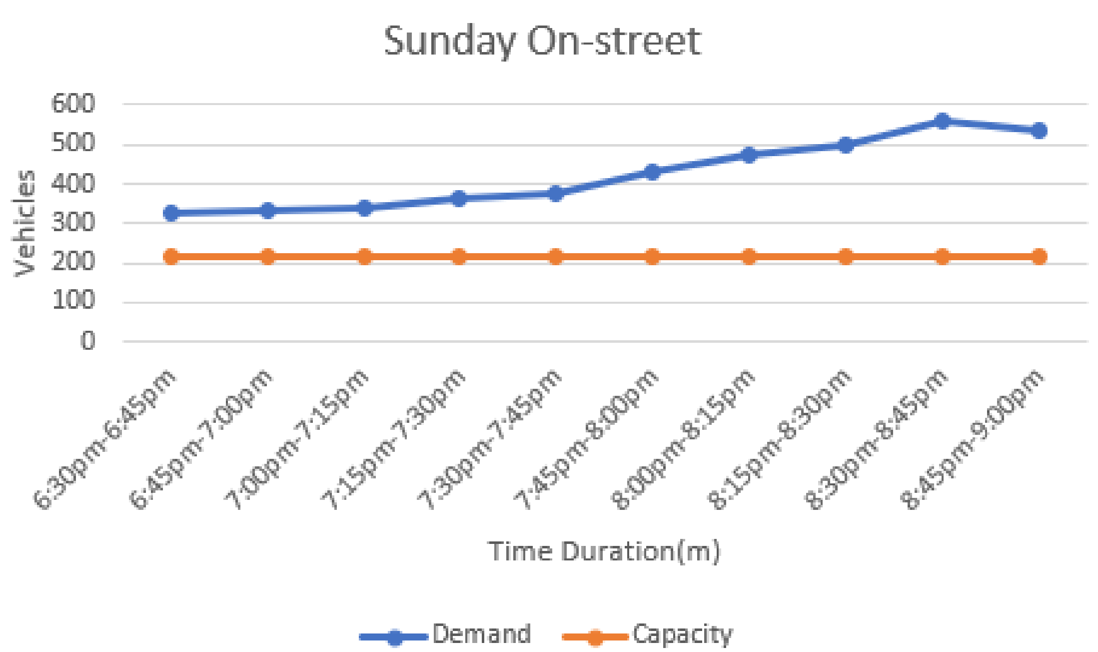


Figure 3.26: Sunday on-street Demand vs. Available Parking

Thursday

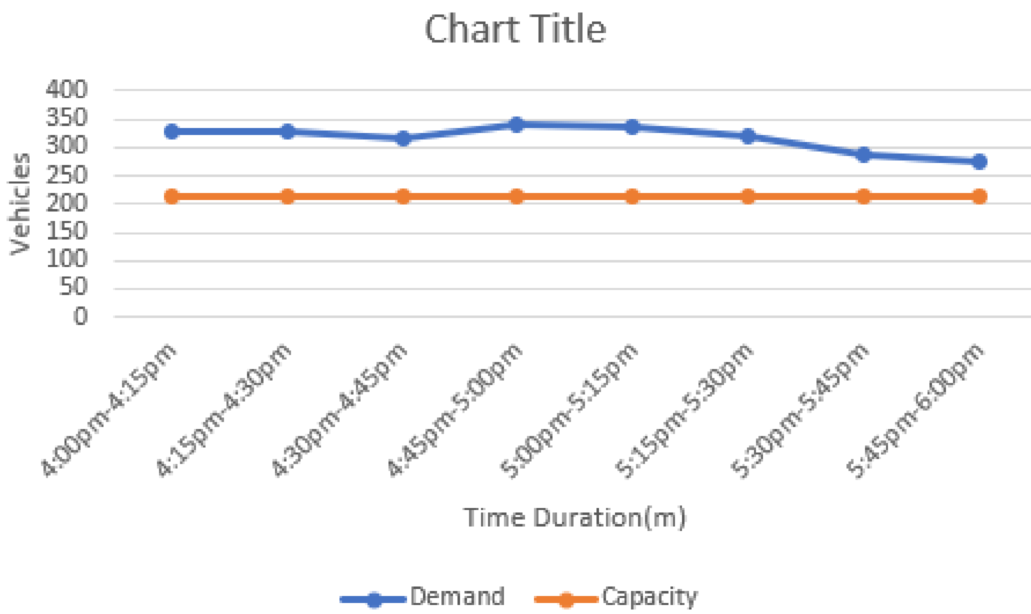


Figure 3.27: Thursday on-street Demand vs. Available Parking

3.2.3 Parking Turnout and Retention time data:

Turn Over Data is in the following order:

- Roundabout
- ON-street Parking

Spot (Roundabout)	Time					Time					
1	2	3	4	5	6	7	8	9	10	11	12
	17:30	18:00	18:30	19:00	19:30	17:30	18:00	18:30	19:00	19:30	Turn Over
1	591	591	591	6	6	1	1	1	1	1	2
2	598	252	25	3133	X	1	1	1	1	0	4
3	432	432	432	432	9323	1	1	1	1	1	2
4	5798	862	1379	126	3298	1	1	1	1	1	5

5	832	4545	736	23	238	1	1	1	1	0	5
6	574	961	85	543	5245	1	1	1	1	1	5
7	170	6643	360	432	864	1	1	1	1	1	5
8	6719	456	927	109	X	1	1	1	1	0	4
9	767	X	9900	314	578	1	0	1	1	1	4
10	243	113	889	715	293	1	1	1	1	1	5
11	393	393	723	376	238	1	1	1	1	1	4
12	957	589	978	752	374	1	1	1	1	1	5
13	193	875	8914	835	634	1	1	1	1	1	5
14	323	600	984	841	745	1	1	1	1	1	5
15	340	1	9911	440	539	1	1	1	1	1	5
16	904	X	745	765	632	1	0	1	1	1	4
17	183	183	196	956	345	1	1	1	1	1	4
18	371	11	671	33	467	1	1	1	1	1	5
19	307	8474	667	536	X	1	1	1	1	0	4
20	210	210	394	511	156	1	1	1	1	1	5
21	7361	213	8474	763	463	1	1	1	1	1	5
22	376	198	4379	905	863	1	1	1	1	1	5
23	3397	19	19	720	8734	1	1	1	1	1	4
24	47	X	393	8473	1245	1	0	1	1	1	4
25	945	1080	730	255	585	1	1	1	1	1	5
26	1733	248	242	906	634	1	1	1	1	1	5
27	8389	301	988	2420	2420	1	1	1	1	1	5
28	19	3397	243	243	X	1	1	1	1	0	4
29	685	839	226	3164	9234	1	1	1	1	1	5
30	X	X	74	5432	646	0	0	1	1	1	3
31	1723	126	204	843	7482	1	1	1	1	1	5

