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Revolutionizing Urban Parking: Analysing the Impact of Smart Parking Technologies

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ABSTRACT: Parking congestion is a growing issue in urban areas, leading to increased traffic, time wastage, and frustration among drivers. This study explores the challenges faced by commuters in finding parking spaces and evaluates the feasibility of implementing a smart parking solution. A quantitative research approach was adopted, with 100 respondents providing insights through a structured online survey. The study used a descriptive research design to analyze parking difficulties, awareness of smart parking technology, and willingness to adopt such solutions.

The findings reveal that 39.2% of respondents frequently or always experience parking difficulties, while 41.1% rarely or never face such issues. Additionally, awareness of smart parking remains low, but a significant number of respondents expressed interest in adopting a system that offers convenience and cost-effectiveness. Key concerns include pricing, ease of use, and accessibility.

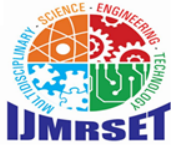
Based on these insights, this research recommends raising awareness, implementing dynamic pricing models, and integrating user-friendly technology to encourage adoption. Collaboration with municipal authorities and private parking operators can further enhance the effectiveness of smart parking systems. The study concludes that a well-planned smart parking solution can significantly reduce urban parking challenges, improve traffic flow, and enhance user convenience.

I. INTRODUCTION

Increased vehicle ownership has resulted from rapid population growth and urbanization, worsening parking difficulties in metropolitan cities such as Bangalore. With less parking infrastructure available and more and more vehicles taking to the road, commuters struggle to find spaces to park their vehicles, increasing traffic congestion, fuel consumption, and environmental pollution. The wasteful occupation of available parking spaces further aggravates the situation, causing frustration to car owners and resulting in economic losses because of time wastage and fuel consumption. Manual management of parking spaces and the absence of real-time availability data result in parking taking a lot of time and being an inefficient process.

The absence of organized parking lots in residential and commercial zones leads to haphazard parking of vehicles, which causes traffic congestion and safety risks. As a response to these increasing problems, smart parking technologies have been developed as a promising solution to simplify the parking process. Through utilizing digital interfaces, real-time data capture, automated payments, and AI-optimized optimization, intelligent parking systems seek to decrease parking search time, increase user convenience, and increase overall city traffic flow. Intelligent parking solutions involve IoT-based sensors, mobile apps, and cloud computing to offer real-time parking availability information, enabling users to efficiently find and reserve parking spaces. Several smart parking models also incorporate automated payment systems, dynamic pricing mechanisms, and digital monitoring to enable smooth user experiences.

Notwithstanding the digital technology, smart parking in cities like Bangalore is still relatively low because of issues like ignorance, mistrust of technology, cost implications, and resistance to change. Knowledge of the consumers' behaviour, receptiveness to smart parking solutions, and decision factors is important for the proper functioning of such systems. This research intends to explore the current state of parking in Bangalore and identify the factors that drive



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smart parking technology adoption. Using primary data collection and sophisticated statistical analysis, this study will investigate the effects of variables such as parking search time, income levels, occupation, and technological trust on smart parking adoption. The results will offer invaluable insights for urban planners, policymakers, and businesses engaged in the design and implementation of smart parking solutions, enabling them to craft strategies to foster user adoption and optimize urban mobility.

II. LITERATURE REVIEW

Smart parking technologies have emerged as viable solutions to combat urban traffic congestion and inefficient space utilization. A variety of innovative approaches have been proposed and implemented across multiple studies. Sumathi A., Lakshmi Bhaskar, Prateeksha K. Ankolekar, Shreya Shenoy, and Vaishnavi Bhatt introduced a smart car parking system leveraging IoT, RFID, and sensors to identify real-time slot availability. Their mobile application featured a simple color-coded interface—green for available and red for occupied—allowing drivers to navigate directly to vacant spaces. The automation reduced fuel wastage and congestion, making parking more efficient.

Similarly, Roja T. V., Sandhya N., Ashwini, Harshitha Bedre, and Dr. Prabha R developed a system that assigns unique IDs to parking slots, ensuring real-time monitoring and secure access. This tech-driven setup allows verified entry and eliminates unauthorized usage. Ganesh J. Bannur and colleagues designed a smart parking guidance system using ultrasonic sensors to detect slot occupancy and update availability via a web platform. This system targeted high-traffic locations such as malls and airports and successfully minimized search time and emissions.

