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Original Article

Impact Assessment of Parking Facilities on Ridership- A Case Study At Selected Stations of Namma Metro

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Abstract - *Navigating Bengaluru's well-known traffic presents a daily challenge. Bengaluru's Namma Metro has been playing a vital role in mitigating the city's transport issues. The difficulty of reaching the stations—the first-mile and last-mile connection—remains a major hurdle for the users. This often forces commuters to continue using their private vehicles, though there is a well-connected metro system in the city. This research investigates the role of parking facilities at metro stations in addressing this first and last-mile issue and assesses their actual effect on the choice to use the metro. Surveys were carried out at Jalahalli, Baiyappanahalli, Mysuru Road, and Yelachenahalli metro stations, as well as in their influence areas. The survey data were combined with a 24-hour video analysis of the Yelachenahalli parking space to study usage, parking patterns, and parking statistics. The analysis shows that parking availability has a strong impact on metro ridership. From the questionnaire survey, it is found that 30% of current "Park and Ride" users stated they would not use the metro entirely if a parking facility is not provided at stations. This suggests that parking is not a supplementary amenity but a fundamental requirement that supports metro usage. Despite high demand, many potential metro users avoid using the parking facility due to high costs, safety issues, and a lack of adequate parking space. Resolving these issues is crucial to encouraging more people to switch from private cars to the metro, a necessary step for reducing traffic congestion on the city's roads.*

Keywords - *First/last Mile Connectivity, Metro Usage, Metro ridership, Park and Ride, Parking facilities.*

1. Introduction

Urban transportation systems are essential to the sustainable growth of urban areas, where growing numbers of people and cars have led to serious problems with traffic, pollution, and mobility. In this sense, reliable, efficient, and ecologically friendly public transportation is provided by mass rapid transit systems, such as Bengaluru's Namma Metro. However, the availability and administration of parking facilities at metro stations. They are one of the most important external elements that affect commuter choices and are crucial to the success and use of such systems.

Parking facilitates smooth first and last-mile connectivity between private and public transportation. The quality, affordability, accessibility, and sufficiency of parking infrastructure can all have a big influence on commuters' choices to use metro services. Potential users are frequently deterred from switching from private vehicles to public transportation by inadequate or badly managed parking, which lowers overall ridership levels. From their residences, which may be located many kilometres from the closest station, commuters can drive or ride their own vehicle, park it safely, and then take the metro to get through the most crowded areas of the city. This concept provides a hybrid solution that combines the efficiency and predictability of the metro for the major commute with the convenience of a private automobile for the initial trip. There are essentially two ways that Namma Metro affects traffic in Bengaluru. Core metropolitan corridors have been effectively decongested, but first- and last-mile connectivity-related supporting infrastructure is necessary to realize their full potential. The most important component of this support system is the availability of parking at more than 80% of its stations.

- Totally, there are 32 stations in the green line, 37 stations in the purple line, and 16 stations in the yellow line that are being operated in NAMMA METRO Bengaluru.
- Among them, 66 stations have a parking facility provided at the station, and 5 stations have a parking facility located near the metro stations. (source: BMRCL)
- Parking has been provided for two-wheelers, cars, and LCVs. Most stations have parking only for two-wheelers.

A "Park and Ride" mentality is deliberately encouraged by this vast parking system. BMRCL has made the metro accessible to a much larger population by facilitating commuters' integration of their private automobile travel with the system, which has greatly reduced traffic on the roads. The strong "Park and Ride" facility continues to be the most

practical and popular way to close the connectivity gap, even though alternative options like feeder buses and shared mobility services are also a part of the ecosystem.

2. Literature Review

2.1. Literature Review on Parking Assessment

The methodology for vehicle parking analysis: case study – city of Prishtina, work carried out by Lajqi Naser et al. (2017). The problem of parking is a serious worry for individuals and the government in Prishtina, the capital of Kosovo, where urban mobility and the growth in private automobiles are permanent trends. Parking management is regarded as vital for tackling difficulties linked to people's mobility and land-use structure. To explore this issue, the first ring of Prishtina's city core was split into eleven sub-zones, with Sub-zone II found to have the most serious concerns. Data for analysis were obtained directly from these sub-zones using an observation survey approach on certain days in 2014 and 2016, from 6:00 to 18:00. The investigation of Sub zone II focuses on essential parking variables such as accumulation, parking loads, parking duration, parking turnover, and the reasons for parking. Four distinct parking places within Sub zone II were selected and analyzed: Parking Lot E, Parking Lot A, Parking Lot M, and Parking Garage PG. To calculate occupancy counts, parking length, turnover for these lots, vehicle entrance and departure numbers, the "In-out survey" approach was applied for data collection.

The results demonstrated a considerable variation in parking statistics between the free parking lots (E, A, M) and the paid Parking Garage (PG). Specifically, the average occupancy for parking lots E, A, and M was over 100% (124.8%, 143.6%, and 116.4% correspondingly), showing demand surpassing available legal spots. In comparison, the average occupancy for Parking Garage PG was substantially lower at 53%, partly because it is a paid parking facility.

The reasons for parking in these regions include closeness to destinations, absence of fees (for E, A, M), home, job, business, shopping, and social activities. To alleviate the parking concerns in lots E, A, and M, the report advises creating an extra parking structure for homeowners and introducing fees for parking bays with a two-hour length [1]. Parking space efficiency monitoring near metro stations in Noida was carried out by Nazim et al. (2020). Research was carried out to track the efficacy of parking spots adjacent to metro stations in Noida, Gautam Budh Nagar, depending on the source that was given. Three separate parking lots were the topic of the study: two for NA personnel (one for two-wheelers and one for four-wheelers) and one for auto rickshaws. Parking information, such as occupancy, accumulation, volume, duration, and load, was obtained and evaluated for the research.

Over the course of five working days, data were acquired employing the license plate technique, which has been defined as a practical and helpful instrument for recognizing vehicle types. The examination of the data obtained indicated the overall average parking efficiency for the tested sites. The two-wheeler staff parking had an average efficiency of 68.75%, the four-wheeler staff parking showed 65.22% efficiency, and the car stand parking was determined to be 69.22% efficient. Given that all assessed efficiencies were over 65%, the research determined that these parking places might be regarded as adequate. At the four-wheeler and vehicle standing sites, some of the difficulties were observed, which also include haphazard parking affecting efficiency. Labeling of parking spaces for optimal space utilization, placing combined entry/exit locations away from the main road to mitigate congestion, and sending traffic police to handle unlawful parking by cars were some of the recommendations that are included [2]. Comparison, analysis, and way forward of various parking policies in metro cities of India was carried out by Pujara and Divi (2022).

This research focuses on the parking rules of the metro in various Indian cities, mainly concentrating on Surat, Bengaluru, Pune, and Delhi. It finds that these policies were based on the framework provided by a toolkit prepared by the Asian Development Bank (ADB) for the Ministry of Urban Development (MoUD) in India, which has major goals for parking policies. The investigation shows that parking regulations often consist of objectives and instructions. While there are aims that are shared throughout cities, such as reducing private car usage and encouraging public transport systems, the clarity and nature of these objectives vary.

The research says that policy objectives typically have no clarity, are subjective, and would benefit from being more focused and quantified. Using Pune's strategy as an example that contains precise aims. Directives, categorized into Policy/Legal/Planning, Administrative, and Direct-Action categories, represent the actionable paths to attain objectives. The report shows that directions need to be explicitly matched with the objectives for improved execution, emphasizing Bengaluru's policy framework in this respect. Key instructions noticed have parking pricing, promoting Park & Ride, implementing technology, and regulating on-street and off-street parking. The result shows that effective parking regulations will have focused and measurable objectives, explicit mapping of directions to objectives, and participation with residents and experts throughout creation [3].

Raju et al. (2023) carried out a study on parking systems and their analysis. The increasing rate of private vehicle usage, encouraged by fast-growing economies and insufficient legislation, has made parking a global issue, acting as a barrier to efficient management of traffic and resource utilization. This issue is particularly present in urban areas of developing countries, such as Ettumanoor, India, where a sudden rise in human population and vehicle numbers (e.g., human population from 45,000 to 1 lakh, vehicles from 2 lakh to over

5 lakhs in 26 years) has led to increased traffic congestion and huge parking demand. Despite two-wheelers accounting for a larger fraction of traffic volume, vehicles demonstrate a higher growth rate over a decade (10-12% compared to 3-9% for two-wheelers), thus creating a larger gap between parking demand and available supply. Recognizing parking as an important yet under-studied feature of personal transportation, this study intends to understand parking decision behavior and real demand by examining key aspects of parking, such as accumulation, volume, load, duration, and supply. Data was obtained from six main routes in Ettumanoor by the in-out survey method.

