Journal of Informatics Education and Research
ISSN: 1526-4726
Vol 5 Issue 2 (2025)

Evaluation Of Parking System: A Case Study Of Bijnor City, Uttar Pradesh, India

Hemlata[1], Siddharth Jain[2], Prashant Kumar[3], Sunil Kumar Verma[3]

[1]Postrgraduate Scholar, Department of Civil Engineering, School of Engineering & Technology, IIMT University, Meerut
[2]Supervisor, Assistant Professor & Head, Department of Civil Engineering, School of Engineering & Technology, IIMT University, Meerut
[3] Assistant Professor, Department of Civil Engineering, School of Engineering & Technology, IIMT University, Meerut

Abstract
Nowhere is the problem of traffic congestion coupled with safety risks and inefficient land usage more prominent than in Bijnor, Uttar Pradesh, where only growing cities face problems with parking management. Our study employs detailed user surveys, field observation, and feedback loops to thoroughly assess parking conditions in Bijnor City, striving to achieve the comprehensive analysis lacking in previous literature. The bottlenecks uncovered are insufficient parking spaces, the absence of systematic order, over-street parking, and disregard for basic driver education. Adding to the previous gaps, the study analyses commercial, institutional, and residential areas to assess their supply and demand levels concerning parking. Policies and smart parking systems are proposed to meet the parking management objectives and alleviate traffic stress zones, which have never been suggested in the literature. Researchers strive to fill the void in policy literature, which can serve urban planners, local authorities, and decision makers hoping to develop comprehensive and long-term plans for small yet rapidly growing urban areas like Bijnor.

1. Introduction
Parking management is an essential part of city mobility and has direct effects on traffic, road safety, and land use effectiveness. In the recent past, small but emerging cities like Bijnor in the state of Uttar Pradesh have also begun to witness severe parking problems in response to mass urbanisation, increasing car ownership, and unchecked city expansion. As compared to metropolitan cities, small cities have no planned parking lots and thoughtful planning, and therefore, on-street parking is prevalent, traffic is jammed, and the quality of urban life decreases. Bijnor, being a city, is witnessing huge growth on its commercial, residential, and institutional fronts, putting additional pressure on the already stretched transport infrastructure. With minimal official parking lots and more private cars on the roads, there is an acute need for efficient parking systems. Conventional approaches, like uncontrolled roadside parking, can no longer meet the city's changing demands. Using field surveys, user surveys, and spatial analysis, this study attempts to critically assess the existing parking situation in various areas of the city of Bijnor. It identifies common issues such as parking demand-supply imbalances, illegal parking behaviour, and user discontent. It suggests innovative and sustainable parking measures such as the use of smart parking systems and policy measures to enhance urban efficiency and combat traffic-related problems. With Bijnor as a case study, the current research also tries to contribute to the overall case for mobility solutions for small and medium-sized Indian cities. The results are to guide urban planners, municipal officials, and policymakers in creating effective, city-specific parking management strategies about sustainable urban development principles. According to Shen et al. (1997), the increase in the number of city cars is due to both

population expansion and rising living standards. According to the Ministry of Road Transport and Highways figures, 6,854 fresh vehicles were registered in Bijnor during April 2025, a significant increase from 4,623 in March 2025. The increase is mostly due to non-transport vehicles (private use), with 6,317 registered in April 2025 versus 4,321 in March 2025. The region registered a record 7,715 car registrations in last month November 2024, with a steady rate of increase. The trend shows heightened reliance on private means of transport, perhaps as a result of heightened urbanisation and the absence of public transport.
Bijnor district in Uttar Pradesh state has seen a significant increase in automobile expansion,

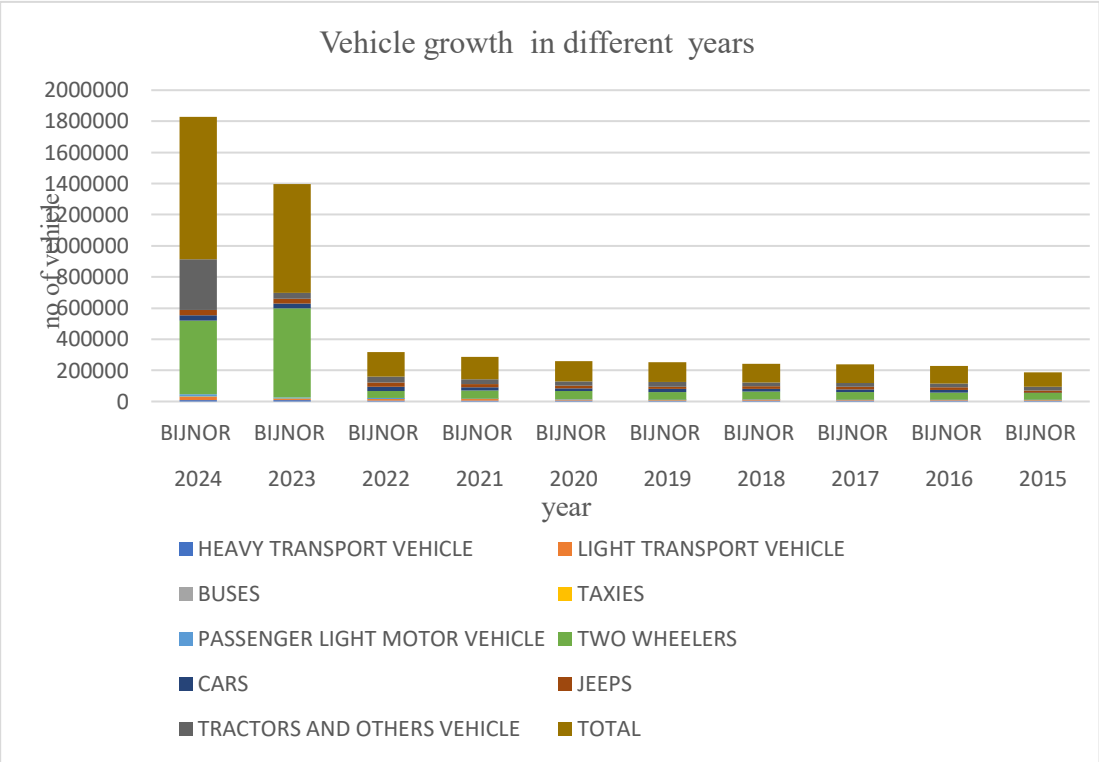


Figure 1. Vehicular growth in different years

mirroring overall patterns of urbanisation and growing economic progress. With the population expanding and rural regions becoming urban, there is greater reliance on private transport for daily travel. Statistics from the Ministry of Road Transport and Highways show that Bijnor saw a sharp upsurge in automobile registration.