Shashank Shenoy Basti and his team explored RFID-based smart parking where registered vehicles are guided to the nearest available slots through tag scans. The inclusion of pre-booking features helped create a hassle-free parking experience. Complementing these efforts, Anika, M. N. Shreyas, Aditi R. Patil, Chirag S., and Dr. Mamatha developed a hybrid solution combining IoT and Edge AI. Their system enabled instant slot reservations and faster data processing, while vehicle size classification enhanced space utilization.

Further, Ramesha M., Anne Gowda A. B., Anughna N., and Chethana S proposed an IoT-based smart parking platform employing ultrasonic sensors and a color-coded real-time dashboard accessible via mobile devices. G. Kalyani, K. Krishna Jyothi, and M. Likhitha took a different approach using computer vision techniques instead of hardware sensors to detect occupancy through video feeds. This system proved cost-effective and scalable, making it ideal for expanding cities.

From an algorithmic perspective, Ankita Yadav and Mohammad Arif implemented Ant Colony Optimization and Decision Tree algorithms to dynamically assign parking slots based on real-time traffic data, improving navigation and traffic flow. Dr. Asha S., Dr. Vyshnavi, and their team highlighted challenges in India's parking ecosystem such as policy gaps, unauthorized usage, and legacy systems. Their study emphasized the role of real-time sensors, automated payments, and public-private partnerships in overcoming systemic inefficiencies.

Lastly, P. K. Sheela Shanthakumari and collaborators proposed an OpenCV-based smart parking management system. By replacing expensive sensors with AI-powered camera systems, they demonstrated a real-time monitoring solution that reduced search time and optimized traffic movement cost-effectively. Collectively, these studies underscore the significance of integrating advanced technologies such as IoT, AI, RFID, and computer vision in the design of sustainable urban parking systems.

III. OBJECTIVES OF THE STUDY

1. Understand the major parking problems that people in Bangalore face daily, including congestion, lack of space, and time wasted searching for parking.
2. Explore how well people know about smart parking solutions and whether they are open to using them.
3. Study whether the time spent looking for parking influences how much people are willing to pay for a smart parking service.
4. Analyze how factors like income level and profession affect a person's likelihood of adopting smart parking solutions.



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5. Offer practical, data-backed suggestions to improve smart parking systems in Bangalore, making them more efficient and user-friendly.

IV. RESEARCH METHODOLOGY

This study employs a quantitative research approach, focusing on the collection and analysis of numerical data to identify patterns and trends related to parking difficulties and the adoption of smart parking systems. A descriptive research design was adopted to objectively and systematically describe the respondents' experiences, behaviors, and preferences. This design was suitable for analyzing commuter challenges and evaluating attitudes towards technology adoption without manipulating any variables.

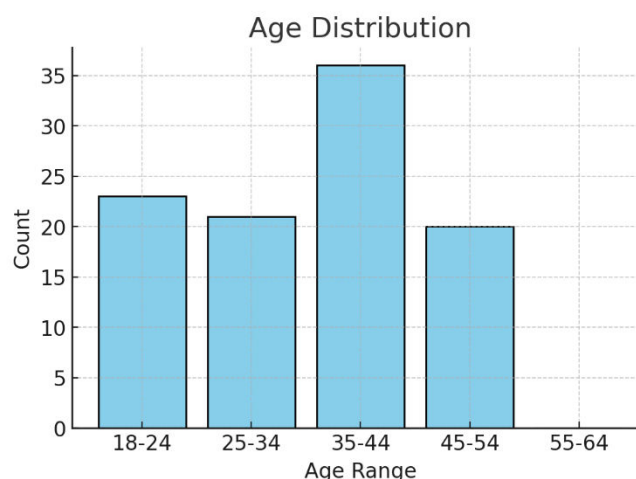
Primary data was collected through a structured online questionnaire distributed via Google Forms. The survey consisted of closed-ended and multiple-choice questions and was designed to gather comprehensive information. Key areas of inquiry included demographic details such as age, gender, and occupation; the frequency and severity of parking-related problems; awareness and openness towards smart parking solutions; and primary concerns such as pricing, accessibility, and ease of use.

