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A Comprehensive Review on Parking Demand Assessment and Management Strategies for Sustainable Urban Mobility

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Abstract: In medium-sized Indian cities, rapid urbanization and growing motorization have had a substantial impact on transportation systems, creating serious parking issues, particularly in commercial areas. Car ownership and travel demand have significantly increased as a result of the fast expansion of commercial activity in cities like Rewa. There is a mismatch between parking availability and demand, nevertheless, because parking infrastructure development has not kept up with this expansion. Widespread problems like uncontrolled on-street parking, decreased road capacity, traffic congestion, longer travel times, and environmental pollution have resulted from this mismatch.
With an emphasis on their applicability to medium-sized urban settings, this review paper summarizes the body of research on parking demand assessment, parking behavior, and management techniques. In order to comprehend parking features and demand patterns, it looks at conventional parking assessment factors such parking accumulation, duration, turnover, and occupancy. The paper also examines contemporary strategies to maximize parking use and minimize search time, such as shared parking ideas, smart parking systems, and machine learning-based prediction models. The study also emphasizes how infrastructure planning, pricing schemes, and parking regulations affect user behavior and travel choices. In order to control parking usage and lessen traffic, demand management techniques such paid parking, time limits, and parking zoning are addressed. Additionally, the potential of cutting-edge solutions like IoT-based systems and automated multilevel parking to increase efficiency is assessed. The review identifies key gaps, particularly the lack of localized data, weak enforcement of regulations, and limited adoption of smart technologies in Indian cities. It concludes that an integrated, data-driven, and context-specific approach is essential for sustainable parking management.

Keywords: Parking Demand, Parking Management, Smart Parking, Shared Parking, Traffic Congestion, Urban Mobility.

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I. INTRODUCTION

Driven by a number of interconnected reasons, urban transport systems in Tier-II and Tier-III cities are undergoing rapid and frequently unstructured transition. The most notable of them is the ongoing rise in car ownership, which is driven by shifting lifestyle preferences, simple access to financing options, and rising income levels. Travel demand inside metropolitan regions has increased concurrently with the growth of commercial activities such as retail markets, shopping malls, offices, and service centers. Unplanned and organic urban expansion, where the availability of infrastructure, such as parking lots and road networks, has not kept up with the rate of urbanization, exacerbates this increase. Parking has become an essential part of traffic and transportation management in this changing urban environment. Because it takes up valuable carriageway space, particularly in crowded commercial zones, it has a direct impact on traffic capacity. Due to their disruption of smooth traffic flow and reduction of effective road width, improper parking practices are a major contributor to traffic congestion. Furthermore, cars looking for parking spots use more fuel and circulate needlessly, which raises air pollution and degrades the environment. Parking is becoming a dynamic aspect affecting total urban mobility and

sustainability rather than a static problem. The absence of parking infrastructure that has been scientifically planned has led to a number of operational and safety issues in cities like Rewa. Uncontrolled on-street parking frequently causes carriageway encroachment, which drastically reduces the roadways' useful width. Traffic congestion, delays, and decreased travel efficiency follow from this.

Additionally, the lack of designated parking spaces and pedestrian walkways puts people in dangerous situations and raises the possibility of collisions and confrontations between cars and foot traffic. Understanding international research trends in parking demand evaluation and management is crucial given these difficulties. In order to find solutions that are workable, sustainable, and flexible to the socioeconomic and infrastructure situations of Indian cities—especially those in the medium and small urban categories—this analysis will examine current approaches and tactics.

II. OBJECTIVES OF THE STUDY

The main objective of this review paper is to examine the existing literature on parking demand assessment methods and parking management strategies to improve traffic operations and promote sustainable urban transportation. The specific objectives are:

- To review the concepts and significance of parking demand assessment in urban transportation planning and traffic management.
- To study the various methods used for parking demand estimation, including parking inventory, occupancy, accumulation, turnover, and parking duration surveys.
- To identify the key factors influencing parking demand, such as land use, vehicle ownership, population density, and travel characteristics.
- To analyze the impacts of parking demand on traffic flow, congestion, travel time, road safety, and environmental sustainability.
- To review different parking management strategies, including on-street and off-street parking management, parking pricing, time restrictions, shared parking, and smart parking systems.
- To evaluate the effectiveness of Intelligent Transportation Systems (ITS) and modern parking technologies in optimizing parking utilization and reducing traffic congestion.
- To identify research gaps and recommend suitable parking demand assessment and management strategies for developing efficient, sustainable, and user-friendly urban parking systems.