The report describes several parking kinds, including on-street (parallel, perpendicular, and angular) and off-street facilities (surface, subterranean, multi-level, roof, and automated systems), each having a specific impact on road capacity, safety, investment, and user convenience. To solve the estimated shortfall of 2048 Equivalent Car Spaces (ECS) in Ettumanoor by 2030, the report provides both short-term supply increases and long-term demand reduction measures. Crucially, it recommends that any new off-street parking facilities should be financially supported by exponentially priced street parking within a 1000-meter radius, to encourage the use of off-street options and prevent their failure due to cheaper on-street alternatives, ideally making these areas "NO PARKING" zones. A cross-subsidy approach incorporating income from both on-street and off-street parking is offered for cost recovery, with higher charges for short-duration on-street parking to capitalize on the preponderance of short-term parkers. Ultimately, the study indicates that providing appropriate parking places, such as the anticipated 1148 square meters necessary for future demand, is crucial for easing traffic congestion and boosting urban mobility in Ettumanoor [4].

2.2. Literature Review on Park and Ride Facilities

Travel behavior of the park and ride users and the factors influencing the demand for the use of the park and ride facility was a work carried out by Hamid et al. (2008). Expansion in vehicle numbers, resulting in severe traffic congestion, lengthy travel delays, heightened emissions, increased noise pollution, and general urban stress, is a substantial issue faced by urban regions, particularly in emerging nations such as India. Public transport typically fails to attract private car users, partially because expanding networks to every section of a city is fiscally impossible, though it is commonly marketed as a tool to increase accessibility and offset these negative consequences. In response, Park-and-Ride (P&R) facilities have arisen as a major approach to encouraging private vehicle users to transfer to public transport, trying to minimize the number of automobiles entering core business areas. However, despite P&R being well-established in developed countries, its implementation in developing nations like India is relatively new, and many existing schemes have failed to attract the desired number of "choice riders" – individuals who have alternative travel modes but still opt for private vehicles.

This underperformance implies that merely having a strategic location for P&R facilities is inadequate; they must properly satisfy certain user criteria to be genuinely effective. Consequently, this study attempted to uncover the important service elements that would inspire choice riders in Delhi to embrace P&R as a dependable and sustainable transport alternative instead of driving alone. To achieve its purpose, the study performed a face-to-face perception survey with 403 private car users (choice riders) in Delhi, especially at parking facilities located near important destinations, enquiring about the perceived relevance of 17 distinct P&R-related aspects. The gathered replies were extensively evaluated using three Multi-Criteria Decision-Making (MCDM) methods: Grey Relational Analysis (GRA), Relative to an Identified Distribution Integral Transformation (RIDIT), and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The consistent findings across all methodologies suggested that cleanliness and good upkeep of P&R facilities [CLN], closely followed by safety and Security Under Monitoring [SEC], were judged the most significant variables by chosen riders.

The high Frequency of Metro Service [FRQ] was also highlighted as a major factor, emphasizing consumers' need to decrease waiting times. Conversely, the Cost-Effectiveness [CST] of P&R compared to private car usage, and the availability of extra facilities like shopping [ADP], were judged to be of least relevance. The clarity and consistency of decision riders' preferences have been indicated by the high positive correlations between the ranks from different analytical methodologies. It shows that more than quantitative elements such as direct cost or time savings, passengers choose qualitative service features, wanting an experience equivalent to their private car use [5].

Exploring the mode change behavior of park-and-ride users was carried out by Islam et al. (2015). Park-and-Ride (P&R) helps in integral congestion management, enhancing public transport mode share, and assists in building a more sustainable transport system. P&R allows commuters to drive to public transport stations and then transfer to higher-occupancy vehicles like trains, buses, or trams to finish their journey, basically helping in providing the first/last mile connection. There has been a known vacuum in rigorously analyzing the efficiency of P&R sites on users' travel mode switching in nations like the USA and Australia, despite their practical relevance and widespread implementation since the 1930s. This particular study intends to solve this gap by analyzing the elements that impact the decision of utilization of P&R services compared to other transport modes. The study includes an interview, a survey performed at a few P&R facilities in Metropolitan Melbourne, obtaining both Revealed Preference (RP) and Stated Preference (SP) data from 143

individuals. Analysis of RP data found that excessively high parking fees in the city and severe traffic congestion greatly tilt commuters towards selecting P&R over driving alone. Using multinomial logistic regression on SP data, the research identified major factors of mode shift behaviour. For instance, when choosing between public transport only and P&R, public transport travel time and transfer time at P&R stations were found to be significant factors; lower public transport travel time increases the likelihood of choosing public transport only, while lower transfer time at P&R makes P&R more appealing. Conversely, when comparing driving alone with P&R, reduced parking costs in the city were found to positively inspire commuters to drive all the way. However, reduced public transit journey time and quicker transfer times at P&R stations improve the chance of selecting P&R over driving. Overall, the survey emphasized that the convenience of the P&R location, contentment with public transport service, and transfer time at the P&R facility were extremely favorable characteristics for users. A recurrent concern identified was the propensity of commuters to park on surrounding streets if the P&R facility was full [6].

Stieffenhofer et al. (2016) carried out work on assessing park-and-ride efficiency and user reactions to parking management strategies. Overutilized park-and-ride facilities represent a rising concern in congested urban regions, worsened by the difficulties transit agencies experience in adequately quantifying their effectiveness, particularly in terms of the number of passengers serviced per parking spot. To address this issue, research was launched in the Central Puget Sound Region of Seattle, Washington. The major aims were to develop and test a technique for assessing the person-efficiency of park-and-ride lots and to obtain user input on various parking management practices targeted at boosting this efficiency. Person-efficiency was defined in the research as the average number of people serviced by each parking space, corresponding to the average passenger occupancy of cars that park at the lot for transit reasons.

The research technique includes both an on-site audit done during peak hours to examine vehicle and passenger movements and determine person-efficiency, and a user intercept survey. The on-site audits verified that person-efficiency values were often very near to 1, with the highest recorded value being 1.080 passengers per parked car, indicating that the majority of individuals parking at these facilities arrive in Single-Occupant Vehicles (SOVs). This coincides with regional data indicating strong utilization rates, with over 78% of spots utilized daily and over half the lots usually full or substantially full. The user survey further corroborated these findings and gave insights into user behaviour and reasons for utilizing the lots, which typically included saving money, convenience, relaxing possibilities on transportation, and avoiding traffic or lack of parking at destinations. Regarding prospective management tactics, users mainly expressed unwillingness to pay for the existing free parking, while more were open to paying for a guaranteed space. Roughly a fifth of respondents stated they would consider carpooling if incentives like fee waivers or guaranteed places were available. Improving bicycle or pedestrian access was not perceived as a particularly inspiring option by users. However, the study revealed the possibility of transferring certain SOV users to existing transit lines to reach park-and-rides, particularly at select sites.

The study stated that the empirical data provided gives rationale for transit authorities to pursue initiatives geared to promote carpooling, multi-occupant vehicle usage, or encourage transit access to enhance the person-efficiency of overutilised park-and-ride facilities [7]. Park and ride location near metro stations (case study: Tehran), carried out by Afsahi and Asgaripour (2018). Tehran, a big and fast-increasing urban centre in Iran with over 10 million population, confronts substantial traffic challenges coming from urbanization and a high vehicle share in daily travels, notwithstanding public transit expansion. With over 18 million daily travels and excessive fuel usage resulting in significant air pollution and health hazards, the city endures enormous traffic congestion, waste of time, and accidents. Park and Ride (P&R), defined as parking spaces connected to public transit that allow commuters to interchange modes, is highlighted as an essential Transport Demand Management (TDM) program to assist in addressing these challenges, although there is a paucity of such facilities in Tehran. This research aims to identify the possible park and ride spots near Tehran's metro stations and analyze travelers' desire to use them in the future.

The methodology includes choosing eligible places near current stations and under-construction metro lines based on criteria provided by regional governments, which is followed by a survey of 500 people near these sites to assess trip characteristics and behavior towards P&R use. The study says that acceptable land for P&R facilities near metro stations, which matches the established criteria, was largely found in the south sections of metro lines 3, 6, and 7, and the east part of line 4, but no eligible locations were discovered in other areas or parts of lines as such. Survey results suggested that a considerable proportion of respondents, approximately 83% of people owning one or more vehicles, expressed a readiness to use the car and metro provided P&R facilities were available near the stations. This suggests great potential for commuter adoption of P&R. The study shows that building P&R lots near metro stations in Tehran's fringe areas is an effective technique for encouraging mode shift from private vehicles to public transport, particularly given current traffic conditions in the city core. Implementation of this is projected to minimize long-distance vehicle journeys and boost transport efficiency. To support this, the report advises creating monitoring programs and proposing incentive measures, such as lower prices for everyday users of P&R lots, to further encourage residents to combine private and public transit modes.