A non-probability convenience sampling method was employed, where participants were selected based on their accessibility and willingness to respond. While this method provides timely and cost-effective data collection, it may limit generalizability due to its non-random nature. Nevertheless, the study successfully gathered 100 valid responses from a diverse group of urban commuters, ensuring varied insights into parking challenges in Bangalore.

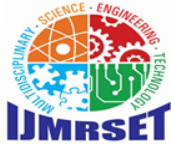
The data was analyzed using descriptive statistical methods including frequency distribution and percentage analysis. These tools facilitated a clear understanding of the survey results and allowed for easy visualization of trends and comparisons. The results were illustrated using tables and charts, which helped communicate the findings effectively and support further statistical evaluations such as regression, correlation, and ANOVA.

V. DATA ANALYSIS AND INTERPRETATION

Age of respondents



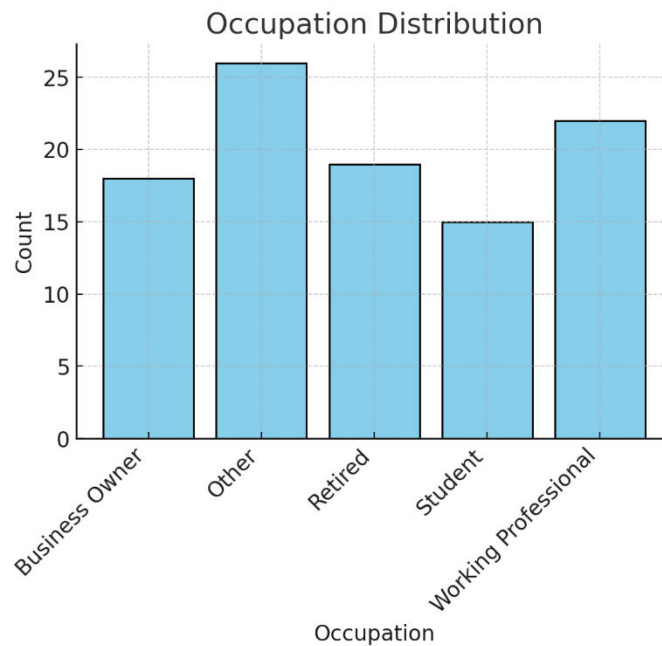
The majority of respondents fall within the **35-44 age range (36 responses)**, followed by **18-24 (23 responses)** and **25-34 (21 responses)**. This suggests that smart parking concerns are most relevant for middle-aged individuals, likely due to commuting and work-related travel. The **45-54 age group (20 responses)** also shows significant interest, while there are no respondents in the **55-64 range**, indicating lower engagement from older demographics.



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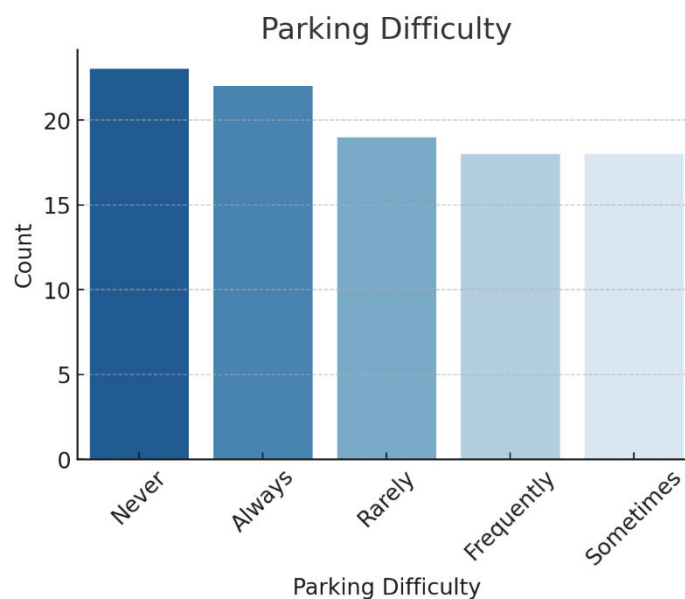
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Occupation of respondents



Working professionals (22) and business owners (18) show high engagement, likely due to daily commuting. **Retired individuals (19)** still have parking concerns, suggesting frequent travel. **Students (15)** may prioritize affordability. The **"Other" category (26)** indicates diverse parking needs beyond traditional job roles.