32	6345	236	367	2546	22	1	1	1	1	1	5
33	2133	2133	20	5723	X	1	1	1	1	0	4
34	410	410	3702	834	826	1	1	1	1	1	4
35	588	X	943	303	X	1	0	1	1	0	3
36	X	5	X	5204	234	0	1	0	1	1	3
37	X	76	X	920	X	0	1	0	1	0	2
38	517	517	517	214	434	1	1	1	1	1	3
39	2675	2675	39	798	344	1	1	1	1	1	5
40	9624	9624	X	504	233	1	1	0	1	1	4
41	460	X	X	644	7881	1	0	0	1	1	3
42	X	X	X	194	2388	0	0	0	1	1	2
43	X	X	7348	422	1661	0	0	1	1	1	3
44	881	685	620	620	X	1	1	1	1	0	3
45	24	4190	618	618	8882	1	1	1	1	1	4
46	686	836	836	521	966	1	1	1	1	1	4
47	733	X	686	836	3455	1	0	1	1	1	4
48	70	X	2796	993	993	1	0	1	1	1	3
49	748	X	350	102	X	1	0	1	1	0	3
50	616	616	602	728	5656	1	1	1	1	1	4
51	9187	690	169	828	3244	1	1	1	1	1	5
52	492	3057	3057	1874	423	1	1	1	1	1	4
53	7985	234	225	487	7444	1	1	1	1	1	5
54	467	867	378	9089	24	1	1	1	1	1	5
55	37	765	96	890	3562	1	1	1	1	1	5
56	2352	8746	356	857	345	1	1	1	1	1	5
57	246	954	4674	4865	245	1	1	1	1	1	5
58	6784	467	848	3546	657	1	1	1	1	1	5

59	4768	5878	6833	758	758	1	1	1	1	1	4
60	3657	4333	674	658	987	1	1	1	1	1	5
61	9789	7685	7999	356	356	1	1	1	1	1	4
62	6777	4673	245	2957	134	1	1	1	1	1	5
63	346	6346	546	235	4855	1	1	1	1	1	5
64	8754	245	74	476	7774	1	1	1	1	1	5
65	678	2467	743	245	8944	1	1	1	1	1	5
66	5767	3566	777	356	9622	1	1	1	1	1	5
67	256	857	356	846	2477	1	1	1	1	1	5
68	356	836	8788	678	573	1	1	1	1	1	5
69	6256	865	75	456	456	1	1	1	1	1	4
70	355	467	8748	8556	842	1	1	1	1	1	5
71	568	2655	56	244	2456	1	1	1	1	1	5
72	836	246	987	497	7842	1	1	1	1	1	5
73	423	4764	322	8435	2455	1	1	1	1	1	5
74	833	3567	445	776	5662	1	1	1	1	1	5
75	2674	566	456	345	879	1	1	1	1	1	5
76	657	657	355	8633	865	1	1	1	1	1	4
77	345	654	745	324	266	1	1	1	1	1	5
78	648	126	3771	256	625	1	1	1	1	1	5
79	964	357	468	2652	357	1	1	1	1	1	5
80	963	256	833	367	367	1	1	1	1	1	4
81	64	64	64	742	3563	1	1	1	1	1	3
82	467	9576	585	2677	289	1	1	1	1	1	5
83	356	868	226	245	1736	1	1	1	1	1	5
84	222	8332	46	46	647	1	1	1	1	1	4
85	2788	84	356	672	266	1	1	1	1	1	5

86	7546	467	467	2334	245	1	1	1	1	1	4
87	895	2626	2626	2626	256	1	1	1	1	1	3
88	763	653	687	345	176	1	1	1	1	1	5
89	653	233	874	563	986	1	1	1	1	1	5
90	235	752	7645	56	56	1	1	1	1	1	4
91	454	754	2658	831	8963	1	1	1	1	1	5
92	837	174	546	2457	864	1	1	1	1	1	5
93	26	26	856	324	3365	1	1	1	1	1	4
94	5677	5677	5677	3666	245	1	1	1	1	1	3
95	335	75	857	466	745	1	1	1	1	1	5
96	7426	6736	64	467	467	1	1	1	1	1	4
97	376	2765	7683	258	672	1	1	1	1	1	5
98	393	388	875	765	5676	1	1	1	1	1	5
99	24	24	24	2765	7562	1	1	1	1	1	3
101	1645	563	246	875	348	1	1	1	1	1	5
102	365	567	567	568	786	1	1	1	1	1	4
103	3471	164	65	65	7584	1	1	1	1	1	4
104	990	990	346	7456	8714	1	1	1	1	1	4
105	107	432	862	2745	143	1	1	1	1	1	5
106	635	3657	245	245	153	1	1	1	1	1	4
107	266	882	278	356	5246	1	1	1	1	1	5
108	4787	367	4167	676	567	1	1	1	1	1	5
109	868	2578	376	437	7888	1	1	1	1	1	5
110	875	7763	76	76	324	1	1	1	1	1	4
111	312	312	764	646	6346	1	1	1	1	1	5
112	456	8426	745	831	918	1	1	1	1	1	5
113	815	815	815	346	1645	1	1	1	1	1	3

114	632	623	858	256	6334	1	1	1	1	1	4
115	355	563	7211	215	314	1	1	1	1	1	5
116	834	436	356	784	227	1	1	1	1	1	5
117	133	133	658	765	765	1	1	1	1	1	4
118	256	846	846	321	8556	1	1	1	1	1	4
119	864	327	645	X	254	1	1	1	0	1	4
120	275	7586	897	897	X	1	1	1	1	0	3
Accumulation						114	108	114	118	108	516
occupancy						0.95	0.9	0.95	0.983333	0.9	4.3