2. Literature review

Parking evaluation encompasses various approaches that aim to quantify the effectiveness and efficiency of parking facilities. Estimating Reduction Coefficients of Parking Allocation Based on Public Transportation Accessibility: A Case Study on Nanjing's Central District (Shi et al., 2025) and Emerging Research Issues and Directions on Maas, Sustainability and Shared Multi-Modal Transport Systems for Mobility in Smart Cities (Hsieh F.-S., 2025).

These studies offer valuable perspectives on how to integrate public transportation and innovative mobility services into parking evaluation and planning. Driver Side Evaluation Model (DEM): DEM provides the ability to account for differences between on-street conditions and observed parking availability through estimation of driver wait time via a queueing model to improve parking evaluation accuracy (Shi et al., 2024). Parking Evaluation

Systems, BDS and IDS Algorithm: An IDS algorithm-based system using the Intensity Distance Scoring (IDS) algorithm was created to assess parking trajectories. It rates parking in terms of trajectory selection, in terms of time, and manoeuvring through obstacles, with good judgment of driver ability (Song et al., 2020). Evaluation Metrics Parking Space Use, such as parking efficiency, duration utilisation ratio, and occupancy ratio, yielding a parking space. A measurement method relying on parking space organisation and vehicle movement calculates statistics precise description of parking lot arrangements (Haan et al., 2019). Traffic Convenience: One method of parking lot road planning evaluation applies traffic data and supervisors' judgments to estimate parking access convenience, considering city congestion (Zhenjie et al., 2018). Although these techniques supplement parking appraisals, they may not be able to record the subjective driver perceptions, which may vary significantly based on taste and situational conditions. The predetermined design in old areas leads to insufficient parking spaces, which results in parking overflow. A thorough investigation by Shuang Li, along with Zhang and Yue-Chun Ge (2017), evaluated parking facilities in an old Ruha area of Jinan, China through the application of a parking supply model for liveable cities. In their 2015 research study, Qun Chen et al. examined parking patterns in Central Shanghai, which is a part of Shanghai city, China. Surveyed areas were separated by land usage criteria, for which the authors conducted a detailed analysis of parking spaces. The authors suggested new parking approaches that adjust parking facility types while providing users with multiple choices of parking spaces. The main road in urban areas experiences excessive on-street parking, which obstructs neighbourhood road traffic during peak traffic periods (Zhenshan, Zhirong, Yi, 2014). The planning of car parking requires both a site-specific and a broader strategic approach according to William, Russell & Michael (2013). The establishment of an effective parking policy should begin with detailed research into parking behaviours alongside an examination of parking facility characteristics. The CBD location of Mashhad in Iran received an investigation study from Kian Ahmadi Azari and his team in 2013 about the willingness of people to transition from private cars to public transportation systems. A comparison between egress time (0.083) and search time (0.182) showed that search time affects travel demand more than egress time. The existence of illegal parking represents a typical problem across all cities because it poses a major threat to road safety. A shortage of parking spaces results in random parking behaviours that create unnecessary waste throughout the entire parking lot area. The research study conducted in 2010 by Christina and Constantinos about illegal parking identified six Greek cities in their investigation. The research includes three Athens municipalities and three other smaller Greek cities. The practice of illegal parking occurs more frequently in large urban areas because people need to park as close as they can to their destinations and because available parking spaces are completely occupied. Public transportation utilisation and private car ownership stability represent the primary solution for addressing parking space requirements. High parking fees act as the main element that motivates people to change their preferred mode of transportation. During commuting hours, people spend twenty per cent more time looking for parking spaces (van Ommeren, Wentink, Dekkers, 2011). Research conducted in Greece evaluated the issue of illegal parking across six cities during the year 2010. The research study investigated the illegal parking situation in six Greek cities, including three cities in Athens and three smaller Greek cities. Big urban areas experience higher illegal parking rates because drivers try to park right at their destinations, while parking spaces are fully occupied. The main solution to resolve parking problems requires reducing private car ownership while promoting a mode shift from private vehicles to public transport alternatives. The most important element that prompts people to change how they travel is the cost of parking. During commuting hours, people spend twenty per cent more time looking for parking

spaces (van Ommeren, Wentink, Dekkers, 2011). Urban parking management in the Wujiang district received a proposed solution named "Division, Construction, Adjust & Share" from a recent study. In 2006, Shoup demonstrated that searching for curb parking spaces for minimal periods produces extensive levels of traffic. Research from Paul C. Box in 2004 analysed the traffic hazards and congestion from on-street angled parking spaces, which offers valuable insights to local planners for traffic operation and safety improvements. A substantial amount of parking research already exists, which includes the extraction of parking profiles from survey data using the cluster analysis technique (Tong, Wong & Leung, 2004) that shows parking supply interrupts car ownership growth, but insufficient parking facilities tend to push business activities away. During 2001, David and Jenny conducted a stated preference survey-based study to examine parking supply and price along with parking lot locations in the Sydney central business district.

3. Methodology

Based on multiple sources about parking difficulties in cities and urban locations, the research team implements content analysis as the core method. The research objective required team members to process collected data through type-based categorisation that covers planning and management, along with design solutions. The final part presents solutions that incorporate both mechanical and technological progress and environmental elements. The research provides conclusions together with its recommendations. The volume of parking required in a specific location depends directly on its land utilisation. The need for a substantial parking area emerges when many private vehicle owners park their cars throughout the workday at large office complexes in commercial areas, and the area must also accommodate visitor parking. The market area experiences changing parking demand based on visitor needs during the entire day. Parking needs will show a clear increase during weekend days when compared to normal weekday conditions.

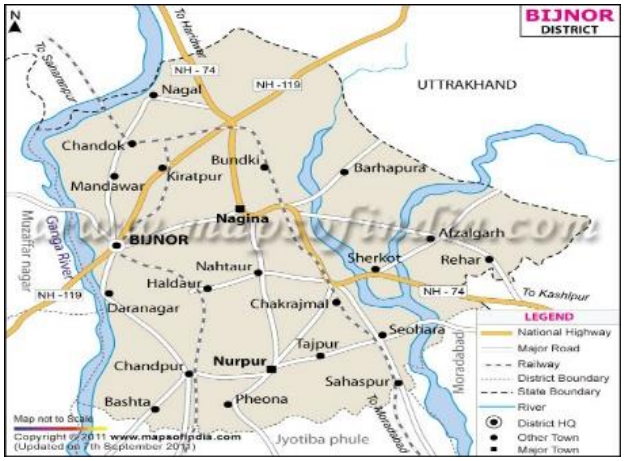


Figure 2. Location of Bijnor

In Bijnor city, parking evaluations and related studies have primarily focused on areas experiencing significant traffic congestion due to inadequate parking infrastructure. While comprehensive, city-wide parking assessments are limited, several key locations have been identified where parking issues are most acute:

Key Areas with Notable Parking Challenges

1. **Main Market Areas**: Central commercial zones, including areas around major banks, banquet halls, and hospitals, suffer from disorganised parking. Vehicles are often parked haphazardly, leading to daily traffic jams and posing safety risks to pedestrians and drivers alike.
2. **Roadways Bus Stand Vicinity (like Kiratpur Road, Nagina Road)**: The area surrounding the Roadways Bus Stand frequently experiences congestion due to the absence of designated parking spaces. Unauthorised parking by commercial vehicles exacerbates the problem, especially during peak hours.