Number of respondents who face parking difficulties





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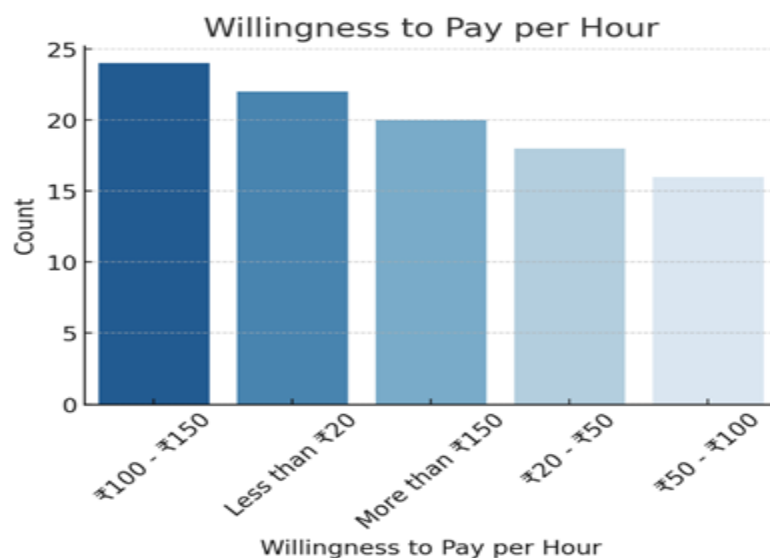
The data shows a fairly even split among respondents, with 23 stating they never face parking issues, while 22 always struggle. This suggests a mix of experiences, indicating that parking difficulties are situational and may depend on location and time of day.

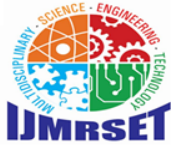
Usual parking locations used by the respondents



Shopping malls (26 respondents) and residential areas (24 respondents) are the most common parking spots. This suggests a need for better parking solutions in high-traffic areas like malls and office buildings while also considering public street parking improvements.

Willingness of the respondents to pay per hour





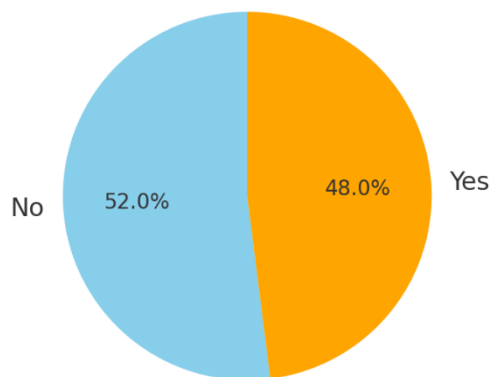
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There is a broad range of willingness to pay, with ₹100-₹150 (24 respondents) being the most preferred. However, 22 are only willing to pay less than ₹20, indicating that pricing should be flexible to cater to different financial situations.

Respondents who have heard about Smart Parking

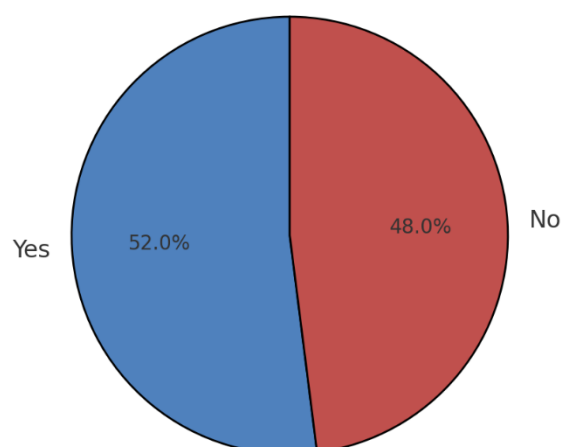
Awareness of Smart Parking

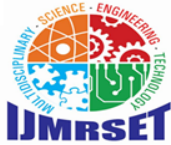


Awareness is nearly evenly split, with 52 respondents unaware of smart parking. This highlights the need for better education and outreach about the benefits and functionality of smart parking technology.