Spot (Roundabout)	Time					Time					
1	2	3	4	5	6	7	8	9	10	11	12
	17:30	18:00	18:30	19:00	19:30	17:30	18:00	18:30	19:00	19:30	Turn Over
1	131	131	676	354	834	1	1	1	1	1	4
2	X	X	X	745	233	0	0	0	1	1	2
3	X	X	X	361	923	0	0	0	1	1	2
4	2486	602	602	391	643	1	1	1	1	1	4
5	1128	1128	361	X	X	1	1	1	0	0	2
6	X	X	2	988	X	0	0	1	1	0	2
7	596	98	98	X	343	1	1	1	0	1	3
8	X	X	X	X	X	0	0	0	0	0	0
9	993	993	993	993	993	1	1	1	1	1	1
10	X	X	X	X	797	0	0	0	0	1	1

11	680	X	620	X	X	1	0	1	0	0	2
12	X	X	5774	337	337	0	0	1	1	1	2
13	X	715	49	473	X	0	1	1	1	0	3
14	X	343	343	1706	1706	0	1	1	1	1	3
15	700	X	10	321	977	1	0	1	1	1	4
16	X	256	65	666	666	0	1	1	1	1	3
17	915	445	500	834	X	1	1	1	1	0	4
18	X	617	369	223	6776	0	1	1	1	1	4
19	X	X	39	X	X	0	0	1	0	0	1
20	474	X	560	560	X	1	0	1	1	0	2
21	396	485	282	436	X	1	1	1	1	0	4
22	4860	975	975	848	234	1	1	1	1	1	5
23	813	20	821	566	X	1	1	1	1	0	4
24	6981	6981	335	335	939	1	1	1	1	1	4
25	976	976	387	251	653	1	1	1	1	1	4
26	715	5179	496	496	9821	1	1	1	1	1	4
27	X	381	2569	490	199	0	1	1	1	1	4
28	X	890	247	585	233	0	1	1	1	1	4
29	X	278	X	7144	9821	0	1	0	1	1	3
30	683	X	X	X	X	1	0	0	0	0	1
31	X	X	743	156	643	0	0	1	1	1	3
32	X	X	X	756	453	0	0	0	1	1	2
33	345	345	755	X	X	1	1	1	0	0	2
34	82	7454	X	X	X	1	1	0	0	0	2
35	X	652	744	X	855	0	1	1	0	1	3
36	245	456	X	367	7975	1	1	0	1	1	4
37	468	X	X	784	367	1	0	0	1	1	3

38	226	226	476	744	X	1	1	1	1	0	3
39	X	X	566	155	788	0	0	1	1	1	3
40	363	466	X	478	997	1	1	0	1	1	4
41	908	464	X	889	X	1	1	0	1	0	3
42	X	X	845	745	714	0	0	1	1	1	3
43	89	89	435	X	X	1	1	1	1	0	2
44	X	648	X	X	243	0	1	0	0	1	2
45	X	X	7654	875	X	0	0	1	1	0	2
46	X	273	657	X	366	0	1	1	0	1	3
47	867	X	X	588	346	1	0	0	1	1	3
48	456	796	779	X	342	1	1	1	0	1	4
49	X	367	X	767	111	0	1	0	1	1	3
50	X	785	785	X	X	0	1	1	0	0	1
Accumulation						26	32	35	36	32	141
Occupancy						0.52	0.64	0.7	0.72	0.64	2.82

Spot (ON-street)	Time					Time					
1	2	3	4	5	6	7	8	9	10	11	12
	17:30	18:00	18:30	19:00	19:30	17:30	18:00	18:30	19:00	19:30	Turn Over
1	X	X	X	X	X	0	0	0	0	0	0
2	X	X	X	X	X	0	0	0	0	0	0
3	X	X	X	X	X	0	0	0	0	0	0
4	X	X	X	X	X	0	0	0	0	0	0
5	X	X	X	X	X	0	0	0	0	0	0
6	X	X	X	X	X	0	0	0	0	0	0
7	X	X	X	X	X	0	0	0	0	0	0
8	X	X	X	X	X	0	0	0	0	0	0
9	X	X	X	X	X	0	0	0	0	0	0
10	X	X	X	X	X	0	0	0	0	0	0
11	296	388	880	9291	61	1	1	1	1	1	5
12	X	X	X	X	X	0	0	0	0	0	0
13	X	X	X	X	X	0	0	0	0	0	0
14	X	X	X	X	X	0	0	0	0	0	0
15	X	X	X	X	X	0	0	0	0	0	0
16	X	X	X	X	X	0	0	0	0	0	0
17	X	X	X	X	X	0	0	0	0	0	0
18	X	256	814	403	403	0	1	1	1	1	3
19	X	3240	173	23	833	0	1	1	1	1	0
20	X	9530	9530	23	833	0	1	1	1	1	4
21	997	776	984	475	X	1	1	1	1	0	0
22	X	32	531	950	992	0	1	1	1	1	4
23	5657	5657	1113	356	245	1	1	1	1	1	0
24	2131	X	65	5052	50	1	0	1	1	1	4
25	X	87	132	617	529	0	1	1	1	1	4
26	X	5866	5866	X	732	0	1	1	0	1	2
27	X	X	3284	3284	2130	0	0	1	1	1	2
28	X	X	9930	984	32	0	0	1	1	1	3
29	X	X	808	808	726	0	0	1	1	1	2
30	X	X	32	32	984	0	0	1	1	1	2

31	X	X	X	199	99	0	0	0	1	1	2
32	X	X	X	688	688	0	0	0	1	1	1
33	X	X	X	5838	5838	0	0	0	1	1	1
34	X	X	X	X	X	0	0	0	0	0	0
35	X	X	X	X	X	0	0	0	0	0	0
36	X	X	X	X	X	0	0	0	0	0	0
37	X	X	X	X	X	0	0	0	0	0	0
38	X	X	866	866	X	0	0	1	1	0	1
39	X	X	X	X	X	0	0	0	0	0	0
40	X	X	X	X	X	0	0	0	0	0	0
41	X	X	790	790	790	0	0	1	1	1	1
42	X	X	X	636	X	0	0	0	1	0	1
43	X	X	X	833	X	0	0	0	1	0	1
44	X	X	X	140	X	0	0	0	1	0	1
45	X	X	X	446	X	0	0	0	1	0	1
46	X	X	141	141	X	0	0	1	1	0	1
47	X	X	X	X	X	0	0	0	0	0	0
48	X	X	X	X	X	0	0	0	0	0	0
49	X	X	X	X	X	0	0	0	0	0	0
50	X	X	X	X	X	0	0	0	0	0	0
Accumulation						4	9	17	23	17	46
occupancy						0.08	0.18	0.34	0.46	0.34	0.92