Analysis of the acceptance of park-and-ride by users: a cumulative logistic regression approach was a work carried out by Huang et al. (2019). Park & ride allows tourists to park their vehicles at peripheral sites and then take public transit, such as light rail or metro, to access metropolitan city cores. This technique would offer benefits, including focusing transit rider demand, increasing transit reach into low-density regions, lowering parking demand in the Central Business District (CBD), and alleviating inner-city street congestion. In countries like the USA and Australia, since the 1930s, there has been a gap in systematically analyzing the effectiveness of P&R sites on users' travel mode change, despite its practical significance and widespread adoption. This specific study intended to solve this gap by analyzing the elements that impact the decision of the users on the utilization of P&R services compared to other transport modes. To assess these, a survey was conducted in Melbourne, Australia, between April and May 2014, gathering 1224 samples. The questionnaire had both Revealed Preference (RP) and Stated Preference (SP) questions; RP questions were intended to understand the existing choices and experiences of the respondents, while SP questions focused on prospective mode acceptance behavior under hypothetical circumstances.

The SP component gave respondents nine realistic scenarios, questioning their willingness to use P&R depending on variable levels of three main factors: Parking Charge (PF) in the CBD, Public Transport Total Trip Time (PTTT), and Total Transfer Time (TT) at the P&R facility. By the cumulative logistic regression model, it is found that P&R Transfer Time (TT) has the highest impact in influencing traveler choice, with greater TT lowering P&R acceptance. The Parking Charge (PF) in the CBD was found to be the next most important element, where a higher parking cost in the CBD has led to the adoption of P&R. Conversely, Public Transport Total Trip Time (PTTT) had the least influence on P&R adoption in this study. RP data suggested that excessively high parking charges in the city and severe traffic congestion greatly predisposed commuters towards P&R over driving alone. The study concluded that while it is impossible to considerably reduce PTTT and TT by engineering improvements, setting fair prices for the CBD parking costs can effectively increase P&R usage. Limitations of the study include its concentration on only these three primary elements, neglecting other factors like parking availability, traffic congestion, and land use features, which also have an impact on P&R [8].

Understanding users' intention to use park-and-ride facilities in Malaysia: the role of trust as a novel construct in the theory of planned behavior research carried out by Ibrahim et al. (2020). P&R is underutilized and has failed to attract the appropriate number of users in emerging countries like Malaysia. This underperformance implies that strategic location alone is insufficient; P&R facilities must successfully fulfill specific user requirements to attract more users. Since prior research has frequently focused on physical attributes or service quality, this study is intended to bridge a gap by studying user behavioral aspects. Specifically, it intended to assess if an enhanced Theory of Planned Behaviour (TPB) model, which contains a unique component of 'trust', could explain the intention of the users to use bus-based P&R facilities in Putrajaya, Malaysia. To achieve the objectives, a survey was conducted with 437 car users in Putrajaya, Malaysia, collecting data to investigate the relationships between core TPB constructs (Attitude, Subjective Norm, and Perceived Behavioral Control) and the new 'trust' construct on the intention to use P&R facilities. The investigation, done using Structural Equation Modelling (SEM), found that Attitude, Subjective Norm, and Perceived Behavioral Control (PBC) all had a considerable positive effect on the intention to utilize P&R facilities, collectively explaining 40% of this intention.

Critically, PBC was revealed as the most important predictor of intention, followed by attitude, demonstrating that users' perceived competence and control over accessing P&R facilities greatly drives their intention. Although trust did not directly affect the desire to utilize P&R facilities, it revealed a large positive indirect influence via Attitude and PBC, implying that confidence in the service provider might promote positive attitudes and perceived control, hence indirectly enhancing P&R usage intention. Subjective norm was revealed to be the least important factor in intention.

These findings underscore the importance of service providers focusing on measures that build user trust, enhance positive attitudes, and increase users' perceived behavioural control, such as increasing bus service frequency, improving routes to reduce travel time, potentially imposing on-site parking fees (to encourage P&R), and robust promotional campaigns. The study indicates that characteristics such as service dependability, security, cleanliness, and maintenance are vital for creating user confidence and, consequently, increasing P&R adoption [9].

Lidström Olsson (2021) carried out research on park and ride, effects on public transport ridership. P&R is a strategy facilitating combined vehicle and public transport trips by giving daytime parking at transit stops, generally intended to recruit new users who would otherwise drive their whole journey. However, the impacts of applying this policy are not well known, and it might possibly clash with other land-use strategies such as transit-oriented development. This study, conducted using data from Stockholm and Uppsala counties in Sweden, aims to evaluate if P&R boosts public transport usage, the magnitude of this impact, and if the effects vary depending on the setting (e.g., rural vs suburban). Both static and temporal analysis were included in this study to compare passengers and parking places across stations and to assess changes at stations where P&R was introduced or increased, respectively. The static study demonstrated a positive

connection between the number of parking places and passenger volumes, with a greater relation reported in more rural sites compared to suburban ones.

However, research revealed unrealistically high increases in passengers per parking place, presumably impacted by low utilization rates at some facilities or the practice of developing P&R capacity based on existing passenger counts. Crucially, the temporal data analysis indicated that stations that adopted or extended P&R facilities enjoyed a statistically significantly larger average passenger rise than the general trend in the transport system throughout the same period. This increase was predicted to be around 0.09% per new parking place or, probably more reliably, about 1.25 more passengers per increased parking space daily. This observed increase in passenger numbers implies that the P&R implementation is likely to lead to a net increase in public transport use at the station, rather than customers just altering their mode of travel for the connecting route to the station [10].

Factors influencing choice of riders for using park-and-ride facilities: a case of Delhi is research carried out by Pitale et al. (2023). This study intended to uncover the important service elements that would persuade choice riders in Delhi to employ P&R as a dependable and sustainable transport alternative over driving alone. To meet this purpose, the study conducted a face-to-face perception survey with 403 private car users (choice riders) in Delhi, especially at parking facilities near important destinations, concentrating on their perceived relevance of 17 distinct P&R-related aspects.

The gathered replies were extensively evaluated using three Multi-Criteria Decision-Making (MCDM) methods: Grey Relational Analysis (GRA), Relative to an Identified Distribution Integral Transformation (RIDIT), and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). From the survey results, it is found that cleanliness and decent upkeep of P&R facilities [CLN], along with the safety and security under supervision [SEC], were the most critical variables for the selection of P&R by riders. Another key element observed was the high Frequency of Metro Service [FRQ], indicating passengers' desire to decrease waiting times. And The Cost-Effectiveness [CST] of P&R compared to driving private automobiles, and the availability of extra facilities like shopping [ADP], were considered to be of least relevance.

The strong positive correlation between the rankings derived from all three analytical methods (Spearman rank correlation coefficients of 0.998 between GRA and RIDIT, 0.958 between RIDIT and TOPSIS, and 0.951 between GRA and TOPSIS) underscored the clarity and consistency of choice riders' preferences. Above quantitative elements, such as cost or time savings, passengers want an experience akin to their own car use; choice passengers value qualitative service features [11].

Research on park and ride parking spaces, a tiered pricing methodology based on subway ride distance by Miao et al. (2024). By identifying the existing P&R optimization approaches in China, which are typically insufficient to handle the specific difficulty, this study suggested and evaluated a tiered pricing mechanism for P&R facilities, depending on the distance commuters travel by subway. The underlying concept is to charge lower parking costs for long-distance subway commuters and higher prices for short-distance riders, seeking to increase P&R utilization, to reduce congestion by encouraging the usage of the subway, and to better control parking space demand. The methodology includes an online Stated Preference (SP) poll performed from March 16 to March 30, 2023, which got 592 valid responses.

The poll supplied respondents with ten scenarios, including short (4 km), medium (10 km), and long (20 km) total trip lengths, offering four travel modes: private automobile, subway, taxi, and P&R services, under both fixed and tiered P&R choices. Fixed Price (FP) and Tiered Pricing (TP) mixed logit models were created to study factors impacting mode choice, based on the data obtained from the poll. A conclusion drawn was that the installation of a tiered pricing system considerably boosted the attraction of P&R facilities to long-distance subway travelers, resulting in a greater proportion of these customers.

The study found ideal tiered parking costs for P&R: RMB 20 for short-distance subway journeys (under 5 km), RMB 10 for medium-distance (5–15 km), and RMB 6 for long-distance (over 15 km). This technique is projected to greatly boost the average income for P&R operators (from RMB 2 to RMB 9.7 per car), potentially cutting government subsidies. Furthermore, the research revealed that a shortage of parking spots at P&R facilities is a significant reason many passengers choose other modes, and factors like the decreased comfort and perceived lack of security during transfers also dissuade consumers [12].

Analyzing the attractiveness of park and ride facilities that influences travel behavior and mode shift by Othman et al. (2025). Park & Ride (P&R) facilities are meant to promote this by giving easy parking near transit hubs, therefore encouraging users to transfer from private automobiles to public transport for a portion of their route. While P&R offers tremendous potential to reduce dependency on private mobility, these services, especially in Malaysia, are typically underutilized. This underutilization is attributed to issues such as inadequate sites, low-quality public transit, and costly parking prices. The study's major purpose was to discover the characteristics influencing P&R usage and recommend solutions to recruit additional automobile drivers. The study includes face-to-face questionnaires with 450 users and non-users of P&R facilities at three significant transit stations in Malaysia: Wangsa Maju, Taman Melati, and Gombak. For existing P&R users, the primary appealing elements were

strong connectivity to other public transport modes (e.g., buses, trains, taxis), convenience of access, the availability of more parking spots, and a short walkability distance from the parking lot to the platform. Conversely, non-users said that P&R would be more desirable if parking were free, combined with promises of safety and security for themselves and their vehicles. Non-users also cited a need for greater information on P&R sites, visible road signs, and facts regarding the cost and time savings of transferring from private to public transport.