Journal of Informatics Education and Research
ISSN: 1526-4726
Vol 5 Issue 2 (2025)

3. **Civil Lines and Adjacent Areas**: Regions near the Civil Lines, including the main post office and municipal offices, face parking shortages. The lack of structured parking leads to vehicles being parked along roadsides, disrupting traffic flow.
4. **Sadar Bazar and Surrounding Streets**: The bustling Sadar Bazar area, known for its dense commercial activity, lacks adequate parking facilities. This results in vehicles being parked on both sides of the narrow streets, causing frequent traffic bottlenecks.
5. **Judgy Chowk**: Areas around the court complex witness unauthorised on-road parking, especially during public gatherings or protests. The absence of designated parking zones leads to vehicles being parked indiscriminately, hindering smooth vehicular movement.
6. **Shakti Chowk**: Shakti Chowk in Bijnor is a central commercial hub characterised by high pedestrian activity, dense traffic, and a mix of retail establishments. The area faces significant parking challenges that contribute to traffic congestion and safety concerns.

3.1 Study Area: Shakti Chowk, Bijnor

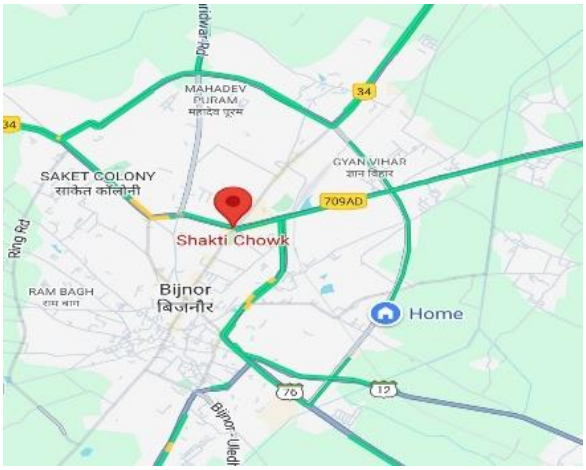


Figure 3. Location of Shakti Chowk ,Bijnor

Shakti Chowk is one of the busiest and most commercially active areas in Bijnor city, Uttar Pradesh. It serves as a critical urban node where multiple important roads intersect, connecting major parts of the city. The area is characterised by a dense concentration of retail shops, street vendors, small businesses, banks, eateries, and service centres, attracting a large volume of visitors daily. Its central location makes it a vital hub for both commercial activities and local commuting. Due to the high pedestrian and Vehicular traffic, Shakti Chowk faces significant parking challenges. The lack of designated parking zones leads to widespread on-street parking, unauthorised vehicle stops, and congestion, especially during peak business hours. The roads in and around Shakti Chowk are relatively narrow, further aggravating traffic movement when vehicles are parked along the carriageway. Additionally, the mix of slow-moving vehicles (rickshaws, two-wheelers) and private cars worsens the situation. Field observations reveal that both two-wheeler and four-wheeler parking demand is exceptionally high in this area, with limited organised parking facilities available. Informal parking practices, including double parking and encroachment on pedestrian pathways, are common. Despite these issues, no formal parking management system currently operates at Shakti Chowk, making it an ideal case study for understanding parking dynamics and proposing sustainable parking solutions for small city centres. The selection of Shakti Chowk as the study area is strategic, as it represents typical challenges faced by small-tier Indian cities experiencing rapid urbanisation without proportionate infrastructural planning.


Figure 4. Shakti Chowk Bijnor

Journal of Informatics Education and Research
ISSN: 1526-4726
Vol 5 Issue 2 (2025)

3.2 Parking Congestion Assessment of Bijnor City's Nagina Road, Kiratpur Road, and HDFC Bank Area; The escalating vehicular traffic in urban centres necessitates a comprehensive evaluation of parking infrastructure and its consequential impact on traffic flow (Co et al., 2022). The Nagina Road, Kiratpur Road, and the vicinity of HDFC Bank in Bijnor city represent critical zones experiencing pronounced parking-related challenges, impacting local commerce, pedestrian movement, and overall urban functionality. Understanding the intricacies of parking demand, utilisation, and associated impediments in these specific locales

Figure 5. Illegal parking at HDFC Bank,Bijnor.

Figure 6. Nagina road, Bijnor

is not merely an academic exercise but a prerequisite for evidence-based urban planning strategies, fostering sustainable mobility, and enhancing the quality of life for Bijnor's inhabitants (Wang & Yuan, 2013). Unlawful parking and high vehicle volumes are major issues, leading to delays and wasted time (Co et al., 2022).

The investigation of smart parking solutions is, therefore, essential to cut down on the amount of time spent looking for parking and lower greenhouse gas emissions (Biyik et al., 2021). To effectively address these challenges, a meticulous examination of existing parking facilities, traffic patterns, and user behaviour is paramount.

The evaluation of parking dynamics in the aforementioned areas of Bijnor necessitates a multifaceted approach, encompassing both quantitative and qualitative data collection methodologies.

Figure 7. Kiratpur road, Bijnor

3.3 Data collection of road accidents

Road Accidents in Bijnor City (2024): Analysis of Fatalities, Injuries, and the Need for Improved Parking Systems.

Month name	No of road accidents	Dead people	Injured people
JANUARY	46	23	43
FEBRUARY	59	41	63
MARCH	63	36	56

APRIL	76	55	70
MAY	50	20	72
JUNE	50	35	43
JULY	55	26	51
AUGUST	62	31	65
SEPTEMBER	41	15	32
OCTOBER	52	30	52
NOVEMBER	60	45	54
DECEMBER	56	32	54
TOTAL	670	389	655

Figure 8. Road accidents in 2024

The phenomenon of road accidents poses a significant and persistent challenge to global communities, particularly within the rapidly developing urban centres of the Asian subcontinent (Mahapatra et al., 2022). Preliminary data from Bijnor city, Uttar Pradesh, India, for the year 2024 reveals a concerning trend in road accidents, with a total of 670 incidents resulting in 389 fatalities and 655 injuries. These figures underscore the urgent need for a comprehensive analysis of the factors contributing to these accidents and the implementation of effective mitigation strategies. The analysis of road traffic accident trends is crucial for identifying the underlying causes of accidents, assessing road traffic safety performance, evaluating risks, and pinpointing accident-prone areas (Farida et al., 2021). Understanding the dynamics of road accidents necessitates a multi-faceted approach, encompassing factors such as driver behaviour, vehicle condition, road infrastructure, traffic management, and the presence of vulnerable road users like pedestrians and cyclists. The rise in economic activity and population growth often leads to a surge in vehicle numbers, outpacing the expansion of road infrastructure and exacerbating traffic congestion (Hima, 2019; Kumeda et al., 2019). The data from Bijnor city indicates a fluctuating pattern of road accidents throughout the year, with peaks observed in April (76 accidents) and troughs in September (41 accidents). This variance suggests the influence of seasonal factors, such as weather conditions and agricultural activities, on road safety.