Spot (ON-street)	Time					Time					
1	2	3	4	5	6	7	8	9	10	11	12
	17:30	18:00	18:30	19:00	19:30	17:30	18:00	18:30	19:00	19:30	Turn Over
1	539	X	X	1670	X	1	0	0	1	0	2
2	X	X	X	7417	7417	0	0	0	1	1	1
3	X	X	X	X	X	0	0	0	0	0	0
4	2111	2111	2111	2111	2111	1	1	1	1	1	1

5	X	X	X	X	X	0	0	0	0	0	0
6	X	X	X	X	X	0	0	0	0	0	0
7	204	X	X	X	955	1	0	0	0	1	2
8	X	X	X	X	X	0	0	0	0	0	0
9	3264	X	X	X	X	1	0	0	0	0	1
10	X	X	X	X	X	0	0	0	0	0	0
11	X	X	X	X	X	0	0	0	0	0	0
12	X	X	X	X	X	0	0	0	0	0	0
13	X	X	X	7884	X	0	0	0	1	0	1
14	X	X	X	4651	4651	0	0	0	1	1	1
15	802	802	119	119	X	1	1	1	1	0	2
16	876	X	323	623	623	1	0	1	1	1	3
17	844	844	886	X	X	1	1	1	0	0	1
18	91	91	91	X	X	1	1	1	0	0	1
19	X	X	X	X	X	0	0	0	0	0	0
20	X	X	X	X	X	0	0	0	0	0	0
21	X	X	X	X	X	0	0	0	0	0	0
22	X	X	X	X	X	0	0	0	0	0	0
23	X	X	X	X	X	0	0	0	0	0	0
24	X	X	X	X	X	0	0	0	0	0	0
25	X	X	X	X	X	0	0	0	0	0	0
26	430	430	X	900	X	1	1	0	1	0	2
27	7585	7585	7585	7585	7585	1	1	1	1	1	1
28	X	X	X	X	X	0	0	0	0	0	0
29	X	X	X	X	X	0	0	0	0	0	0
30	X	X	X	X	X	0	0	0	0	0	0
31	294	294	294	294	294	1	1	1	1	1	1

32	942	942	X	X	X	1	1	0	0	0	1
33	X	X	X	X	X	0	0	0	0	0	0
34	X	X	X	X	X	0	0	0	0	0	0
35	X	X	X	X	X	0	0	0	0	0	0
36	X	X	X	706	706	0	0	0	1	1	1
37	X	X	X	X	421	0	0	0	0	1	1
38	517	X	X	567	124	1	0	0	1	1	3
39	604	604	604	604	604	1	1	1	1	1	1
40	961	913	3525	3525	3525	1	1	1	1	1	3
41	588	588	588	588	588	1	1	1	1	1	1
42	622	622	622	622	622	1	1	1	1	1	1
43	385	385	X	X	X	1	1	0	0	0	1
44	524	524	524	X	X	1	1	1	0	0	1
45	6178	6178	6178	6178	6178	1	1	1	1	1	1
46	77	77	77	77	77	1	1	1	1	1	1
47	509	509	509	509	509	1	1	1	1	1	1
48	426	426	426	426	426	1	1	1	1	1	1
49	448	448	448	448	448	1	1	1	1	1	1
50	X	X	X	X	X	0	0	0	0	0	0
Accumulation						24	19	17	21	19	39
occupancy						0.48	0.38	0.34	0.42	0.38	0.78

3.2.4 Survey forms:

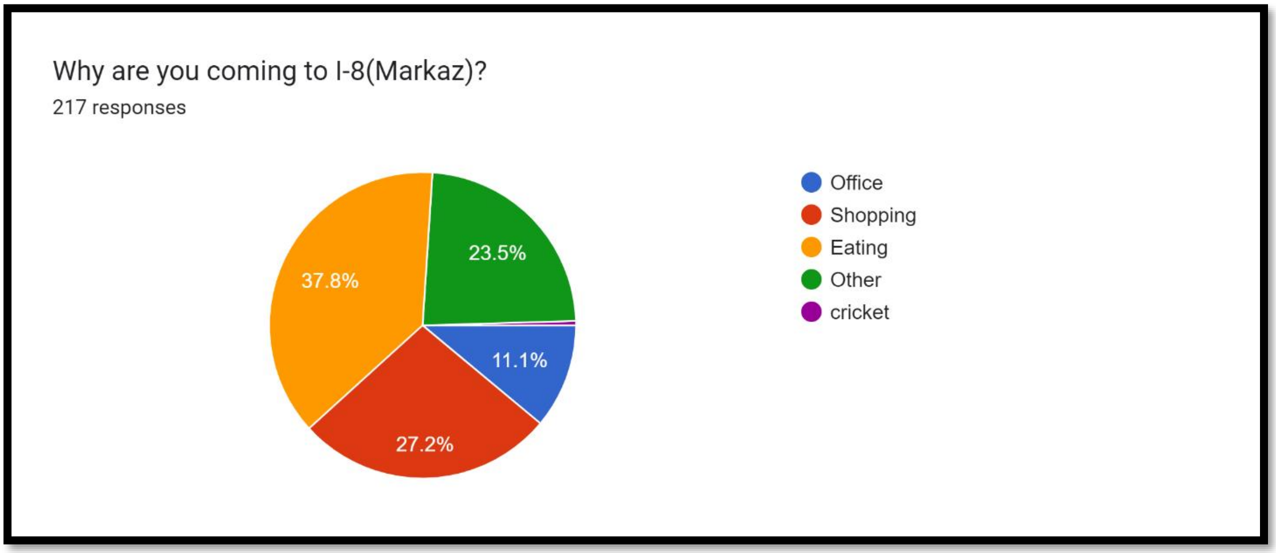


Figure 3.28: Survey Results

3.2.5 Advantages of this methodology

- Provides a direct count of the number of parking spots available and occupied in the specific area of interest.
- Allows for tracking individual parking spots and the duration of their occupancy.
- Can provide insight into turnover rates and the availability of parking over time.