A prevalent complaint for both user and non-user groups was the difficulty in locating a parking place. Overall, there is a strong potential for greater P&R usage, with 96% of non-users indicating readiness to investigate it, particularly if it proves to be faster and cheaper than driving their automobiles [13].

2.3. Literature Gap

From the literature review conducted, the following gaps were identified:

- Most of the research focused on evaluating park and ride amenities to determine their effectiveness and analysing their appeal.
- No research has been done on how parking facilities affect Namma Metro's ridership in Bengaluru.

2.4. Scope of the Work

Public transport plays a vital role in the mobility of people in urban areas. But still, first/last mile connectivity is the biggest issue for people when it comes to the metro. Most people depend on their personal vehicles for first/last-mile connectivity. Provision for the parking of these vehicles at metro stations helps the users and promotes the usage of public transport.

The present work involves the behavioural study of various metro users to understand the effect of parking on the ridership of the metro, and also the study of parking to arrive at various parking statistics.

3. Objectives

- Behavioral study of metro commuters, metro parking users, and individuals who do not use both services.
- To study the effect of parking on the ridership of the metro.
- To evolve various parking statistics by studying parking at metro stations.

4. Methodology

The methodology for the current study is shown in the flow chart below. It includes the selection of the study area for the survey conduction at the metro stations and their influence area. Later, the data collected will be analysed to understand the behaviour of the metro and parking users.

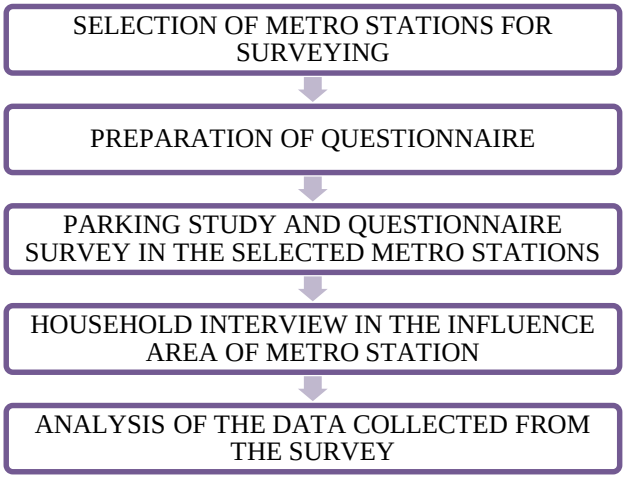

Fig. 1 Flowchart representing the methodology of the study

5. Data Collection

5.1. Study Area

A survey was conducted in the following metro stations for the parking study and to understand the behaviour of the metro users.

- JALAHALLI
- BAIYAPPANAHALLI
- MYSURU ROAD
- YELACHENAHALLI

5.2. Questionnaire for the Survey

- Google Form is the platform used for the preparation of the questionnaire for the face-to-face and household interviews. A single questionnaire was used for both.
- A face-to-face interview was conducted on the platform and entry and exit gates, parking areas of the selected metro stations.
- A household interview was conducted in the influence area of the metro stations.

The questionnaire was prepared to survey the following four categories of people.

- Commuters use both the metro and parking facilities.
- Commuters use only the metro facility.
- Commuters using only the metro parking facility.
- Commuters are not using both the metro and parking facilities.

The questionnaire for the survey included personal information, questions regarding their origin and destination, access distance, access modes, information regarding BMTC usage, and feeder bus information.

5.3. Survey Conduction

- A survey was conducted on weekdays for all 4 selected stations.
- The survey was conducted from 8:00 am to 2:00 pm.

- For each station, there were 10 enumerators surveying at both platforms, near ticket counters, metro station entry and exits, and parking.
- After surveying the stations, household interviews were also conducted in the catchment area.
- Since it was difficult to survey people who park but do not use the metro, the number of those people has been taken.
- Parking video and the count have been obtained by BMRCL to study parking statistics.
- In total, 620 samples were collected from all four stations and their catchment area.
- Out of 620 samples, 608 obtained valid responses after data cleaning.
- Among them, 148 is from Jalahalli, 147 is from Baiyappanahalli, 161 is from Mysuru road, and 152 is from Yelachenahalli.

Table 1. Parking lot details at metro stations (source: BMRCL portal)

Parking Lot Details at Metro Stations.					
Sl. No	Name of Stations	Area (In sq. mtr)	No. of Vehicles		
			2 Wheeler	4 Wheeler	LCV
1	Jalahalli	1300	120	52	0
2	Baiyappanahalli-NGEF Side	10,800	500	270	0
	Baiyappanahalli-OMR Side	2600	215	72	0
3	Mysuru Road- Main	9200	790	240	10
	Mysuru Road- RSS Side	5000	0	222	0
4	Yelachenahalli	3163	412	61	0

6. Data Analysis

6.1. Analysis of the Questionnaire Survey Data

Table 1 represents the parking lot details of the selected metro stations, and Table 2 gives fare details for parking. Figure 2 represents station-wise metro and parking usage.

Table 2. Fare chart of parking at metro stations (source: BMRCL portal)

Class Of Vehicle	For The First 4 Hours (₹.)	For Every Subsequent Hour Or Part There Of (₹)	Maximum Charges For The Day (₹)
Two-Wheeler	15	5	30
Car	30	10	60
Light Commercial Vehicle	75	25	150
Cycle	₹ 1 Per hour and maximum of ₹ 10/- Per Day		
Note: Overnight Parking is not available.			

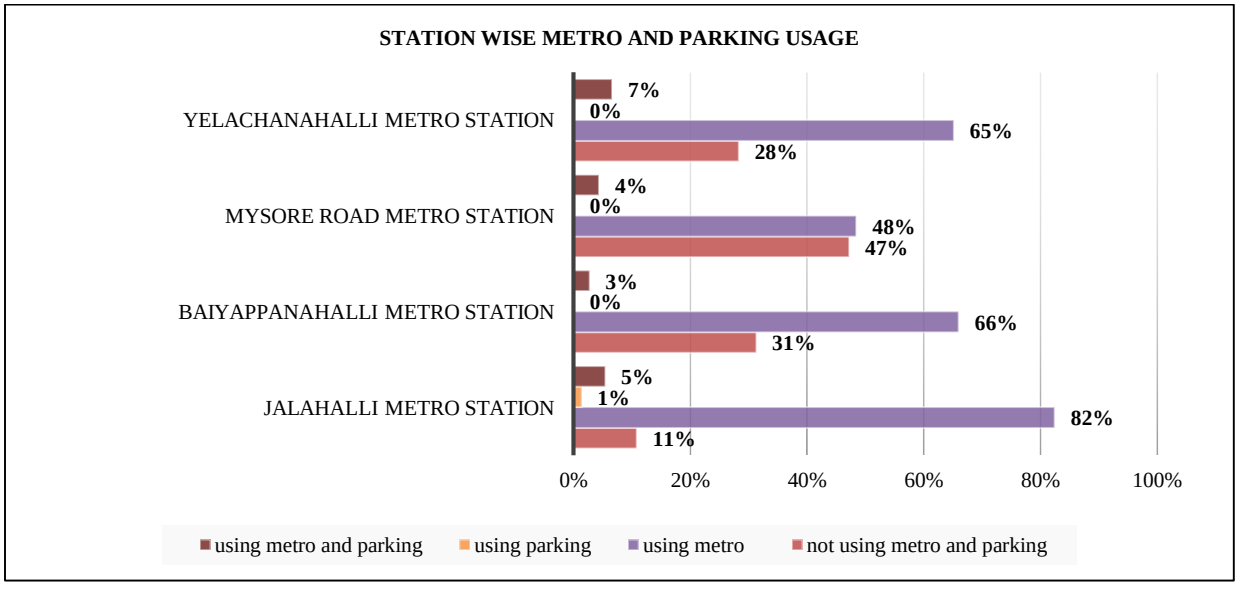

Fig. 2 Station wise metro and parking usage

6.1.1. Demographic Overview of the Respondents

Table 3. Demographic overview of the respondents

		Frequency	Percentage
Gender	Female	208	34%
	Male	400	66%
Age group	18-25	208	34.21%
	26-40	302	49.67%
	41-60	93	15.30%
	> 60	5	0.82%
Occupation	Business	2	0.33%
	Employed (full-time)	421	69.24%
	Employed (part-time)	8	1.32%
	Homemaker	21	3.45%
	Retired	6	0.99%
	School/college student	105	17.27%
	Self employed	44	7.24%
	Unemployed	1	0.16%
Monthly income	<10,000	12	1.97%
	10,000-25,000	66	10.86%
	25,000-50,000	136	22.37%
	50,000-1,00,000	144	23.68%
	1,00,000-2,00,000	55	9.05%
	>2,00,000	24	3.95%
	No income	55	9.05%
	Prefer not to say	116	19.08%

Table 3 gives information about the demographic details of the respondents. Among the 608 respondents, 66% of respondents were male, and 34% were female. Among these respondents, the age groups of 18-25 and 25-40 were high, with the percentages of 34.21 and 49.67 respectively, and 69.24% of them were full-time employees. 19.08% of respondents preferred not to reveal their monthly income, and 22.37% of them come under 25,000-50,000, and 23.68% of them come under 50,000-1,00,000 income group. Among 608 respondents, 69% of them were regular commuters in the metro, and 31% of people use the metro frequently.