III. REVIEW OF LITERATURE

Table 1: Comparative Study

SN	Author(s) & Year	Study Focus	Methodology / Approach	Key Findings	Inference / Insight
1	Yan et al. (2020)	Shared Parking Behavior	Hybrid Random Parameter Logit Model + Cumulative Prospect Theory	User participation influenced by psychological factors and revenue uncertainty	Behavioral factors are critical for successful shared parking implementation
2	Zhao et al. (2021)	Shared Parking Optimization	Mathematical modeling and heuristic algorithms	Improved spatial and temporal utilization of parking spaces	Shared parking effectively reduces the parking demand–supply gap
3	Waheed et al. (2021)	Smart Parking System	Learning automata, reservation system, and encryption	Reduced waiting time and improved parking	Smart reservation systems significantly improve parking efficiency

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				allocation efficiency	
4	Provoost et al. (2020)	Parking Occupancy Prediction	IoT and Machine Learning (Neural Networks, Random Forest)	Accurate prediction of parking occupancy	AI-based prediction minimizes parking search time
5	Christiansen et al. (2017)	Parking and Travel Behavior	Regression analysis using travel survey data	Parking availability and pricing influence private vehicle usage	Parking policies can effectively manage travel demand
6	Wang et al. (2021)	Automated Parking	Reinforcement Learning-based optimization	Reduced waiting time in multi-level parking facilities	Automation improves parking efficiency in limited spaces
7	Singh et al. (2020)	Parking Optimization	Firefly Algorithm with Neural Network	Reduced parking search time and enhanced system performance	AI and metaheuristic techniques improve parking management
8	Parmar et al. (2020)	Parking Demand Assessment	Comprehensive literature review	Identified factors such as parking cost, accessibility, and walking distance	Scientific parking demand assessment is essential for effective planning
9	Gomaria et al. (2021)	Parking Behavior Analysis	Clustering techniques (DBSCAN and K-Means)	Identified temporal parking patterns	Data analytics supports better parking planning and management
10	Jonkeren et al. (2020)	Bicycle Parking Behavior	Behavioral and policy analysis	Highlighted the importance of bicycle parking near transit stations	Integration of bicycle parking with public transport is necessary
11	Jian et al. (2020)	Car Sharing and Parking Sharing	Integrated system modeling	Improved utilization of transportation resources	Shared mobility significantly reduces parking demand
12	Findley et al. (2020)	Parking Safety	Crash data analysis	Parking maneuvers increase accident risk	Proper parking design enhances road safety
13	Biswal et al. (2013)	Parking Space Analysis	Comparative study	Evaluated the efficiency of different parking layouts	Efficient parking design increases parking capacity

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14	Hoehne et al. (2019)	Parking Infrastructure Growth	Spatial analysis	Excessive parking provision leads to inefficient land use	Optimized parking infrastructure planning is essential
15	Horng et al. (2019)	Parking Search Mechanism	Cooperative vehicle communication	Reduced parking search time through communication systems	Smart communication systems improve parking efficiency
16	Khalid et al. (2021)	Smart and Autonomous Parking	Survey study	Discussed future scope of autonomous valet parking	Automation represents the future direction of parking systems
17	Kirschner et al. (2020)	Parking Policy	Empirical urban study	On-street parking policies influence user behavior	Effective parking policies are essential for demand management
18	Levin et al. (2020)	Autonomous Vehicle Parking	Infrastructure design study	Autonomous vehicles may reduce future parking demand	Autonomous vehicles will transform parking infrastructure requirements
19	Li et al. (2020)	Automated Garage Systems	System design and scheduling	Improved vehicle handling efficiency in automated garages	Automation increases parking throughput and operational efficiency
20	Mei et al. (2019)	Parking Pricing vs. Reservation	Comparative analysis	Parking pricing is more effective than reservation strategies in certain situations	Economic measures can effectively regulate parking demand

IV. DISCUSSION

The reviewed literature indicates that parking demand assessment and management have become essential components of urban transportation planning due to rapid urbanization and the continuous increase in vehicle ownership. Traditional parking management approaches primarily focused on providing additional parking spaces; however, recent studies emphasize optimizing the utilization of existing parking infrastructure through advanced technologies, intelligent transportation systems (ITS), and effective policy interventions.