3.2.6 Disadvantages of this methodology

- Time-consuming and labor-intensive, as it requires manual counting and tracking of individual parking spots.
- Limited to a specific time period, which may not be representative of overall parking demand.
- Potential for human error in recording and tracking data.
- May not capture data on parked vehicles without license plates or parked in illegal locations.

CHAPTER 4

4. ANALYSIS and RESULTS

4.1 Parking Data Analysis

Here are the problems that we have identified in our research regarding parking in I-8 Markaz, explained in detail:

1. Irregular Parking by Drivers:

One of the major problems that we have identified in our research is that drivers in I-8 Markaz tend to park their vehicles at irregular places that are not designated for parking, instead of using off-street parking options that are available. This behavior contributes to congestion on the streets and can create safety hazards for pedestrians and other drivers.

Additionally, almost 60% of the Off-street Parking is free. There may be several reasons why drivers choose to park in irregular places. For example, they may feel that on-street parking is more convenient or accessible than off-street options, or they may be unaware of the available off-street parking facilities. Additionally, parking on the street may be free or less expensive than using off-street options, which can be a motivating factor for some drivers.

2. Insufficient On-Street Parking Capacity:

Another significant problem that we have identified is insufficient parking capacity on the street. This means that there are not enough parking spots available for the number of vehicles that need to park on the street. As a result, drivers may park in areas that are not designated for parking, which can cause congestion and safety hazards.

3. Office People Use On-Street Instead of Off-Street:

We have also found that office workers tend to use on-street parking instead of off-street options. This can lead to a shortage of parking spaces on the street and contributes to traffic congestion as drivers circle around looking for available parking spots. It may also cause difficulties for residents who need to park on the street for long periods of time, such as overnight.

4. Traffic Congestion:

Another problem that we have identified is traffic congestion. The parking problems in I-8 Markaz contribute to this, as drivers may circle around looking for parking spots or park in areas that obstruct traffic flow. This can result in slower travel times, increased fuel consumption, and air pollution, as well as safety hazards for pedestrians and drivers.

5. Illegal Parking:

Illegal parking refers to the act of parking a vehicle in a location where it is prohibited by law or municipal regulations. This can include parking in no-parking zones, on sidewalks, or in areas reserved for emergency vehicles, loading and unloading, or disabled persons.

Illegal parking can cause inconvenience to pedestrians, block traffic, and create safety hazards. It can also result in fines, towing, and impoundment of the vehicle.

Some common examples of illegal parking include parking in fire lanes, parking too close to intersections or crosswalks, parking in bike lanes or bus stops, and parking in front of driveways or entrances.

Parking in areas reserved for people with disabilities without the appropriate permit is also considered illegal parking.

In some areas, parking on certain days or during specific hours may be prohibited, and failure to comply with these regulations can result in fines or penalties.

It's important to be aware of parking regulations in your area and to park in designated areas to avoid causing inconvenience, safety hazards, or legal consequences.

6. Inefficient Parking management:

Inefficient parking management refers to a lack of proper planning, organization, and enforcement of parking policies and regulations. This can result in a range of problems such as congestion, illegal parking, and reduced accessibility to parking spaces.

Examples of inefficient parking management include inadequate signage, insufficient parking capacity, poor layout or design of parking facilities, lack of maintenance, and inadequate parking enforcement.

Inefficient parking management can lead to frustration and inconvenience for drivers, as well as safety hazards for pedestrians and other road users. It can also contribute to traffic congestion and air pollution, as drivers may circle around searching for parking spaces.

Effective parking management requires careful planning, regular maintenance, and consistent enforcement of regulations. This can include the use of technology, such as sensors or mobile apps, to monitor and manage parking spaces, as well as the implementation of pricing policies to encourage turnover and reduce demand. By improving parking management, cities and municipalities can reduce traffic congestion, enhance safety, and improve accessibility for all road users.

7. Inadequate public transportation:

The lack of adequate public transportation in I-8 Markaz, Islamabad can lead to parking issues, as individuals may resort to using private vehicles instead of public transportation due to the inconvenience and unreliability of the existing public transportation options.

This can result in a higher demand for parking spaces in the commercial center, leading to congestion and competition for available parking spots. Limited parking availability can further exacerbate the parking issues, as drivers may park their vehicles illegally or in unauthorized areas, such as no-parking zones, sidewalks, or in front of entrances, creating safety hazards for pedestrians and other road users.

Moreover, the increased use of private vehicles due to inadequate public transportation can contribute to traffic congestion, air pollution, and carbon emissions, further exacerbating the negative effects of the parking issues.

To address the parking issues caused by inadequate public transportation in I-8 Markaz, Islamabad, improving the public transportation system can be a viable solution.

Developing a reliable, efficient, and accessible public transportation system, such as a metro or light rail, can encourage people to use public transportation instead of private vehicles, reducing the demand for parking spaces in the commercial center. Additionally, the implementation of smart parking solutions, such as digital parking meters or parking guidance systems, can help optimize the use of available parking spaces and reduce congestion.

8. Double Parking:

Double parking issues in I-8 Markaz, Islamabad refer to the practice of parking a vehicle beside another parked vehicle that is already occupying a parking spot or in the middle of the road, resulting in reduced accessibility and safety hazards for pedestrians and other road users.

In I-8 Markaz, double parking is a common issue due to the limited parking availability and high demand for parking spaces. Drivers may park their vehicles beside other parked vehicles, blocking them in and making it difficult for them to exit their parking spot. This can cause inconvenience for other drivers who need to park their vehicles or for the blocked-in drivers who may need to wait until the double-parked vehicle moves before they can leave.

Furthermore, double parking can also create safety hazards, as it can obstruct the view of other drivers or pedestrians, leading to accidents and injuries. It can also impede the flow of traffic, causing congestion and delays.

To address the double-parking issues in I-8 Markaz, several solutions can be implemented. Increasing the parking capacity and optimizing the use of existing parking spaces can help reduce the demand for double parking. Additionally, enforcing parking regulations and penalizing drivers who double park can deter the practice and encourage compliance with parking rules. Improving public transportation options in the area can also encourage people to use public transportation instead of private vehicles, reducing the demand for parking spaces and the occurrence of double parking.