Vehicle ownership details of the respondents are shown in Figure 3. Bicycle, two-wheeler (bike/scooter), and four-wheeler (cars) were considered.

The majority of the respondents own one or two two-wheeler and a single four-wheeler.Most of the respondents have different purposes to travel through the metro, and these purposes are shown in Figure 4. 74% of the respondents travel for work/office purposes, 13% of the trips were made for recreational/social purposes, and 11% of the trips were made for school/college.

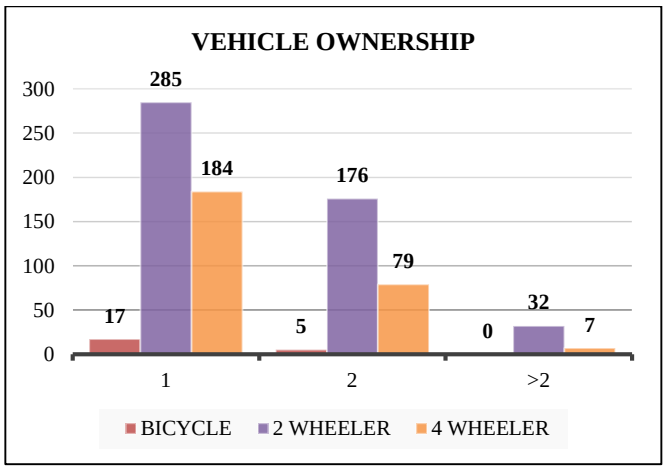

Fig. 3 Vehicle ownership chart of the respondents

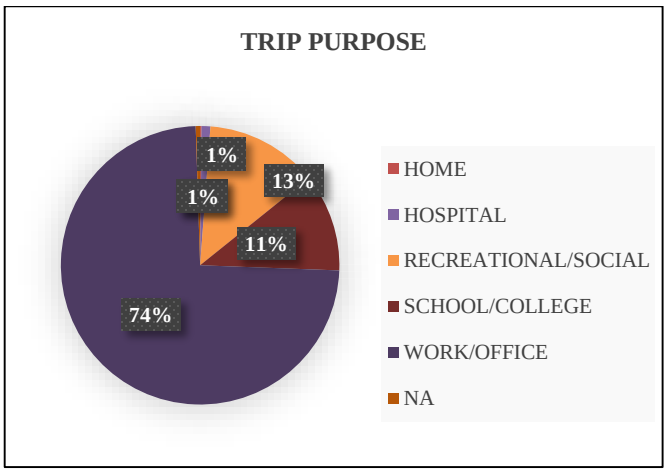

Fig. 4 Trip purpose

6.1.2. Metro and Parking Users' Perception

The current work involves the behavioral study of the respondents to understand commuter preferences and travel patterns in relation to parking facilities and metro usage.

Table 4. Metro and parking users

Category	Percentage
Not using metro and parking	4.77%
Using metro	65.13%
Using parking	0.33%
Using metro and parking	29.77%

People using both the Metro and Parking

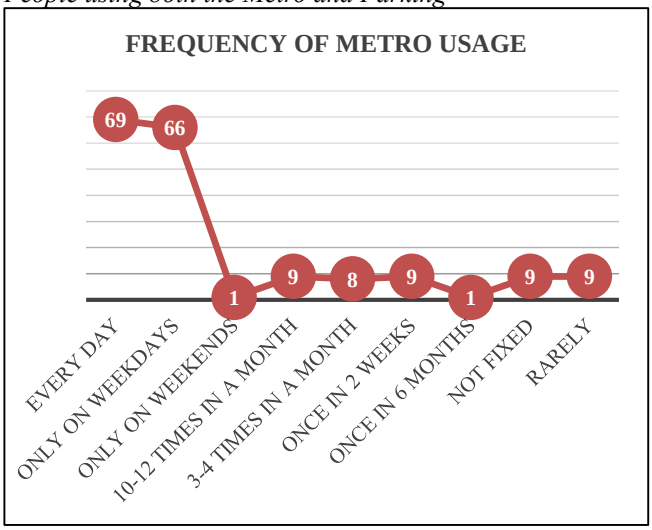

Fig. 5 Frequency of metro usage

29.77% of the respondents uses both the facilities. The Frequency of metro and parking usage of the respondents who use both the facilities are shown in Figure 5 and 6. Daily and weekdays users of metro and parking are likely to be high.

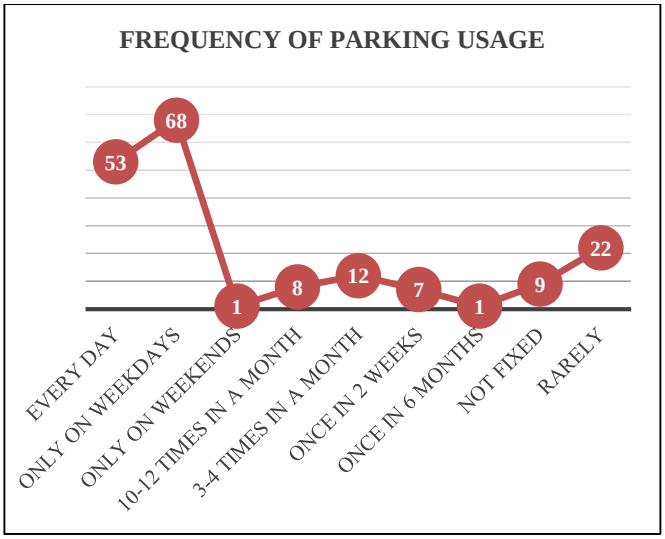

Fig. 6 Frequency of parking usage

Figure 7 represents the access distance of respondents using both the facilities. Among the respondents who use both the facilities, 32% of the people come from the distance of 1-3 km, 25% of the people come from the distance of 3-5 km, 28% of the people come from the distance more than 5 km.

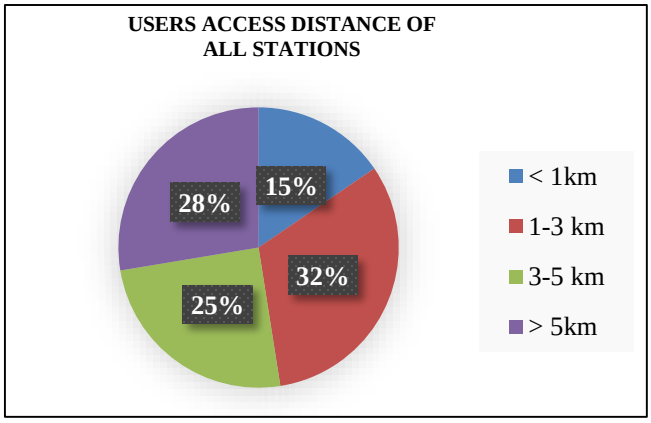

Fig. 7 Access distance of respondents using both the facilities

From all the respondents surveyed it is found that most of them depend upon two wheeler and walk for their first/ last mile connectivity, in those two wheeler is of 81% as shown in Figure 8. But these percentages vary with the stations based on the transport facilities available at the stations. In Jalahalli, two wheeler users are around 75% and 13% of the users had used public transport, in Baiyappanahalli, 84% of the users depend on two wheeler, in Mysuru road, 78% of the users depend on two wheeler and 12% of the users depend on the four wheeler, and in Yelachenahalli, 82% of the users depend on two wheeler and 12% on walk.

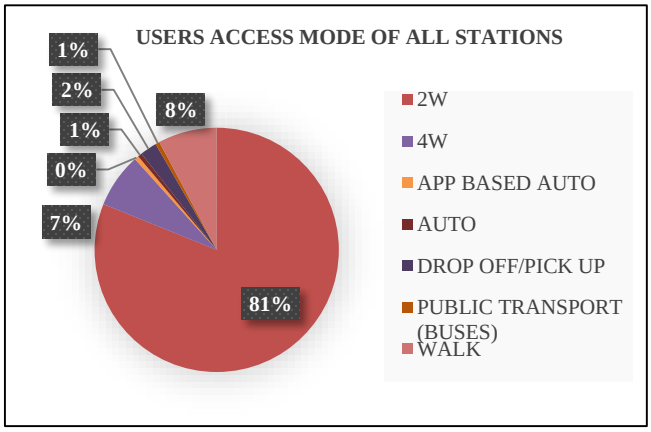

Fig. 8 Access mode of respondents using both the facilities

People using only Metro

Among the total respondents surveyed, 65.13% of them were the people who use only metro but not parking. This category is surveyed to know their travel behavior and also access mode to reach metro. The details regarding their willingness to use parking in the future and also the reasons for not using parking after having the vehicles were also

collected so to understand their travel behavior. Their metro usage frequency is shown in Figure 9. Most of them are used daily and only on weekdays.