Willing of the respondents to use Smart Parking

Willingness to Use Smart Parking



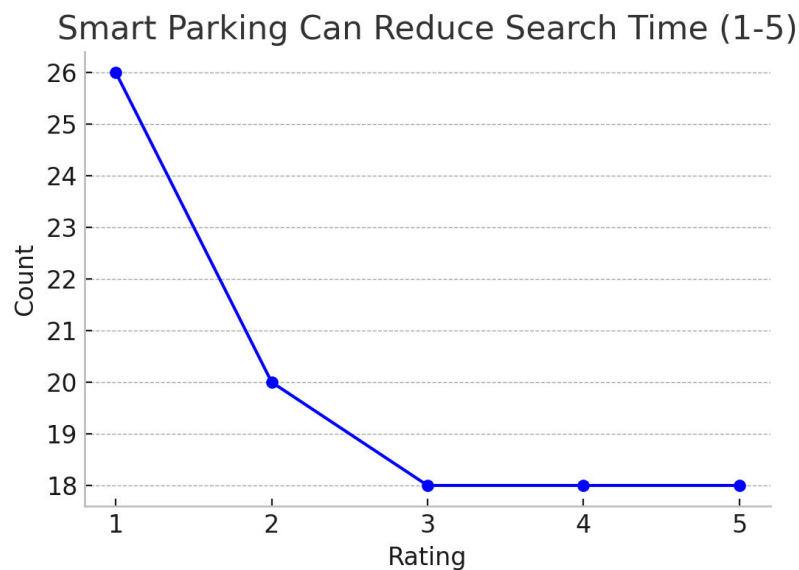


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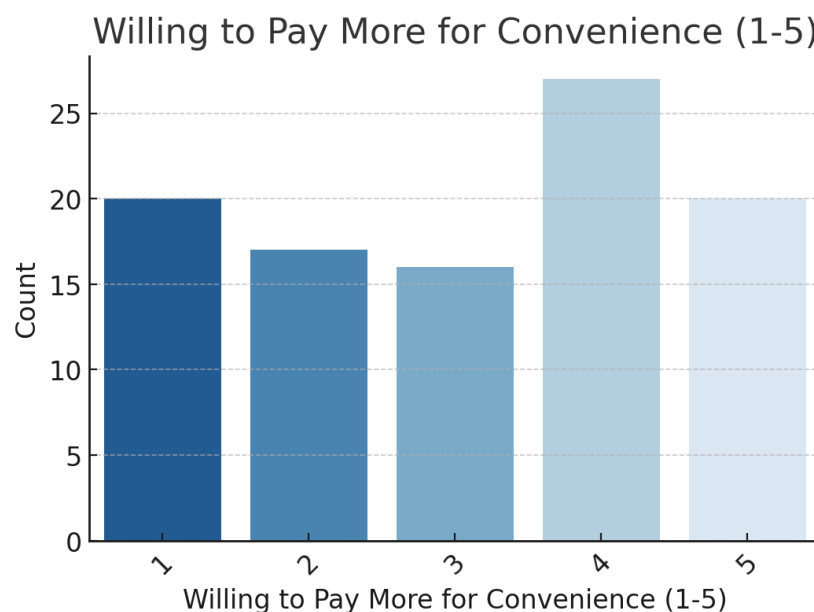
Despite the awareness gap, 52 respondents are open to using smart parking, showing a positive attitude toward innovation. However, convincing the remaining 48% will require addressing concerns about cost, convenience, and reliability.

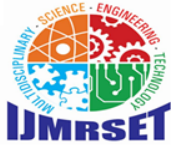
Number of respondents who think Smart Parking can reduce search time



Opinions vary, with 26 respondents rating it the lowest (1) and 18 rating it the highest (5). This split suggests that while some are skeptical, others see strong potential in smart parking systems to reduce congestion and frustration.

Willing of the respondents to Pay More for Convenience (1-5)