9. Poorly Designed Parking Areas:

Poorly designed parking areas in I-8 Markaz, Islamabad refer to parking lots or areas that are not designed or configured properly to accommodate the number of vehicles that require parking or do not meet the needs of the users.

In I-8 Markaz, poorly designed parking areas can cause several issues. For example, insufficient parking capacity can result in a shortage of parking spaces, leading to drivers parking their vehicles in unauthorized areas or blocking entrances, creating safety hazards and impeding the flow of traffic. Additionally, poorly marked parking spaces, unclear signage, or inadequate lighting can make it difficult for drivers to navigate the parking lot, increasing the risk of accidents or collisions.

Furthermore, parking areas that are not accessible to individuals with disabilities or lack proper facilities, such as pedestrian walkways, bike racks, or charging stations, can limit the accessibility and convenience of the parking area.

To address the issues caused by poorly designed parking areas in I-8 Markaz, several solutions can be implemented. Designing parking areas to meet the needs of the users, such as providing adequate parking spaces, clear signage, and lighting, can improve accessibility and safety. Providing accessible parking spaces and facilities for individuals with disabilities can also enhance the inclusivity of the parking area. Moreover, implementing smart parking solutions, such as digital parking meters or parking guidance systems, can optimize the use of available parking spaces and reduce congestion. Finally, conducting regular maintenance and upkeep of the parking areas can ensure that they remain safe and functional for users.

10. Environmental Impacts:

Environmental impact due to parking issues in I-8 Markaz, Islamabad refers to the negative effects on the environment caused by the high volume of vehicles in the area and the associated parking issues.

The parking issues in I-8 Markaz can lead to environmental degradation in several ways. For example, the increased use of private vehicles due to inadequate public transportation and limited parking availability can contribute to traffic congestion, resulting in increased fuel consumption and emissions of harmful pollutants such as carbon dioxide, nitrogen oxides, and particulate matter. These pollutants can negatively affect air quality, leading to health issues for residents and workers in the area.

Additionally, parking issues can lead to the degradation of natural habitats and biodiversity in the area. For example, the construction of parking structures or the conversion of green spaces into parking lots can destroy habitats for wildlife and reduce the quality of the local environment.

To mitigate the environmental impact of parking issues in I-8 Markaz, several solutions can be implemented. One solution is to improve public transportation options in the area, such as developing a reliable, efficient, and accessible public transportation system, which can encourage people to use public transportation instead of private vehicles, reducing the number of vehicles on the road and associated emissions. Implementing green infrastructure solutions, such as rain gardens or green roofs, can help to mitigate the negative impacts of parking lots on natural habitats and the local environment. Finally, promoting sustainable transportation options, such as cycling or walking, can also help reduce the environmental impact of parking issues.

Overall, these parking problems can have significant negative impacts on the quality of life for residents, workers, and visitors in I-8 Markaz. They can contribute to safety hazards, traffic congestion, and air pollution, and make it more difficult for people to access businesses and services in the area. Addressing these problems through policy and infrastructure changes could improve the live ability and sustainability of the area.

4.2 Mitigations

Mitigations which can be effective to reduce the parking problems:

There are several possible solutions that could be implemented using Intelligent Transportation Systems (ITS) to address the parking problems in I-8 Markaz. But we are combining following four systems to make Smart Parking in I-8 Markaz:

4.2.1 Dynamic Message Signs:

Installing dynamic message signs at strategic locations in the area can help guide drivers to available parking spots. The signs can display real-time information about parking availability and direct drivers to open spaces, which can reduce the time drivers spend looking for parking and alleviate congestion on the streets. Dynamic message signs (DMS) can be a useful tool to help mitigate parking issues in several ways:

1. **Real-time information:**

DMS can display real-time information about parking availability in specific areas or garages, helping drivers quickly find available parking spots. This can reduce traffic congestion caused by drivers circling around in search of parking, ultimately making the parking process more efficient and reducing the time it takes to find a spot.

2. **Parking guidance:**

DMS can provide guidance on where to park in a specific area, reducing confusion and increasing efficiency in parking. This can help prevent drivers from parking in prohibited areas, such as loading zones, fire lanes, or in front of fire hydrants.

3. **Directing traffic:**

DMS can be used to direct traffic to available parking spaces. For example, if one parking garage is full, DMS can direct drivers to another nearby garage with available parking spots. This can help prevent traffic congestion caused by drivers all trying to park in the same location.

4. **Emergency notifications:**

DMS can also be used to notify drivers of any emergencies or special events that may impact parking. This can include road closures, detours, or parking restrictions during certain events.

Overall, dynamic message signs can be a valuable tool to help mitigate parking issues by providing real-time information, parking guidance, directing traffic, and notifying drivers of emergencies or special events.

4.2.2 Smart Parking Meters:

Replacing traditional parking meters with smart meters can help manage parking more efficiently. Smart meters can accept a variety of payment methods, such as credit cards and mobile payments, and can provide real-time data on parking availability. This information can be shared with drivers through mobile apps or dynamic message signs, making it easier for them to find parking.

Smart parking meters can be effective in mitigating parking issues by:

1. **Reducing illegal parking:**
   Smart parking meters can detect when a vehicle has overstayed its allotted time, and alert parking enforcement officers to issue a citation. This can discourage illegal parking and free up spaces for other drivers.

2. **Efficient use of parking spaces:**
   Smart parking meters can provide real-time information on parking availability, helping drivers quickly locate an available spot. This can reduce congestion caused by drivers circling around in search of a parking spot.

3. **Easy payment options:**
   Smart parking meters can accept various payment methods, including credit cards and mobile payments, making it more convenient for drivers to pay for parking.

4. **Predictive analytics:**
   Smart parking meters can collect data on parking usage, allowing city planners to analyze and optimize parking management strategies. This can help cities better allocate parking resources and reduce congestion.

Overall, smart parking meters can be an effective tool in mitigating parking issues by reducing illegal parking, optimizing parking space usage, providing easy payment options, and collecting data for analysis and optimization.

4.2.3 Parking Loop Detectors:

Installing a parking loop detector can provide drivers with information about available parking spaces.

Parking loop detectors are a technology that can be effective in reducing parking issues by:

1. **Real-time occupancy monitoring:**
   Parking loop detectors can detect when a vehicle enters or leaves a parking space, allowing for real-time monitoring of parking space occupancy. This information can be used to direct drivers to available spaces, reducing congestion and making parking more efficient.