Several researchers have highlighted that parking demand is influenced by various socio-economic and transportation factors, including land use, population density, vehicle ownership, parking pricing, accessibility, walking distance, and public transport availability. Accurate estimation of parking demand through occupancy surveys, accumulation studies, turnover analysis, and parking inventory surveys is fundamental for effective parking planning.

Recent advancements in Artificial Intelligence (AI), Internet of Things (IoT), Machine Learning (ML), and Reinforcement Learning have significantly improved parking management systems. Smart parking guidance systems enable drivers to locate vacant parking spaces in real time, thereby reducing parking search time, vehicle delays, fuel consumption, and traffic congestion. Reservation-based parking systems and

automated parking garages have further enhanced parking efficiency by maximizing space utilization.

Shared parking has emerged as a promising strategy for balancing parking demand and supply. Studies have demonstrated that shared parking allows multiple users to utilize the same parking space at different times, thereby reducing the need for constructing additional parking facilities. However, successful implementation depends on user acceptance, appropriate pricing mechanisms, and supportive government policies.

Parking pricing policies have also proven effective in regulating parking demand. Dynamic pricing encourages better utilization of available parking spaces while discouraging long-term occupation of premium parking locations. Similarly, restrictions on on-street parking and the promotion of off-street parking contribute to smoother traffic operations and improved road safety.

The literature also indicates that future parking management will increasingly rely on autonomous vehicles, connected vehicle technologies, and intelligent parking infrastructure. Automated valet parking systems and cooperative vehicle communication are expected to transform urban parking operations by reducing parking space requirements and improving accessibility.

Overall, the reviewed studies emphasize that a combination of technological innovation, effective parking policies, scientific demand assessment, and sustainable urban planning is necessary to address the growing parking challenges in modern cities.

V. RESEARCH GAP

Although considerable research has been conducted on parking demand assessment and management, several research gaps remain.

- Most existing studies have been conducted in developed countries with homogeneous traffic conditions, whereas limited research addresses heterogeneous traffic conditions commonly observed in Indian cities.
- Many parking demand models do not adequately consider mixed traffic comprising two-wheelers, auto-rickshaws, cars, buses, and non-motorized vehicles.
- Limited studies have integrated parking demand assessment with traffic congestion, travel time, and roadway capacity analysis.
- Few studies have investigated parking characteristics in medium-sized Indian cities such as Rewa, where roadside parking and informal parking practices significantly affect traffic flow.
- The application of Artificial Intelligence and Smart Parking Systems remains limited in developing urban areas due to infrastructure and financial constraints.
- There is insufficient research on evaluating the effectiveness of integrated parking management strategies that combine parking pricing, shared parking, intelligent parking guidance, and policy interventions under Indian traffic conditions.
- More city-specific parking demand models are required to support sustainable urban transportation planning and policy development.

VI. GENERAL BACKGROUND

Parking is the act of stopping and disengaging a vehicle and leaving it unoccupied. Parking is inevitable but is creating problems also, especially in urban areas. Parking is usually made along the sides of the street or road itself near to residence, shopping malls, markets or other busy areas. This might reduce the capacity of the roadway, if not properly managed. Proper parking management strategies and proper enforcement is necessary for urban areas. If properly managed, parking facilities can generate revenue also. It could also help in reducing the demand for parking.

A. Types of Parking

Parking is usually done along the sides of the street. It could be shifted to some other places as a part of parking management. Based on this, parking could be categorized into on-street parking and off-street parking

On-street Parking: Along the sides of the road itself is known as on-street parking. This is the most common type of parking. In some roads, there could be restrictions which might be intended to avoid obstructions to nearby facilities. Restrictions are imposed commonly using sign boards. Parking could

be done on only one or both sides of the roadway. On-street parking could be divided into following types based on the parking angle:

Parallel parking: The vehicles are parked along the length of the road. In this type, there is no backward movement involved while parking or unparking the vehicle. Thus, it is the safest type of parking. But, it requires more kerb length and thus reduces the parking capacity. It causes least obstruction to through traffic.