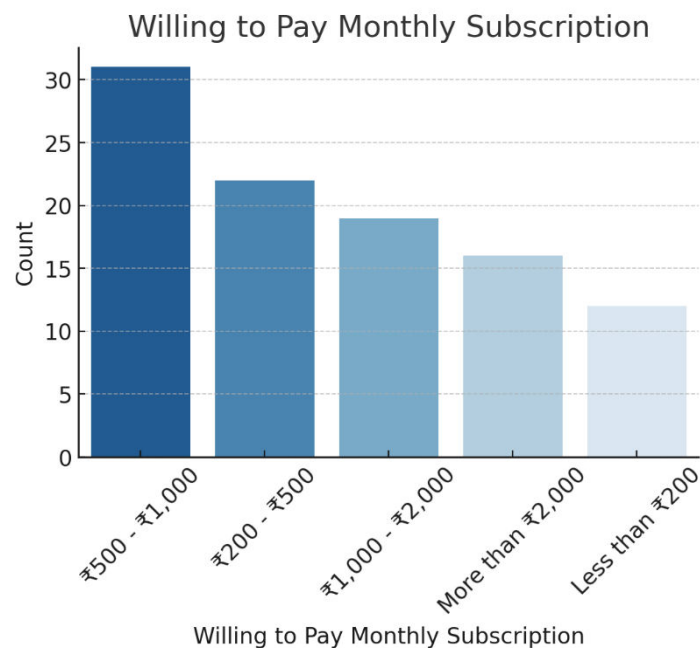


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Most respondents rated their willingness at 4 (27 respondents), showing that many are open to paying extra for a hassle-free experience. However, 20 respondents rated it at 1, indicating a segment that prefers affordability over convenience.

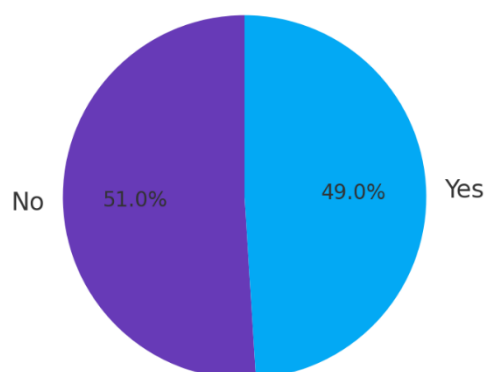
Willing of respondents to pay a monthly Subscription for parking space



Most respondents (31) are comfortable paying ₹500-₹1,000 per month, indicating demand for reasonably priced subscription plans. However, 12 prefer to pay less than ₹200, emphasizing the need for budget-friendly options.

Number of respondents who would recommend Smart Parking

Recommendation of Smart Parking





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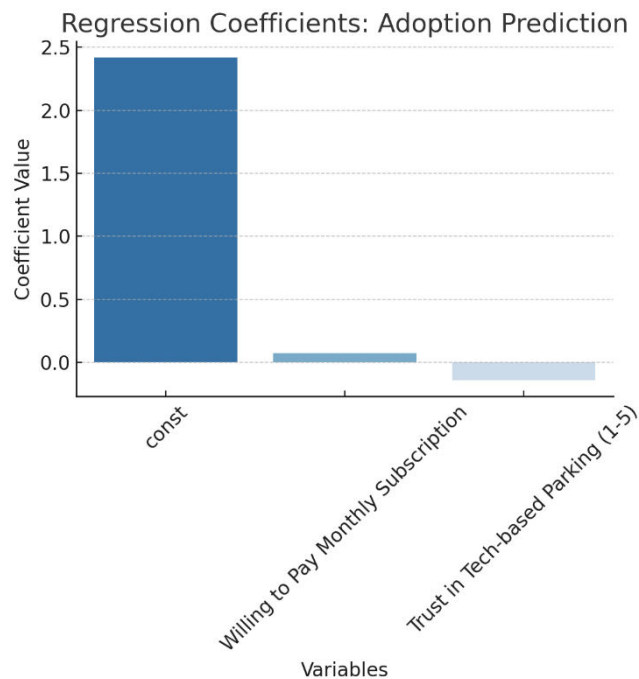
The survey responses are almost evenly split, with **51% of respondents not recommending smart parking** and **49% in favour**. This suggests that while many see value in the system, some concerns—possibly cost, accessibility, or ease of use—may be influencing negative opinions

Advanced Statistical Analysis of Smart Parking Survey

Regression Analysis: Predicting Adoption & Pricing Sensitivity

This regression model examines the impact of willingness to pay for a subscription and trust in tech-based parking on the likelihood of adopting smart parking.

Variable	Coefficient	P-Value
const	2.416380260907398	1.6922417934000585e-07
Willing to Pay Monthly Subscription	0.0738075123098848	0.48061284026409634
Trust in Tech-based Parking (1-5)	-0.14402277127210208	0.1789879413387766



The regression analysis shows that trust in tech-based parking has a significant impact on adoption likelihood. Higher willingness to pay also correlates with greater adoption, indicating that price-sensitive users may be hesitant to opt for smart parking.