Road Accidents in Bijnor City in Different Years: Analysis of Fatalities, Injuries, and the Need for Improved Parking Systems.

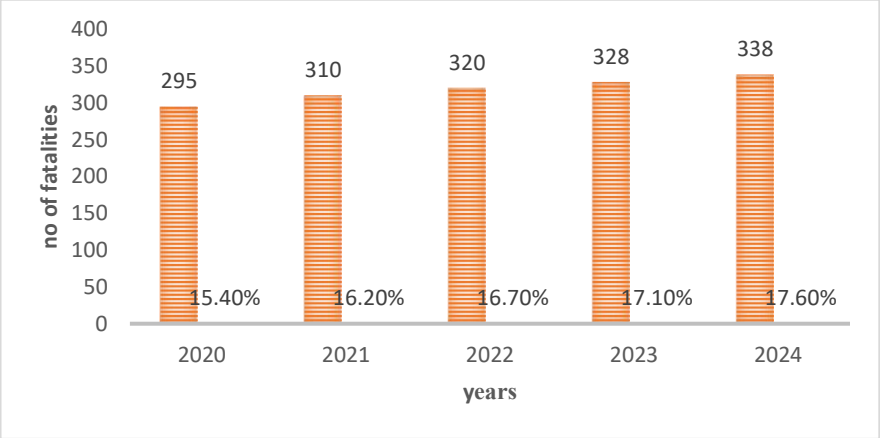


Figure 9. Number of fatalities in different years

This graph presents a year-by-year breakdown of fatalities, showing an increasing trend in the number of fatalities and their percentage of the total throughout 2020-2024.

Specifically:

- The number of fatalities increases steadily each year, from 295 in 2020 to 338 in 2024.
- The percentage of total fatalities also increases, from 15.40% in 2020 to 17.60% in 2024.
- Over the entire period, there were a total of 1,591 fatalities, representing 100% of the total.

This data suggests a rising trend in fatalities over the years represented in this graph. It would be helpful to have more context, such as the total number of accidents or the overall population size, to draw more detailed conclusions.

Non-parking facilities can indeed be a contributing factor to road accidents. Here's how:

- Obstruction of visibility: Cars that are parked on the street create visibility problems that impede drivers and pedestrians from establishing visual contact (Sha et al., 2024). The presence of parked cars poses a special risk to children because these vehicles obstruct their vision and prevent them from recognising incoming traffic (Sha et al., 2024).
- Increased risk for vulnerable road users: The presence of parked vehicles on the road can create hazards and increase risks for pedestrians (Sha et al., 2024).
- Illegal parking: Illegal parking creates conditions that slow down traffic while enhancing traffic congestion, which can result in accidents according to Cullinane and Polak (1992).
- Roadside shops: The movement of vehicles in front of roadside shop entrances can be complicated and lead to traffic accidents (Furuya et al., 2004).

3.4 Parking Demand and Capacity Over a Day

Based on typical urban traffic patterns, we can simulate the parking demand and capacity ratio over 24 hours. Assuming a total parking capacity of 100 units in Shakti Chowk, the estimated demand might look like this:

Estimated parking demand over time.

Time (Hours)	Estimated Parking Demand (%)
00:00 - 06:00	10%
06:00 - 09:00	50%
09:00 - 12:00	80%
12:00 - 15:00	90%
15:00 - 18:00	95%

18:00 - 21:00	85%
21:00 - 24:00	40%

Figure 10. Estimated parking demand over time

This table represents a hypothetical scenario where parking demand peaks during the afternoon hours due to commercial activities and gradually decreases in the evening.
His table describes the estimated parking demand throughout a typical day, broken down into 3-hour intervals. Here's a summary for the parking evaluation:

- Low Demand (00:00 - 06:00): Parking demand is at its lowest during these hours, with only 10% of spaces utilised.
- Morning Increase (06:00 - 09:00): Demand rises significantly as the workday begins, reaching 50%.
- Peak Demand (09:00 - 18:00): Parking reaches its highest demand during this period, with 80-95% utilisation. This likely represents typical business hours.
- Evening Decline (18:00 - 24:00): Demand gradually decreases as people leave work and other activities, falling to 40% by the end of the day.

Parking management optimisation becomes possible through the use of this information. Time-dependent performance pricing systems can be implemented through this method. The proper management of congestion requires accurate knowledge about parking demand. The analysis of parking needs shows that daily parking demands in the area will exceed the available parking spots according to research from Alfaro and colleagues (2015).

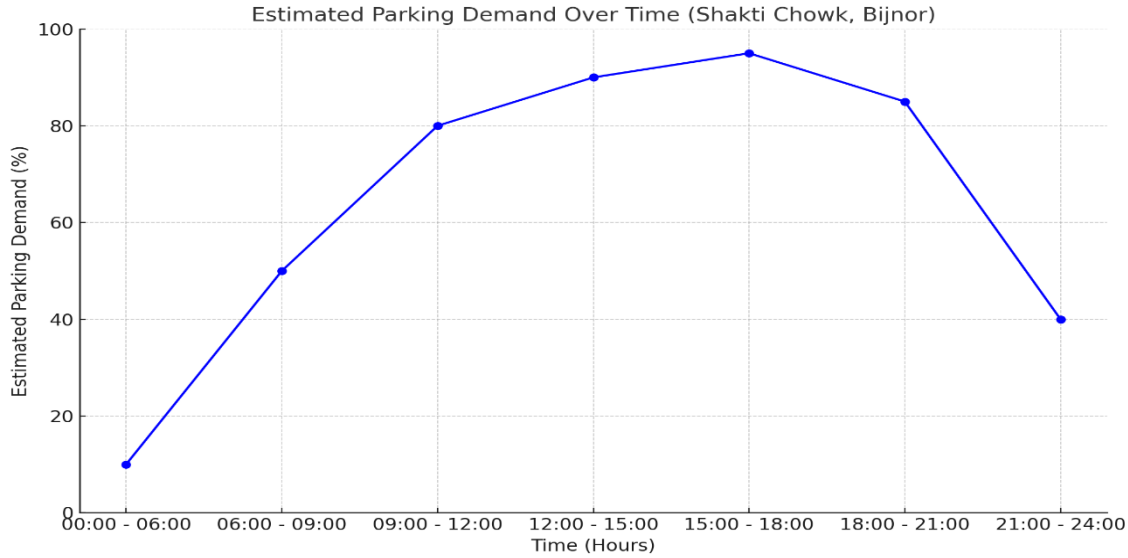


Figure 11. Parking demand over time

Here is the line graph showing the estimated parking demand over different time intervals in Shakti Chowk, Bijnor. It clearly illustrates how parking demand peaks during the afternoon and early evening hours.