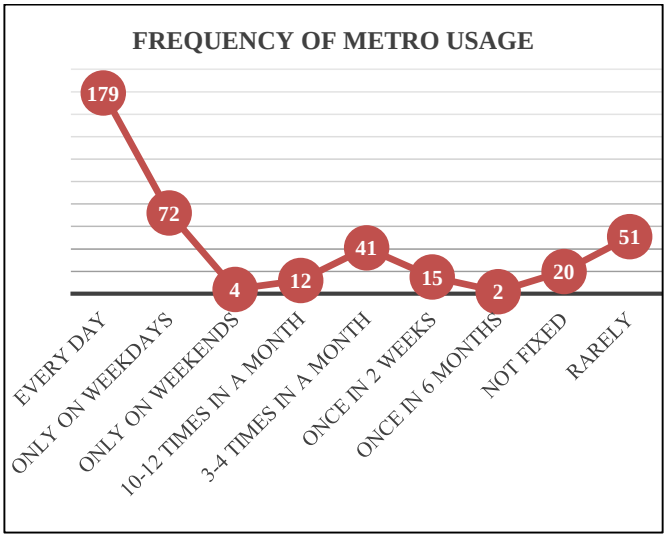

Fig. 9 Metro usage frequency by only metro users

Figure 10 and Figure 11 shows the graphs that represent the access distance and access mode of the respondents using only metro but not parking. Overall, 44% of the users come from the distance less than 1 km. In Jalahalli, 35% of the users come from a distance less than 1 km and 24% of the users are from the distance 1-3 km and these people mostly depend on public transport (buses) and on walking. In Baiyappanahalli. 55% of the users come from the distance less than 1 km and 54% of the users depend on walking to reach metro station. In Mysuru road metro station, users mostly depend on public transport (buses) and walking for access. In Yelachenahalli, 58% of the users come from the distance less than 1 km and they depend on walking and app based auto for access.

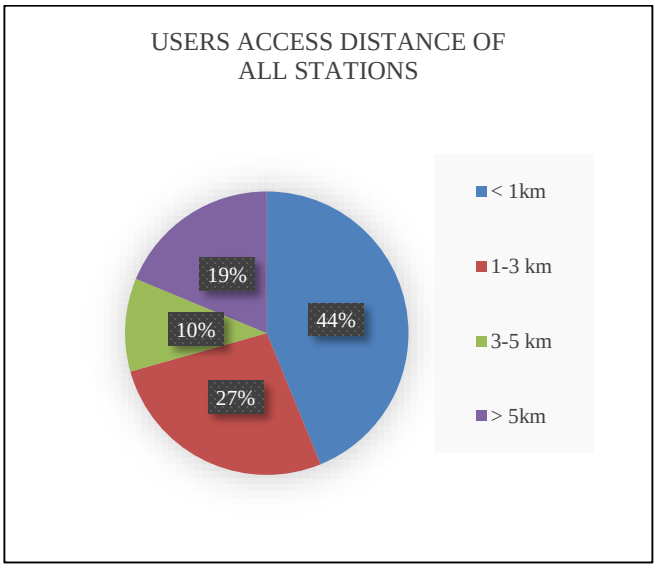

Fig. 10 Access distance of respondents using only metro

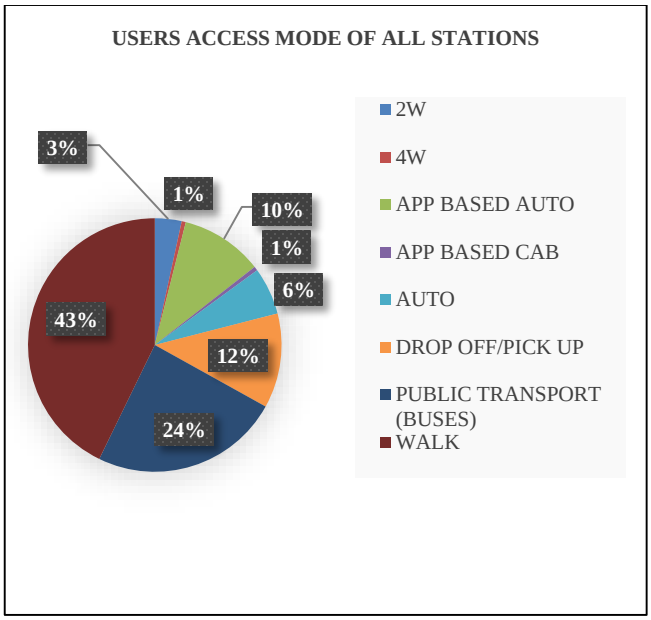

Fig. 11 Access mode of respondents using only metro

People not using both the Facilities

4.77% of the total respondents surveyed do not use any metro facilities though they stay in the influence area of the metro and household interview was conducted in the influence area of metro.

Out of them, 29% of the respondents depend on two wheeler, 26% of the respondents depend on walking, 14% of the respondents depend on drop off/pick up for making their trip which is shown in the Figure 12. And metro is not there in their mode choice set because of the various reasons as shown in Figure 13.

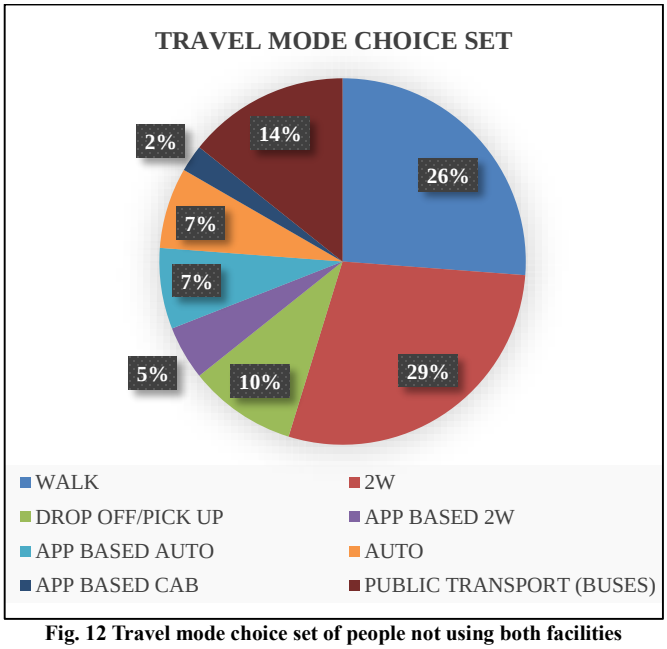

Fig. 12 Travel mode choice set of people not using both facilities

People making shorter trips comprise of 22%, 16% of them do not use metro because of the lack of proper first/last mile connectivity, 14% of them do not use metro because of their comfort, and because of lack of flexibility in route changes 12% of them do not use metro, another 12% do not use metro because of their personal vehicle ownership.

Respondents asked about their willingness to shift to metro, 64% of them do not want to shift, 15% of them were ready to shift if the first/last mile connectivity is improved, 15% of them were ready to shift if the prices of metro is reduced. This is shown in Figure 14.

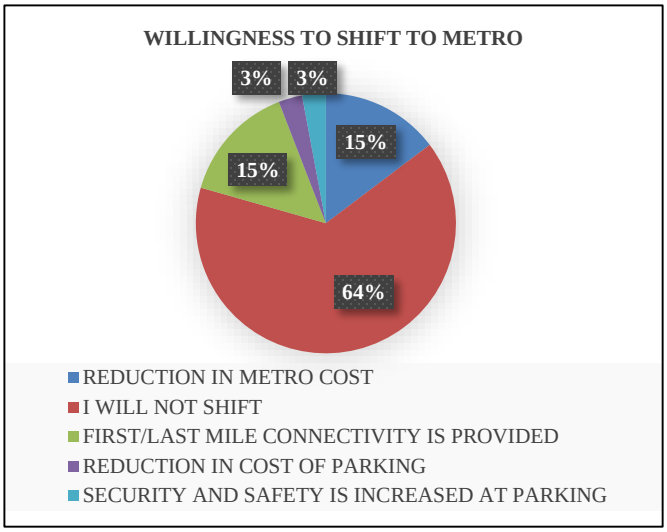

Fig. 13 Willingness to shift to metro of non users

6.1.3. Respondents' Perspective on Prices of Metro and its Parking

26% of the total respondents surveyed find parking charges reasonable, 23% of the total respondents find it high and around 50% of respondents do not have idea about parking charges, which is shown in figure 15. 72% of respondents find the charges of metro very high and 25% of the respondents find it reasonable, which is shown in Figure 16.