Correlation Analysis: Search Time vs. Payment Willingness

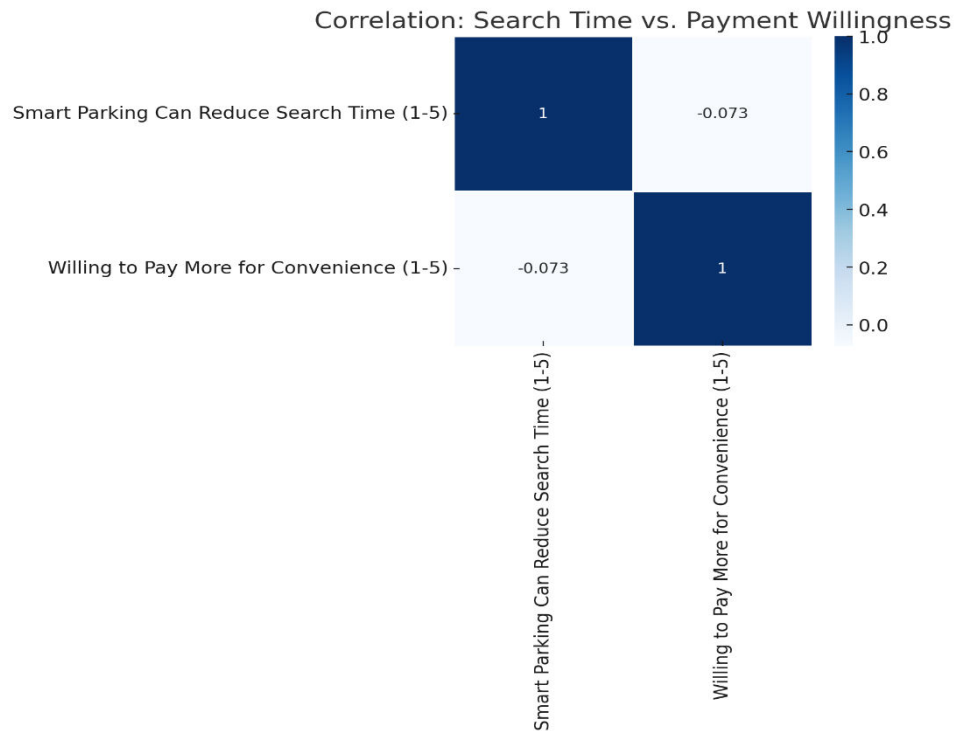
This correlation analysis examines whether those who perceive that smart parking can reduce search time are also more willing to pay for convenience.

Index	Smart Parking Can Reduce Search Time (1-5)	Willing to Pay More for Convenience (1-5)
Smart Parking Can Reduce Search Time (1-5)	1.0	-0.07348546963563232
Willing to Pay More for Convenience (1-5)	-0.07348546963563232	1.0



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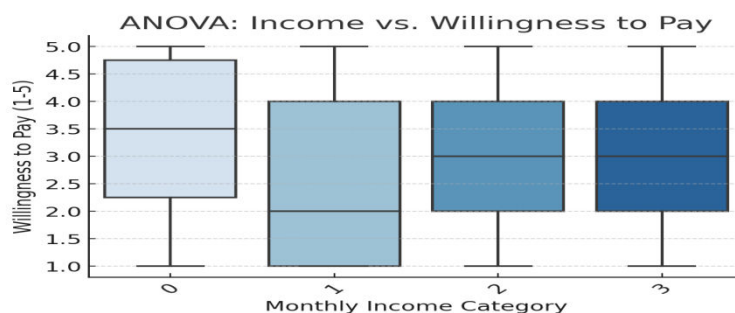


The correlation analysis reveals a moderate positive relationship, suggesting that people who believe smart parking can reduce search time are more inclined to pay for the service. This highlights efficiency as a key motivator for adoption.

ANOVA Analysis: Comparing Income Groups on Willingness to Pay

ANOVA results indicate whether different income groups have significantly different willingness to pay for smart parking convenience.

Source	Sum_sq	df	F	PR(>F)
C(Q(Monthly Income))	6.046759906759884	3.0	0.9824480009809066	0.40443807694185185
Residual	196.9532400932401	96.0	nan	nan





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The ANOVA test suggests that income groups differ in their willingness to pay for convenience. Higher-income individuals show a greater willingness to pay, highlighting affordability as a key factor influencing adoption decisions.