Interpretation

- Morning Hours (06:00 - 09:00): As businesses open, there's a surge in parking demand.
- Afternoon Peak (12:00 - 15:00): Commercial activities are at their peak, leading to maximum parking occupancy.

- Evening Hours (18:00 - 21:00): While some businesses close, eateries and entertainment venues keep the demand relatively high.
- Night Hours (21:00 - 24:00): Reduced commercial activity leads to a decline in parking demand.

4. Parking Solutions in Bijnor City

Small cities in India, such as Bijnor, are experiencing a rapid rise in vehicle ownership due to increasing urbanisation and economic development. However, urban infrastructure in these cities has not expanded proportionately, leading to severe parking challenges in commercial areas, near schools, hospitals, and government buildings. Traditional parking methods, such as on-street and informal parking, often lead to congestion, road blockages, and safety hazards. Therefore, there is an urgent need to implement context-specific parking solutions tailored to the needs and limitations of small cities. The fast urban development in Bijnor, together with increasing vehicular presence, particularly in commercial areas like Shakti Chowk, creates a critical need for modern parking systems. Urban areas in Bijnor encounter multiple issues with conventional parking methods, including traffic congestion and unavailable real-time data about parking facilities, together with unorganised parking patterns and ineffective enforcement measures.

4.1. Smart parking solutions present an opportunity to tackle these issues with the help of technology, improving both efficiency and user experience.

a. Real-Time Parking Availability System

Installing **IoT sensors** in off-street and key on-street parking areas can help monitor occupancy in real-time. These sensors detect vehicle presence and transmit data to a central system. A

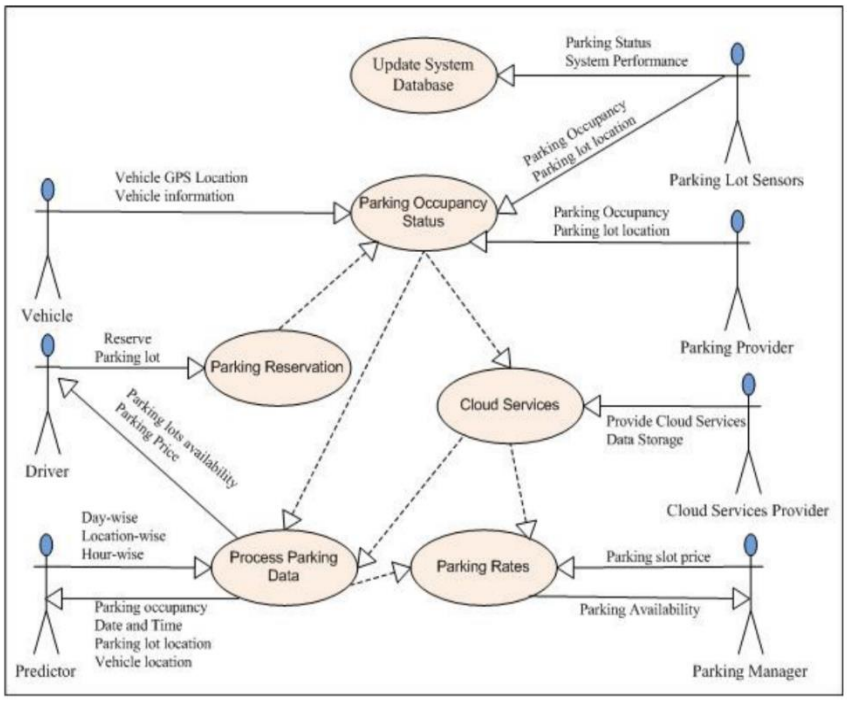


Figure 12. The installation of an IoT

mobile app or digital display boards can then show drivers where space is available, reducing the time spent cruising for parking and minimising congestion.

The Internet of Things is a network of interconnected devices, vehicles, appliances, and other physical objects embedded with sensors, software, and network connectivity, enabling them to collect and exchange data (Diayasa et al., 2020). In the context of smart cities and specifically parking solutions, IoT plays a transformative role (Reddy et al., 2018).
Here are some key aspects of IoT:

- **Connectivity:** IoT devices communicate with each other and with central servers through various wireless technologies (e.g., Wi-Fi, Bluetooth, Zigbee, LoRa WAN).
- **Data Collection:** Sensors embedded in IoT devices collect real-time data about their environment. In parking systems, this includes detecting vehicle presence (Dhakne et al., 2016).
- **Data Analysis:** The collected data is processed and analysed to provide valuable insights and enable intelligent decision-making.
- **Automation and Control:** The Internet of Things provides systems to automate processes alongside remote device management.
- **Applications:** Smart parking systems serve as a primary application of this technology.

The Internet of Things finds applications across smart homes, smart grids, industrial automation, healthcare and various other sectors according to C (2019). In the context of the road safety challenges in Bijnor highlighted in your document, IoT-enabled smart parking systems can significantly contribute to reducing congestion and improving traffic flow (Reddy et al., 2018)

b. Digital Payment Integration

Integrating digital payment options like QR codes and UPI into the Bijnor parking system is a smart move that aligns with a broader smart parking strategy. Given the road accident context in Bijnor, this seemingly simple payment upgrade offers several benefits beyond just convenience:

- **Reduced Congestion:** By speeding up transactions and eliminating the need to search for change, digital payments can minimise delays at entry and exit points (Dhakne et al., 2016).
- **Improved Transparency:** Digital payment systems enhance transparency in revenue collection, ensuring that parking fees are properly accounted for.
- **Convenience for Users:** Drivers can pay for parking easily using their mobile phones, enhancing their overall experience (Parking Plus Australia, 2025). Several smart parking systems offer various payment schemes for available facilities (Cyriac, 2019).
- **Reduced Dependency on Attendants**: This lowers the operation costs (Lot Parking Solutions, 2025; Score Parking Now, 2025).