Perpendicular parking: In this type, vehicles are parked perpendicular to the road. It consumes more road width compared to other types, thus reducing through traffic capacity. It needs less kerb space. So, a greater number of vehicles could be parked. The complex maneuvering in this type of parking could cause accidents. Angular parking Angular parking is similar to perpendicular parking, except that the parking angle is inclined. As parking angle increases, a greater number of vehicles could be parked. Thus, angular parking could help in occupying more vehicles compared to parallel parking. Also, it consumes less road width than perpendicular parking. The parking angle could be 30°, 45° or 60°.

Off-street Parking: These are parking areas in some urban centers, which are exclusively allotted for parking which will be at some distance away from the main stream of traffic. Such a parking is referred to as off-street parking. They could be managed by either private or public agencies. Access for these facilities could be for public or private use. Construction of such facilities might require large amount of funding. This cash could be returned by collecting parking fees. Also, it should not be too high, which might encourage on-street parking.

The types of off-street parking facilities include:

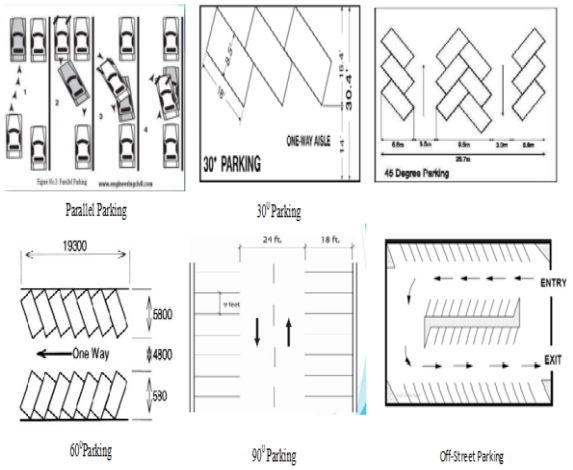
Surface car parking: These are parking facilities provided at the surface and at some distance from the area of activity. Arrangements are made for systematic entry and exit of the vehicles. Proper the circulation area should be there for the vehicles to move around. Stalls should be there with suitable dimensions as per the need. The main advantage for this type of parking is that it requires minimum investment. Also, this could be facilitated only if there is availability for proper land area. Land cost in urban areas could come out as an issue during investment.

Underground parking: This is usually built if there is not much space available for surface parking. It is usually located near urban centers or shopping malls where space is less. The construction of this facility could be costlier due to the fact that it requires extensive excavation, construction of retaining walls, ventilation and lighting. Also, it could be single level or multi-level and it depends on the type of soil available at the site and also the level of water table there. Underground parking facility requires illumination during all hours.

Multi-level Car Parking: These are parking facilities which have more than two-levels above the surface. They are usually provided in apartments & commercial establishments including malls, multiplex for parking of cars. This requires large amount of investment as well as large extent of parking space. The major problem faced by this facility is that it is difficult to get returns because vehicle owner's reluctance to park in a multi-level car parking facility. In urban areas, most of the vehicle park for short durations. Drivers of such vehicles would not like park in a multi-level facility because of the chance of time loss and maneuvering difficulty. Thus multi-level parking systems are not always a feasible solution for parking woes.

Roof parking: Roof top parking is one of the creative ways to solve parking problems in urban areas. This kind of parking does not require extra land space as it utilizes the area above roofs. Also, investment will be much lesser. Access ramps or mechanical lifts should be provided for vehicles to access roof.

Automated parking systems: In this type of parking, after the vehicle is parked on the platform, the system will move the vehicle to available parking spaces somewhere in the structure. The vehicles can be moved horizontally as well as vertically within the system. The major advantage is that the parking space could be smaller because no one need to get in and out of the vehicle and it parks by itself. Since it is automatic, it does not require any staff.



B. Parking Parameters

The extent of improvement required for a parking facility could be identified only after analyzing the existing parking conditions prevailing in the region. This study could be done by finding out certain parking parameters. These parking parameters include:

Parking Accumulation: It is the total number of vehicles which was parked in a given interval of time. It can be depicted by using an accumulation curve with number of vehicles on ordinate and the time interval on abscissa. Accumulation curve for each type of vehicle at a particular parking spot could be drawn. The maximum value of accumulation at a given time interval will give the peak parking demand for that parking area.