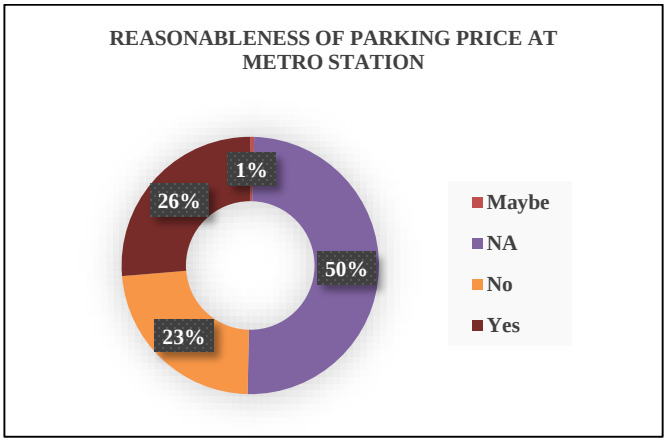

Fig. 14 Reasonableness of parking usage at metro station

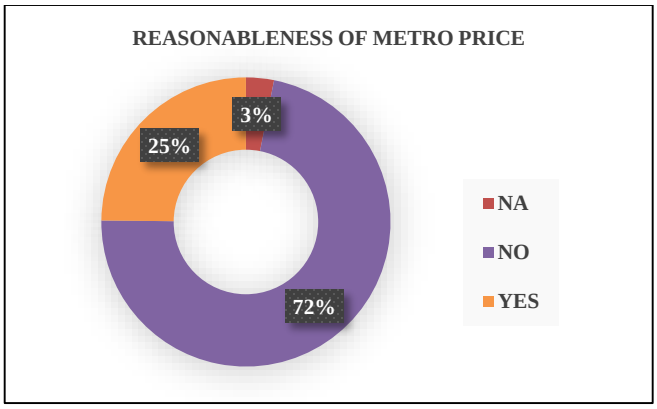

Fig. 15 Reasonableness of parking usage at metro station

Most of the respondents find that the rise in price has occurred after many years so the prices are reasonable. As shown in the Figure 17, 55% of respondents' trip making by metro has been affected by the increase in fare of metro.

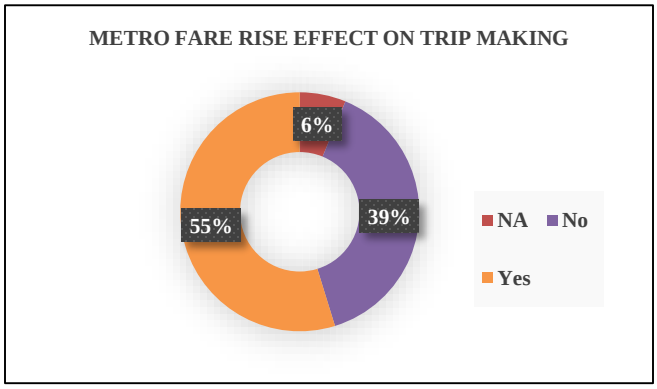

Fig. 16 Effect on trip making by metro fare rise

6.1.4. Information about BMTC (Bengaluru Metropolitan Transport Corporation) Buses

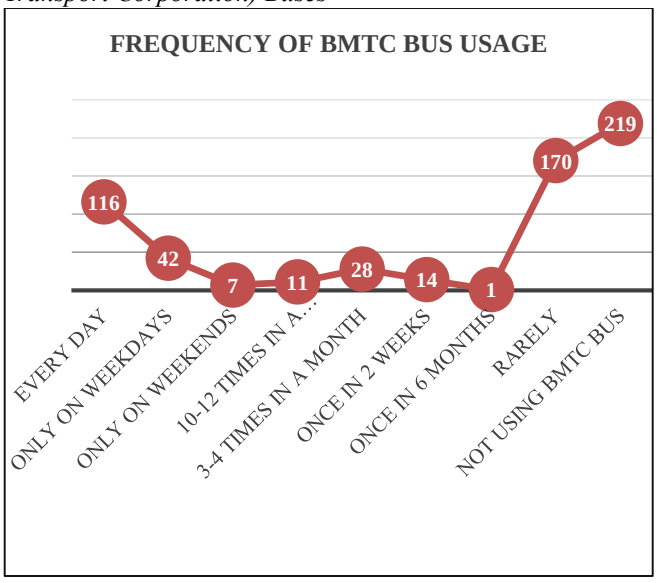

Fig. 17 Frequency of BMTC bus usage

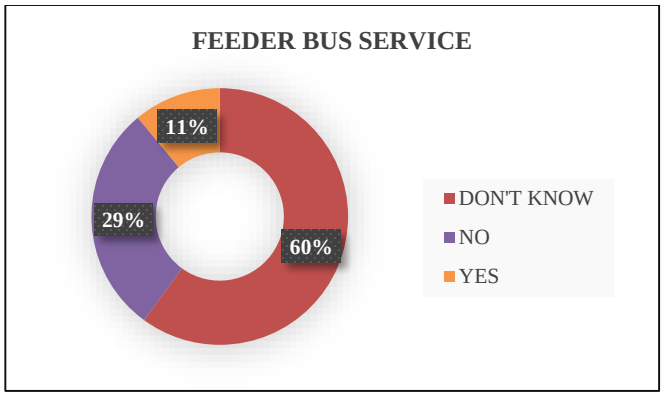

Fig. 18 Information about metro feeder bus services

From the Figure 18, 36.02% of them do not use BMTC bus services, 27.96% of them rarely use BMTC bus services and 19.08% respondents use it regularly. Metro Feeder is a bus route designed to transport passengers between a metro station and their destination, providing a "last-mile connectivity" solution. Figure 19 shows that 60% of the respondents were unaware of these services. 29% of the respondents do not have this service on their routes.

6.2. Analysis of Parking Survey (Video Analysis)

Parking survey has been conducted to arrive with a few of the parking statistics to understand how effectively the parking facilities are being utilized at the stations. The study has been carried out at Yelachenahalli station. 24 hours duration video has been analyzed at a duration of 15 minutes.

Table 5. Parking statistics

Parking volume	731 VEH/DAY
Peak 15 minutes volume	699
Peak 15 minutes	02:00-02:15
Parking load	7710
Parking capacity	11352
Parking index	0.679175476

Table 5 represents the various parking statistics analyzed using the video. Figure 20 represents the parking accumulation; graph has been plotted with time of the day in horizontal axis and number of vehicles in vertical axis. It shows the parking accumulation at various times of the day. 2 pm to 3 pm has highest number of vehicles.

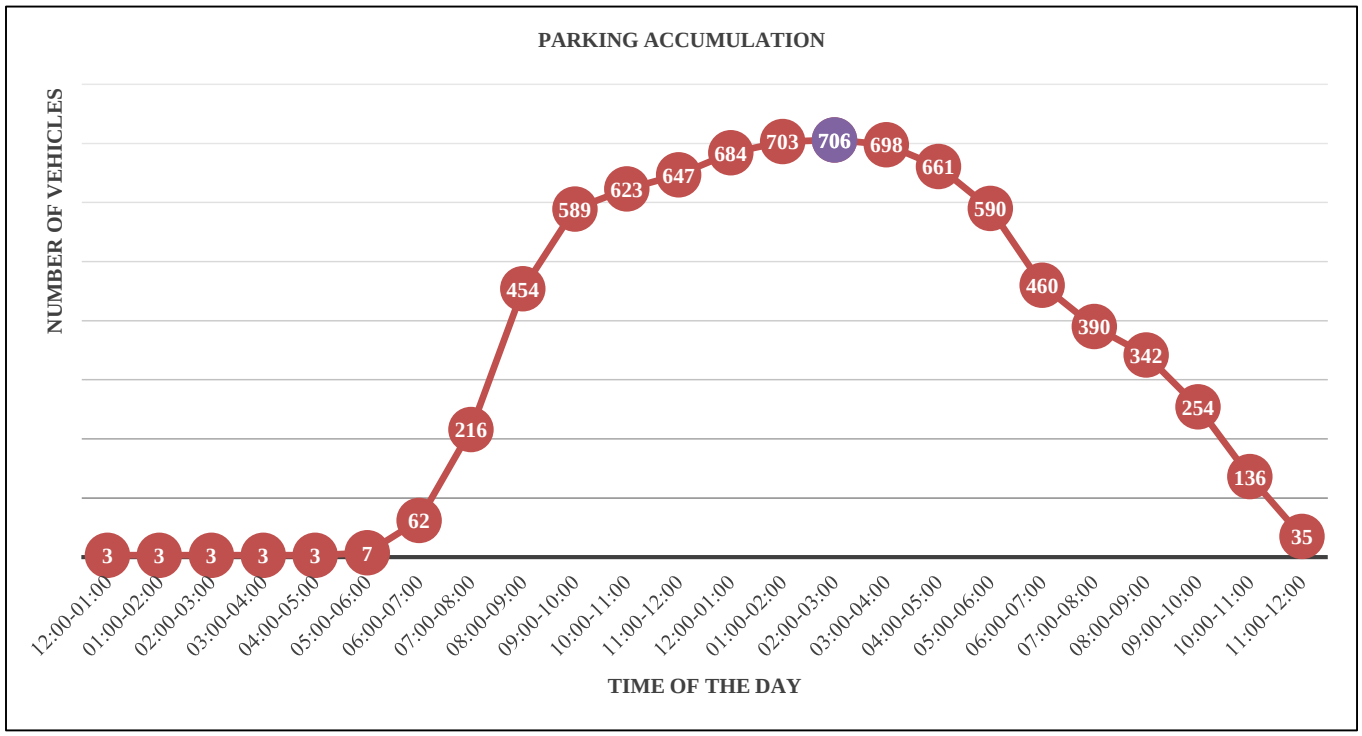

Fig. 19 Parking accumulation

7. Findings and Conclusion

7.1. Findings

Based on data obtained from the survey, the following findings were obtained. From Figure 21, showing the access mode v/s access distance graph, it is clear that people coming from the distance less than 1km and few people from the distance 1-3 km depend on walk for first mile connectivity, two wheeler is the preferred mode for the people coming from the distance less than 1km to more than 5 km, public transport (buses) had been mostly preferred by the people who travel from the distance more than 5 km. Next to walking, people depending on two-wheeler for their first mile connectivity are more and facility of parking is necessary for them which does encourage park and ride facility.