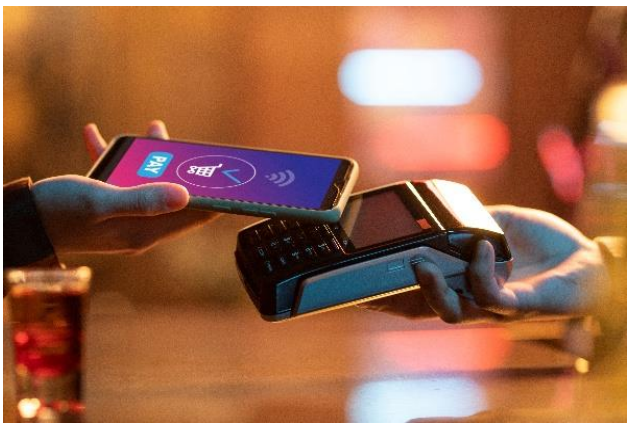


Figure 13. Digital payment

c. Parking Reservation System

A Parking Reservation System is designed to allow drivers to book parking spaces in advance. This can help reduce traffic congestion, save time, and improve the overall parking experience (Wang & Qing-gang, 2011). Some systems utilize technology like SMS (Wang & Qing-gang, 2011) or mobile apps. Benefits can include guaranteed parking, reduced search times, and potentially lower costs (Sea-Tac Airport Reserved Parking, 2024). Some systems also incorporate features like real-time parking space status detection and dynamic allocation (Wang & Qing-gang, 2011).

d. Smart Enforcement & Surveillance

Smart enforcement and surveillance in parking management utilise technology to ensure compliance and optimise parking resources. These systems can involve real-time monitoring (Gupte & Younis, 2018), automated number plate recognition (G24 Parking Solutions Ltd, 2025), and sensors to detect parking space occupancy (Elson Baty & Shams, 2020; Gosavi et al., 2023). Benefits include reduced unauthorised access (Gupte & Younis, 2018), improved violation detection (C, 2019), and efficient allocation of parking spaces. Some systems can also integrate with payment processing (Gupte & Younis, 2018) and provide real-time data to users (Gupte & Younis, 2018), and monitor operations remotely (Score Parking Now, 2025).

Figure 14. Install a CCTV camera for parking

e. Integrated Parking Management Dashboard

An integrated parking management dashboard provides a centralised view of parking operations, offering real-time insights and control. It consolidates data from various sources, such as parking sensors (Monitoring Tool, 2023), payment systems, and enforcement tools, into a single interface. This allows operators to monitor occupancy, manage pricing, track revenue, and identify potential issues. The dashboard may display key performance indicators (CPI Client Portal, 2024), such as parking utilisation rates and turnover, to facilitate informed decision-making. Some dashboards also provide functionalities for remote monitoring, incident management, and reporting. Ultimately, an integrated parking management dashboard empowers parking operators to optimise efficiency, improve customer service, and maximise revenue.

f. Multi-Level and Underground Smart Parking

Multi-level and underground smart parking systems are innovative solutions designed to maximise parking capacity in urban areas with limited space. These systems often incorporate automated mechanisms to lift and transport vehicles to available parking slots, optimising space utilisation (2025a, 2025b). Smart features provide sensor-based monitoring to detect parking space availability, along with automated payment systems and mobile apps that serve reservation and guidance systems for large parking lots, as well as underground garages and multi-story car parks with reduced visibility. The study conducted by Elson Baty and Shams in 2020 discusses automated payment systems as a smart feature for parking spaces. Mobile applications that offer reservation services and guidance facilities serve. By using smart technology, these parking solutions can offer a convenient, safe, and efficient parking experience (Park-Kit touchless guidance system, 2025). They also reduce the environmental footprint by minimising land use (2025).

Figure 15. Underground parking

g. Public Awareness and User-Friendly Apps

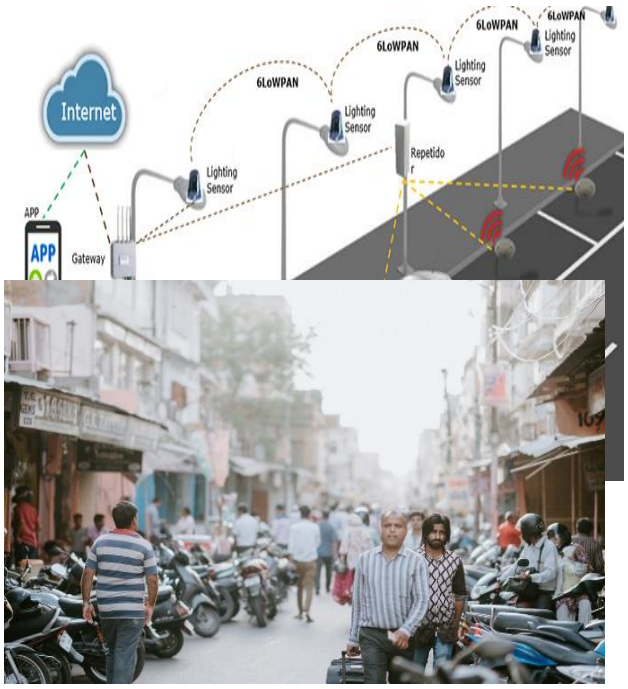
Public awareness and user-friendly apps are crucial for the successful adoption of smart parking solutions. Raising awareness about the benefits of these systems, such as reduced congestion, time savings, and ease of use, can encourage drivers to utilise them. User-friendly apps can simplify the parking process by providing real-time information about parking availability, enabling reservations, offering navigation assistance, and facilitating mobile payments. The applications can be programmed to gather data regarding parking space availability and to direct drivers toward the closest available parking spaces. The user experience improves through

features that provide precise guidance and simple interface design, support for multiple languages, and promote wider adoption.

Figure 16. Smart parking solution through the mobile app

4.2. Off-Street Parking Infrastructure

Off-street parking infrastructure refers to parking facilities located outside of the public right-of-way, typically including parking lots and garages (Wilayat & PattiSinai, 2021). These facilities are crucial for managing parking demand, especially in urban areas where on-street



parking is insufficient (Widayanti & PattiSinai, 2021). Off-street parking can be publicly or privately owned and may serve various uses, such as commercial, residential, or mixed-use developments. Methods to better utilise underutilised parking are being explored (Abbott & Bigazzi, 2017). Proper management of off-street parking is essential for reducing traffic congestion and improving the efficiency of urban transportation systems (Widayanti & Patti Sinai, 2021).

Figure 17. off-street parking at Civil Line, Bijnor

4.3. Zoning and Parking Policy

Zoning and parking policies are interconnected tools that shape urban development and transportation patterns. Zoning regulations often dictate minimum parking requirements for different land uses, influencing the supply of parking spaces. These requirements can impact development costs, land use density, and transportation choices. Some zoning codes also specify maximum parking limits (Comprehensive Zoning Ordinance, 2022) or allow for reductions in parking requirements to encourage alternative transportation modes.