Parking Volume: It is defined as the total volume of vehicles parked at a given duration of time. Repeating vehicles are not considered for finding this parameter. It depicts the actual volume of vehicles entered into the area.

Parking load: The area under accumulation curve gives the parking load. It could be obtained by multiplying the number of vehicles occupying a parking area at each time interval with the time interval. Its unit is vehicle hours.

Average parking duration: It could be defined as the time duration for which the vehicles each type is parked in a given area. It could also be defined as the ratio of total vehicle hours to the total number of vehicles parked.

Parking supply: Parking supply could be defined as the total number of available space required for the vehicles to park. It is usually expressed as per the space requirement for cars.

C. Parking Surveys

Parking surveys are commonly done to find out the parking parameters. The most commonly employed parking survey methods include in-out survey, fixed period sampling and license plate method of survey.

In-out survey: In this survey, the occupancy count in the selected parking lot is taken at the beginning. Then the number of vehicles that enter the parking lot for a particular time interval is counted. The number of vehicles that leave the parking lot is also taken. The final occupancy in the parking lot is also taken. Here the labor required is very less. Only one a person may be enough. But from this survey, one cannot get any data regarding the time duration for which a particular vehicle used that parking lot. Thus, we cannot estimate the parking fare from this survey.

Fixed period sampling: For quick survey purposes, a fixed period sampling can be done. This is almost similar to in-out survey. All vehicles are counted at the beginning of the survey. Then after a fixed time interval that may vary between 15 minutes to 1 hour, the count is again taken. Here there are chances of missing the number of vehicles that were parked for a very short duration. License plate method of survey Using License plate method of survey, the most accurate and realistic data could be obtained. In this type of survey, every parking on the road is monitored at a continuous interval of 15-30 minutes or so and the license plate number is noted down. This will give the data regarding the duration for which a particular vehicle was using the road way as parking. This will help in calculating various parking statistics and the fare because fare is estimated based on the duration for which the vehicle was parked. If the time interval is shorter, then there are less chances of missing short-term parkers. But this method is very labor intensive.

VII. CONCLUSION

The literature review demonstrates that effective parking demand assessment is essential for improving urban mobility and reducing traffic congestion. Various parking survey methods, including occupancy, accumulation, turnover, and parking

inventory surveys, provide valuable information for estimating parking demand and evaluating parking performance.

Recent advancements in Artificial Intelligence, Machine Learning, Internet of Things, and Intelligent Transportation Systems have significantly improved parking management by reducing search time, optimizing parking utilization, and enhancing user convenience. Shared parking, automated parking systems, and dynamic parking pricing have emerged as sustainable strategies for addressing parking shortages in urban areas.

Despite these advancements, developing countries continue to face significant parking challenges due to rapid urbanization, increasing vehicle ownership, inadequate parking infrastructure, and weak enforcement of parking regulations. Therefore, scientific parking demand assessment combined with efficient management strategies is essential for reducing congestion, improving travel efficiency, enhancing road safety, and promoting sustainable transportation.

The findings of this review provide valuable guidance for researchers, urban planners, and policymakers in developing effective parking management strategies suitable for rapidly growing cities.

VIII. FUTURE SCOPE

Future research should focus on developing city-specific parking demand prediction models using Artificial Intelligence, Machine Learning, Geographic Information Systems (GIS), and Big Data analytics. Smart parking technologies integrated with IoT sensors, mobile applications, and cloud-based platforms can provide real-time parking information and improve parking utilization.

Further studies should investigate the integration of parking management with traffic signal optimization, public transport systems, and sustainable mobility planning. Research is also required to evaluate the impacts of electric vehicles, connected vehicles, and autonomous vehicles on future parking demand.

For Indian cities, particularly medium-sized cities such as Rewa, future studies should develop localized parking demand models considering mixed traffic conditions, roadside activities, land-use characteristics, and socio-economic factors. Such studies will support evidence-based urban planning and contribute to more efficient, sustainable, and user-friendly parking management systems.

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