2. **Enforcement:**
   Parking loop detectors can be used to enforce parking regulations by alerting parking enforcement officers when a vehicle has overstayed its allotted time. This can help discourage illegal parking and free up spaces for other drivers.

3. **Optimization:**
   Parking loop detectors can collect data on parking space usage, allowing city planners to analyze and optimize parking management strategies. This can help cities better allocate parking resources and reduce congestion.

4. **Cost-effective:**
   Parking loop detectors are a cost-effective technology compared to other parking management solutions, such as building new parking structures or implementing on-street parking meters.

Overall, parking loop detectors can be an effective tool in reducing parking issues by providing real-time occupancy monitoring, enforcement of parking regulations, optimization of parking management strategies, and cost-effectiveness.

4.2.4 License Plate Recognition or Sensor Boards containing Arduino:

License plate recognition technology can be used to monitor parking spaces in real-time, alerting parking enforcement officers when a vehicle has overstayed its allotted time or parked illegally. This can improve the efficiency of parking enforcement, reduce the number of illegally parked vehicles, and alleviate congestion on the streets.

License Plate Recognition (LPR) and Sensor Boards containing Arduino can be helpful in mitigating parking issues by:

1. **Real-time monitoring:**
   LPR and Sensor Boards containing Arduino can provide real-time monitoring of parking space occupancy, allowing drivers to quickly locate available spaces and reducing congestion caused by drivers circling around in search of a parking spot.

2. **Enforcement:**
   LPR and Sensor Boards containing Arduino can be used to enforce parking regulations by detecting when a vehicle has overstayed its allotted time and alerting parking enforcement officers to issue a citation. This can discourage illegal parking and free up spaces for other drivers.

3. **Improved parking management:**
   LPR and Sensor Boards containing Arduino can collect data on parking usage, allowing city planners to analyze and optimize parking management strategies. This can help cities better allocate parking resources and reduce congestion.

4. **Cost-effective:**
LPR and Sensor Boards containing Arduino are a cost-effective technology compared to other parking management solutions, such as building new parking structures or implementing on-street parking meters.

Overall, License Plate Recognition and Sensor Boards containing Arduino can be helpful in mitigating parking issues by providing real-time monitoring, enforcement of parking regulations, improved parking management, and cost-effectiveness.

Overall, implementing these solutions using ITS can help manage parking more efficiently and reduce traffic congestion in I-8 Markaz. It can also provide a more convenient and safer parking experience for drivers, which can contribute to the overall livability and sustainability of the area.

4.2.5 Smart Parking System:

A smart parking system is a technology-driven parking management solution that utilizes various sensors, cameras, and software to optimize parking space utilization, reduce traffic congestion, and improve overall parking management.

Smart parking systems can provide real-time information on parking availability, directing drivers to available parking spaces, and providing a more efficient parking experience.

The plan is to install loop detectors and Dynamic Message signs at all ON and Off-street parking areas. The loop detectors will monitor parking spaces and only allow vehicles to park if a space is available. The detectors will be connected to sensors, such as Arduino Sensor boards or cameras that can read license plates, to track occupancy. The Dynamic Message signs will also display real-time information about available parking spaces. When a vehicle leaves a parking space, the loop detector will allow another vehicle to park in that spot and the Message sign will update to indicate an available parking spot. If no spaces are available, the Message sign will direct drivers to other nearby empty parking lots. These systems work together to optimize parking utilization and improve the overall parking experience.

Here are some additional ways that a smart parking system can be made more effective:

a. **Integration with mobile apps:**
A smart parking system can be integrated with a mobile app that allows drivers to reserve parking spaces in advance, pay for parking, and receive real-time updates on parking availability. This can greatly improve the overall parking experience for drivers.

b. **Predictive analytics:**
A smart parking system can use predictive analytics to forecast parking demand based on historical data and events in the area. This can help city planners optimize parking management strategies and reduce congestion.

c. **Smart payment systems:**
A smart parking system can incorporate contactless payment methods, such as mobile payments or credit card readers, to provide a more convenient and efficient payment experience for drivers.

d. Intelligent parking guidance:
An intelligent parking guidance system can use data analytics and machine learning algorithms to optimize parking guidance and direct drivers to available parking spots in real-time, reducing congestion and improving traffic flow.

e. Environmental sensors:
Environmental sensors can be installed in parking lots to monitor air quality, noise levels, and other environmental factors. This can provide valuable data for city planners to make informed decisions about parking management strategies.

Explanation:

So, Basically, the primary problem is the lack of available parking on the streets, which leads to drivers parking in irregular places that are not designated for parking, causing congestion issues. Furthermore, there is an empty off-street parking area where drivers do not park. To mitigate this issue, the plan is to use smart parking technology. Loop detectors and Dynamic Message Signs will be installed at all parking locations, including on and off-street parking areas, with parking meters charging drivers for parking. These detectors and signs will be connected to the parking spots through Arduino sensors, providing real-time information about parking availability. When a car leaves a parking spot, the loop detector and Dynamic Message Sign will show the availability of the spot, guiding drivers to empty parking spaces and reducing the need for drivers to search for available parking. A figure from the SUMO simulation of I-8 Markaz shows the location of the loop detectors in red circles.

Figure 4.1: Screen Grab of simulation from SUMO (Roundabout)

Figure 4.2: Screen Grab of simulation from SUMO (North)

So, according to the current situation Off-street parking will be left empty most of the time. But, when all 231 On-street spots fill up then the loop detectors won't let any driver to park at On-street until any vehicle leaves the spot.

So, when all spots are occupied the Dynamic Message signs will shows the message which guides the driver to go to the nearest available On or Off-street Parking.

The Figure below shows that the loop detector won't let any driver park his/her vehicle at On-street at random place once the parking is full.

Figure 4.3: Screen Grab of simulation from SUMO (South)

We can see in the figure all the spots are occupied at ON-street at this place and loop detectors don't let any driver park his/her vehicle and all are waiting but when Dynamic Message sign also install with loop detectors it guides these vehicles to go to the nearest available parking. This system will apply at each ON-street and Off-street at I-8 Markaz.