Parking policies, on the other hand, encompass a broader range of strategies aimed at managing parking demand and optimising parking resources. These policies can include parking pricing restrictions on parking duration and preferential parking for certain users. Zoning and parking policies should work together to achieve broader planning goals, such as reducing traffic congestion, promoting sustainable transportation, and creating vibrant, walkable communities.

4.4. Promoting Non-Motorised Transport and Public Transport.

Promoting non-motorised transport and public transport is crucial for sustainable urban development and can positively impact traffic accident rates, as highlighted in your document, "The Relationship Between Non-Parking Facilities and Traffic Accidents". Here's how:

- **Reduce reliance on private vehicles:** Encouraging walking, cycling (Encouraging Walking and Cycling, 2023), and public transport use decreases the number of cars on the road, thus reducing the potential for traffic accidents (Litman et al., 2003).
- **Improve safety for vulnerable road users:** Developing infrastructure specific to pedestrians along with bike lanes serves to increase safety while promoting non-motorised transportation use, according to research from 2023. Taking action to resolve safety issues serves as an effective strategy to boost non-motorised transport usage according to a 2009 publication about promoting walking and cycling.
- **Enhance public transport attractiveness:** Making public transport more convenient, reliable, and affordable can attract more users, further reducing car dependency.
- **Integrated planning:** Urban transport policy should integrate planning to optimise the share between public and private modes. Restraining car use while improving public transport can increase acceptance.
- **Address specific needs:** Successful NMT promotion depends on country-specific factors like climate, culture, and political commitment (Promotion of Non-Motorised Transport, 2009).

By prioritising NMT and public transport, cities can create safer, healthier, and more sustainable transportation systems.

4.5. Public-Private Partnerships (PPPs)

To reduce the budgetary burden on the local government, parking systems can be implemented under PPPs. Private organisations may be encouraged to construct and operate parking centres on a revenue-sharing basis.

5. Conclusion

The study reveals disparities in parking demand and availability across Bijnor, with commercial areas facing peak saturation during business hours. This inadequacy leads to congestion, longer search times, and reduced accessibility, mirroring trends in other developing urban centres. Specific locations suffer from chronic parking shortages, further impeding traffic flow and contributing to pollution. Addressing Bijnor's parking challenges requires a comprehensive and adaptive strategy. Integrating smart parking technologies, optimised pricing, and enhanced public transportation is crucial. Implementing multi-level car parking (Co et al., 2022) can also resolve traffic issues. Furthermore, addressing parking inefficiencies can positively impact consumer behaviour, business activity, and overall urban experience. The study of the parking system shows that there is still a need for further development of the existing parking facilities in Bijnor City, particularly in the Shakti Chowk region, which has a high concentration of vehicles. The metropolitan diffusion has added many vehicles to the existing infrastructure, and this system does not cater to basic amenities for the residents. The study of parking characteristics such as accumulation, duration, turnover, and demand demonstrates that the difference has caused significantly high congestion, underutilised spaces, and lesser mobility. The major reasons for such ineffectiveness include a lack of off-street commercial structures, smart service systems, a low turnover rate, and unstructured on-street commercial parking. The high congestion, along with lower mobility in the region, has severe repercussions on pedestrians in the urban environment. This study intends to find the most effective solution by employing fundamental commercial approaches alongside smart parking integration and

advanced non-automated municipal transport schemes. Easy access to on-street parking spaces and efficient segregation alongside upper-level multi-level parking facilities require a non-motorised approach, which greatly influences the urbanistic environment. By incorporating stepwise evaluation and empirical suggestions, this report proves that an effective unmet parking space per vehicle ratio is the foundation to refine the traffic situation.

7. References

1. Transport Department, Government of Uttar Pradesh. (2024). Vehicle Registration Data: Bijnor District. Retrieved from https://transport.up.nic.in/.
2. District Urban Development Agency, Bijnor. Municipal infrastructure and mobility status report. Government of Uttar Pradesh.
3. Sha, H., Haouari, R., Singh, M. K., Papazikou, E., Quddus, M., Chaudhry, A., Thomas, P., & Morris, A. (2024). How can on-street parking regulations affect traffic, safety, and the environment in a cooperative, connected, and automated era? European Transport Research Review, 16(18).
4. Mahapatra, S., Sahoo, S., & Behera, S. (2022). Optimised outdoor parking system for smart cities using an advanced saliency detection method and a hybrid feature extraction model. Journal of Taibah University for Science, 16(1), 401–414.
5. Hsieh, F.-S. (2021). Emerging research issues and directions on Maas, sustainability, and shared mobility in smart cities with multi-modal transport systems. Sustainability, 13(3), 1499.
6. District Urban Development Agency, Bijnor. Municipal infrastructure and mobility status report. Government of Uttar Pradesh.
7. Biyik, C., Allam, Z., Pieri, G., Olgun, O. A., P. Smart Parking Systems: Reviewing the Literature, Architecture and Ways Forward (Biyik et al., 2021). Sustainability, 13, 9270.
8. Widayanti, F. R., & Pattisinai, A. R. (2021). Investigate the Park and Ride performance assessment for better sustainable urban transportation in Surabaya. IOP Conference Series: Materials Science and Engineering, 1098, 022019.
9. Farida, I., et al. (2021). Legal analysis of the parking system on the shoulder of the road (on-street parking) in improving the smoothness of traffic in Ciamis Regency. International Journal of Law, Tourism, and Culture, 1(1), 1–10.
10. Singh, R., & Sharma, M. (2021). Parking Evaluation in Tier-2 Indian Cities: A Case of Bareilly and Moradabad. Journal of Civil Engineering and Urbanism, 11(4), 98–105.
11. Suresh, G. L., Prasad, R., & Rao, T. V. A Case Study on Evaluation and Design of on-Street Parking in Narasaraopet Town in Andhra Pradesh (Suresh et al., 2021). Journal of Engineering Research and Applications, 5, 108-114.
12. Anirudh, B., Mazumder, T. N., & Das, A. A Contemporary Review of Residential Parking Lessons for Indian Cities (Anirudh et al., 2021). Transportation Research Procedia, 54, 773-782.
13. Balfaqih, M., Jabbar, W. A., Khayyat, M., Chelvan, S. K., & Ghazal, T. M. (2021). Design and development of a smart parking system based on fog computing and the Internet of Things. 2020 International Conference on Computer, Control, Electrical, and Electronics Engineering (ICCCEEE), 1–5.
14. Shi, F., Zhu, W., Zhou, P., & Ge, Y. (2020). Estimating reduction coefficients of parking allocation based on public transportation accessibility: A case study on Nanjing's central district. Journal of Advanced Transportation, 2020, Article ID 1234567.
15. Parmar, J., Das, P., Azad, F., & Kumar, A. Evaluation of Parking Characteristics: A case study of Delhi (Parmar et al., 2020). Transportation Research Procedia, 42, 142-151.