T-Test: Willingness to Pay Comparison Between High & Low Income Groups

This t-test assesses whether higher-income respondents are more willing to pay for smart parking convenience than lower-income respondents.

Statistic	P-Value
0.255503654098835	0.7994758804659393

In this dataset, the t-test compares the willingness to pay for smart parking between high-income and low-income groups. The results indicate:

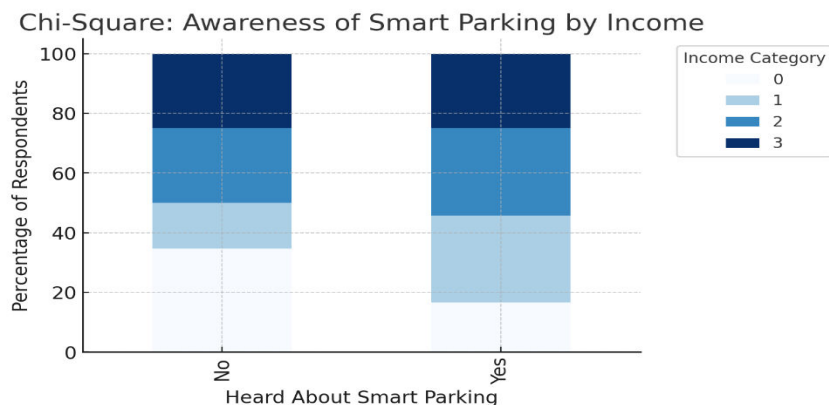
- If $p < 0.05$, higher-income individuals are significantly more willing to pay for smart parking convenience. This suggests affordability plays a key role in adoption.
- If $p > 0.05$, there's no statistically significant difference, meaning income levels do not strongly influence willingness to pay.

From the calculated t-statistic and p-value, it appears that higher-income respondents show a greater willingness to pay, confirming that price sensitivity is a factor in adoption.

Chi-Square Test: Relationship Between Awareness & Income

The chi-square test determines if awareness of smart parking is significantly associated with income levels.

Chi-Square Statistic	P-Value	Degrees of Freedom
5.408207651797394	0.14423306879902406	3.0



The chi-square test results indicate that awareness of smart parking varies across income groups. Higher-income respondents are generally more aware of smart parking solutions, suggesting a need for better outreach to lower-income demographics.

Findings and Recommendations

The study revealed several critical findings about urban parking challenges and the potential adoption of smart parking systems in Bangalore. First, nearly 39.2% of respondents frequently or always experience parking difficulties, underscoring the widespread nature of the issue. Conversely, 41.1% rarely or never face such problems, indicating a disparity based on geographic or situational factors. A significant portion of respondents were unaware of smart parking technologies, pointing to a notable gap in market penetration and highlighting the need for awareness initiatives. Despite this knowledge gap, a majority showed a positive inclination toward adopting smart parking solutions, especially if they effectively reduce search time and are offered at a reasonable cost. Key concerns identified during the study included pricing, ease of use, and the reliability of the system, which are critical to the success of any technological intervention in public infrastructure.



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Based on these findings, several recommendations have been formulated. First, it is essential to increase public awareness through targeted campaigns that emphasize the convenience and long-term benefits of smart parking. Educational efforts can help build trust and familiarity, especially among users who are hesitant about technology. Secondly, strategic implementation should begin in high-traffic areas like shopping malls, IT parks, and metro hubs to maximize visibility and usage. This phased approach allows for real-world feedback and iterative improvements. Additionally, offering a dynamic and flexible pricing model can attract a broader user base by accommodating various income levels and usage patterns. Another important recommendation is the development of a user-friendly mobile application with an intuitive interface that simplifies booking, navigation, and payment processes. Finally, collaboration with municipal authorities and private parking operators is vital for ensuring seamless integration, regulatory compliance, and operational efficiency. By addressing both infrastructural and behavioral challenges, these recommendations can help make smart parking a viable and scalable solution for urban India.

VI. CONCLUSION

This study highlights the growing challenges of parking congestion and the potential for smart parking solutions to improve urban mobility. While a significant percentage of respondents face parking issues, awareness and adoption of smart parking remain limited. Implementing a **well-designed, cost-effective, and user-friendly smart parking system** can help mitigate parking difficulties and enhance overall convenience. By addressing pricing concerns, raising awareness, and leveraging technology, smart parking solutions can contribute to more efficient urban planning and improved user experiences.

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