By this system at peak time all 350-400 surplus On-street vehicles will be transferred to the respective Off-street empty parking spots and still left some empty parking spots which means the capacity is enough to meet the demand of the vehicles. So, due to this system the congestion inside the CBD has been reduced to a minimum as shown in the figures below.

4.3 Ways to restrict office people to park at On-street:

When hourly charges are applied to parking meters on ON-street parking, individuals who park there for the whole day (such as office workers) will avoid parking there due to the high cost. They will instead choose to park at Off-street parking. This will result in short-term visitors such as shoppers and diners to park at ON-street parking, which will decrease the turnover rate of the parking spots and increase their availability.

The other ways to restrict office people from parking at on-street parking spaces is to implement a parking permit system that only allows authorized users to park in those areas. Employees who have been granted parking permits can park on the designated on-street parking spaces, while unauthorized vehicles will be denied parking privileges. Another approach is to use time-limited parking meters that require payment to park, so that office people who want to park for an extended period are discouraged from using on-street parking spaces. Furthermore, local authorities can impose parking restrictions, such as time limits or no-parking zones, in the areas surrounding the office buildings to discourage employees from parking in these areas. By implementing these measures, office people can be restricted from using on-street parking spaces, leaving them available for other users.

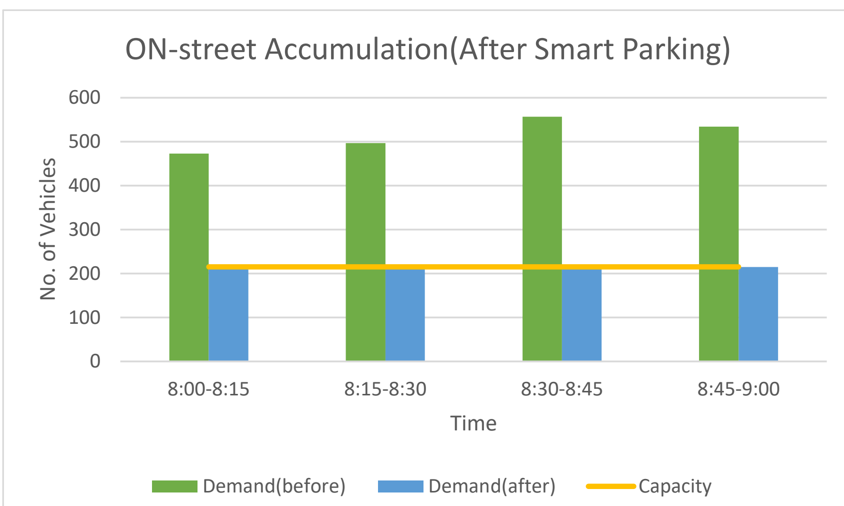


Figure 4.4: Results of using Smart Parking

CHAPTER 5

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In this study, we aimed to analyze the parking occupancy patterns in the 1-8 CBD area. By implementing a methodology that involved manually counting both on-street and off-street parking spots and recording the registration numbers of occupied spots, we were able to gather valuable insights into the parking situation in the area.

The findings from our study indicate that there is a significant demand for efficient parking management solutions in the 1-8 CBD. We observed a high occupancy rate during our data collection period, which suggests that there is a need to optimize parking resources and improve overall accessibility for motorists.

Furthermore, the data collected revealed fluctuations in parking spot occupancy over the 3.5-hour period. This highlights the dynamic nature of parking in the area, with vehicles constantly entering and exiting parking spots. These findings emphasize the importance of implementing a smart parking system to streamline parking operations and enhance the overall parking experience.

5.2 Recommendations

Based on the conclusions drawn from our research, we provide the following recommendations for improving the parking situation in the 1-8 CBD:

1. **Implementation of a Smart Parking System:** We recommend the adoption of a smart parking system that utilizes technologies such as sensors, data analytics, and real-time monitoring. This system can provide accurate information on parking spot availability, enabling motorists to make informed decisions and reduce the time spent searching for parking.

2. **Integration of Mobile Applications:** Developing a mobile application that connects drivers with available parking spots and provides real-time updates on occupancy can significantly enhance convenience and efficiency. Integrating features such as navigation, reservation, and payment options can further streamline the parking process.

3. **Parking Guidance and Signage:** Enhancing the visibility of parking facilities through clear signage and real-time guidance systems can assist drivers in locating available parking spaces more efficiently. Clear directional signs and digital displays can minimize congestion and improve traffic flow within the CBD.

4. **Pricing and Incentives:** Implementing a dynamic pricing strategy that adjusts parking fees based on demand can help optimize parking space utilization. Additionally, offering

incentives such as discounted rates for off-peak hours or rewards for carpooling can encourage sustainable parking practices.

5. **Collaboration with Stakeholders:** Foster collaboration between local authorities, urban planners, property developers, and parking facility operators to develop comprehensive parking management strategies. Encouraging dialogue and cooperation can lead to innovative solutions that address the specific needs of the I-8 (or any other) CBD.

5.3 Future Research

While this study provides valuable insights into the parking situation in the I-8 CBD, there are several avenues for further research:

1. **Long-term Parking Behavior:** Investigate the long-term parking behavior and preferences of motorists in the CBD area. Understanding factors such as parking duration, preferred parking facilities, and peak hours can inform the development of more targeted parking management strategies.

2. **Impact of Smart Parking Systems:** Conduct studies to evaluate the impact and effectiveness of implementing smart parking systems in terms of reducing congestion, improving traffic flow, and enhancing the overall urban mobility experience.

3. **Sustainability and Environmental Impact:** Explore the potential environmental benefits of smart parking systems, such as reduced vehicle emissions and improved air quality. Assess the overall sustainability implications of parking management strategies in the I-8 CBD.

4. **User Experience and Satisfaction:** Investigate the user experience and satisfaction levels of motorists using smart parking systems. Evaluate factors such as ease of use, reliability, and the impact on overall satisfaction with the parking process.

5.4 Final Words

In conclusion, our research sheds light on the pressing need for an efficient parking management system in the I-8 CBD. The implementation of a smart parking system, integrated with mobile applications and advanced technologies, holds significant potential for improving the parking experience, reducing congestion, and enhancing urban mobility. By embracing these recommendations and conducting further research, we can work towards creating a sustainable, user-friendly, and future-proof parking ecosystem in the I-8 CBD.

CHAPTER 6

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