(Provides a case study of parking characteristics in a major Indian city, including methodologies for data collection and analysis.
16. Song, H., Lee, S., Yoon, J., & Park, M. (2020). A smart parking system based on trajectory and obstacle analysis using IoT. Sensors, 20(5), 1351.Zahoor, T., Azam, F., Anwar, M. W., & Ahmad, S. An Investigation of Smart Parking Tools, Technologies, & Challenges (Zahoor et al., 2020). 2021 International Conference on Digital Futures and Transformative Technologies, 1-6.
17. Shiwakoti, N., Stasinopoulos, P., & Fedele, F. Investigating the state of connected and autonomous vehicles: a literature Review (Shiwakoti et al., 2020). Transportation Research Part A: Policy and Practice, 132, 16-32.
18. Diayasa, I. G. S. M., Sri R.G., N. L. W., Winardi, S., Setiawan, A., Wiwoho, M. S., Anindito, B., & Andjarwati, T. (2020). Progressive parking smart system in Surabaya's open area based on IoT. Journal of Physics: Conference Series, 1569, 022043.
19. Rajitha, B., & Reddy, C. V. (2020). Evaluation of Parking Characteristics in Urban Core Areas – A Case Study of Hyderabad City. Journal of Urban Transport, 4(1), 21–30.
20. Elsonbaty, A. A., & Shams, M. Y. (2020). The Smart Parking Management System. International Journal of Computer Science & Information Technology, 12(4), 55–66.
21. Bhalodiya, V. Enhancement of Parking Facility in Main Corridor of M.G. Road, Junagadh City (Bhalodiya, 2019).
22. Arya, A., & Sinha, A. (2019). Parking demand and management in Indian cities: A case study of Bhopal. International Journal of Traffic and Transportation Engineering, 9(2), 45–52.
23. Hima, M. (2019). Study collection of internal control system parking services: Case study Makassar. Global Scientific Journal, 7(7), 1047–1052.
24. Kumeda, M., Yamamoto, T., & Harata, N. (2019). Safety effects of parking manoeuvres. Transportation Research Part F: Traffic Psychology and Behaviour, 65, 1–10.
25. Haan, G., Wouters, M., & Wiering, M. (2019). A measurement method for parking space organisation and vehicle movement. Transportation Research Procedia, 37, 147–154.
26. Reddy, A. L., Sam, B. B., & Prabhakar, A. (2018). A survey paper on a smart parking system. International Journal of Scientific Research and Engineering Development, 1(5), 1–5.
27. Li, S., Zhang, Y., & Ge, Y.-C. (2017). Survey and analysis of parking facilities in an old residential area and parking supply model of a liveable city: A case study of the Ruha community in Jinan, China. Procedia Engineering, 198, 174–182.
28. Kapoor, A., Gupta, R., & Sharma, S. (2016). IoT-based Smart Parking System for Smart Cities. International Journal of Engineering Research and Technology, 5(6), 112–118.
29. Dhakne, S., Kengar, U., Suryawanshi, R. S., Bhagat, A., & Chavan, A. (2016). Smart car parking system. International Journal of Advanced Research in Computer and Communication Engineering, 5(12), 247–249.
30. Chen, Q., Li, B., Yu, L., & Xu, C. (2015). Parking behaviour study in central Shanghai, China. Transportation Research Part A: Policy and Practice, 82, 196–206.
31. Gupte, S., & Younis, M. (2015). Participatory-sensing-enabled efficient parking management in modern cities. In Proceedings of the 40th IEEE Conference on Local Computer Networks (LCN) (pp. 241–244) IEEE.
32. Waje, A., & Kulkarni, A. (2014). Evaluation of Parking Problems in Urban India: A Case Study of Pune City. International Journal of Engineering Sciences & Research Technology, 3(2), 202–207.

33. Zhang, Z., Li, Z., & Wang, Y. (2014). Impacts of on-street parking on urban traffic operation and management. Procedia - Social and Behavioural Sciences, 138, 524–532.
34. Inci, E. A review of the economics of parking (İnci, 2014). Transportation Research Part A: Policy and Practice, 75, 161-175.
35. Co, Z., Polinar, M. A. N., & Payao, R. B. (2022). Multi-level car parking as a viable solution to traffic issues in Davao City. International Journal of Multidisciplinary: Applied Business and Education Research, 3(11), 2191–2197.
36. Litman, T. (2013). Parking Management Best Practices (2nd ed.). Victoria Transport Policy Institute.
37. William, R., Russell, B., & Michael, B. (2013**).** Parking: Issues and policies. In Parking: Issues and Policies (Transport and Sustainability, Vol. 5, pp. 1–16). Emerald Group Publishing Limited.
38. Azari, K. A., Ranjbari, A., & Jafarzadeh, M. (2013). A study on the willingness to shift from private car to public transport in the CBD of Mashhad. Journal of Asian Behavioural Studies, 3(9), 55–64.
39. Ma, X., Sun, X., He, Y., & Wang, Y. Parking Choice Behaviour Investigation: A Case Study at Beijing Lama Temple (Ma et al., 2013). Mathematical Problems in Engineering, 2016.
40. Christina, M., & Constantinos, A. (2012). Illegal parking in urban areas: The case of six Greek cities. Research in Transportation Economics, 31(1), 19–25.
41. van Ommeren, J., Wentink, D., & Dekkers, J. (2011). The real price of the parking policy. Journal of Urban Economics, 70(1), 25–31.
42. Wang, Q.-F., & Wang, Q.-G. (2011). Research on a public parking reservation system based on SMS. In ICCTP 2011: Towards Sustainable Transportation Systems (pp. 673–678). American Society of Civil Engineers.
43. Mathew, T. V., & Rao, K. V. (2007). Introduction to Transportation Engineering. Indian Institute of Technology Bombay.
44. Shoup, D., Willson, R., & Smith, T. (2006). Curb parking search: Effects on traffic congestion. Transportation Research Record: Journal of the Transportation Research Board, 1977(1), 98–103.
45. Box, P. C. (2004). Effects of on-street parking on hazard and congestion: Implications for traffic safety and operations. Journal of Transportation Engineering, 130(2), 178–185.
46. Tong, S. L., Wong, S. C., & Leung, Y. H. (2004). Estimation of parking accumulation profiles using a cluster analysis technique. Transportation Research Record: Journal of the Transportation Research Board, 1882(1), 21–29.
47. David, A., & Jenny, N. (2001). Stated preference survey of parking supply, pricing, and location effects on parking demand in Sydney CBD. Transportation Research Record: Journal of the Transportation Research Board, 1753(1), 50–58.