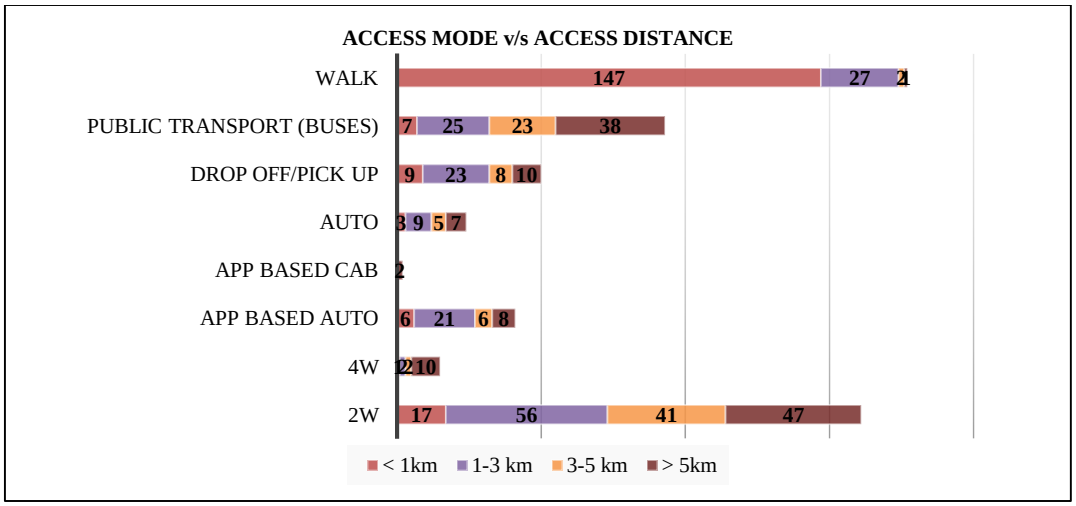

Fig. 20 Access mode v/s access distance graph

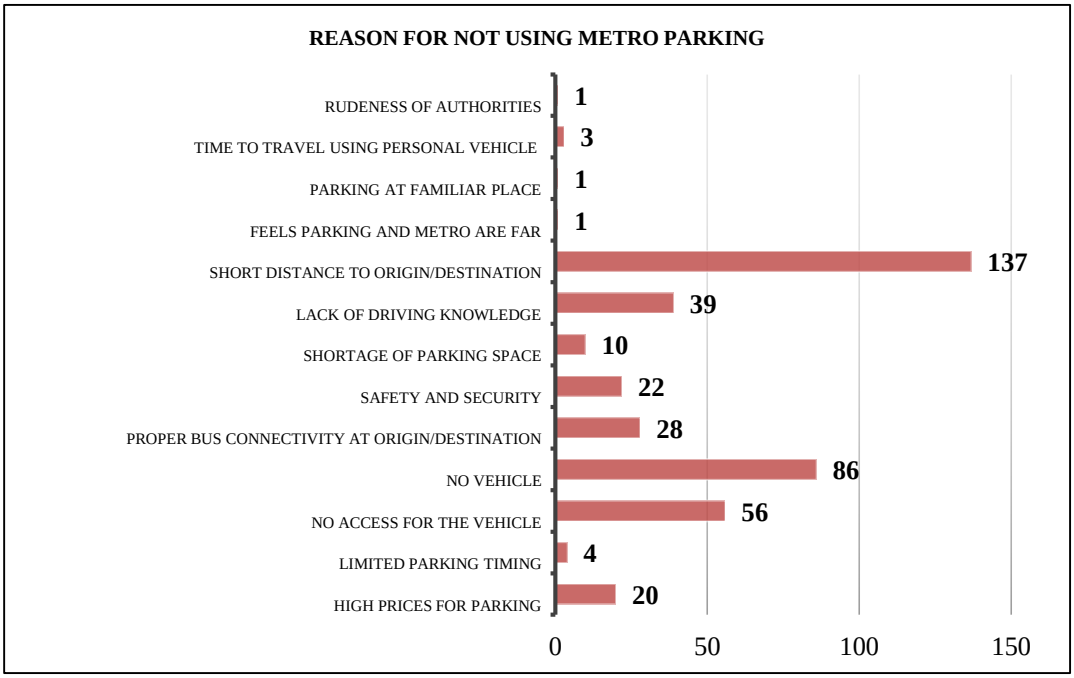

Fig. 21 Reasons for not using metro parking

Figure 22 shows the reasons for not using metro parking by the users who use only metro. Most people do not use metro parking because of the short distance to origin/destination, no vehicle, no access for the vehicle, lack of driving knowledge, proper bus connectivity. Few of them do not use metro parking because of safety and security in the parking area, high prices of parking, and shortage of parking spaces.

Respondents using both metro and parking facilities were asked about the usage of metro in the future if the parking facility is removed, 30% of the respondents stated that they do not use metro if parking is removed, 42% of the respondents stated that they will continue using metro though the parking is removed. This has been shown in the Figure 23.

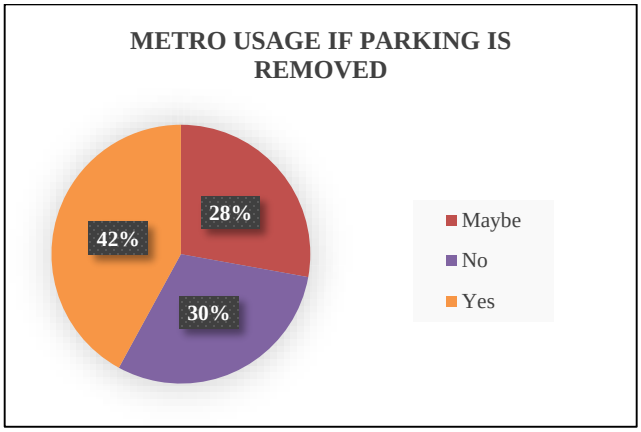

Fig. 22 Metro usage if parking is removed

Respondents using only metro were asked about their usage of metro in the future if the charges at metro parking is reduced, 7% of the users stated that they will use metro if the prices are reduced and 15% of them might use but not sure and 40% of them do not use metro parking though the prices are reduced. This has been shown in the Figure 23.

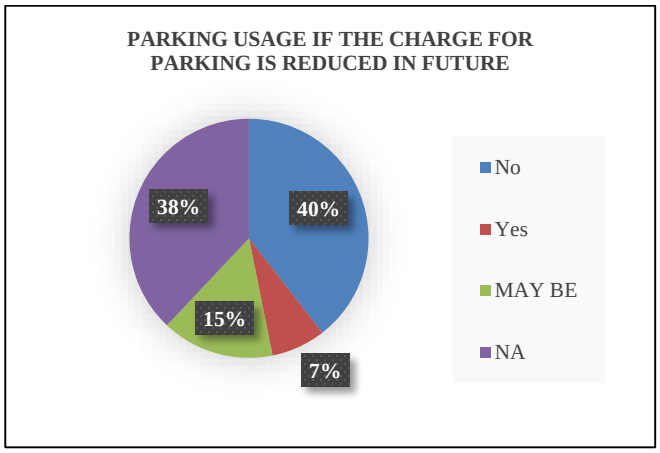

Fig. 23 Parking usage if the charge for parking is reduced

7.2. Conclusion

This section summarizes the impact of parking on the ridership of the metro using the results of the survey and its analysis. From the results obtained by analyzing the survey data, parking at the metro stations has serious impact on the ridership of the metro. The following are the conclusions drawn from the survey results.

- 29% of the respondents coming from various distances depend on their personal vehicles (two wheeler and four wheeler) to reach metro stations. Parking spaces at the metro stations facilitates and encourage people to use park and ride facilities. This also shows the demand for parking spaces at stations.
- 30% of the respondents who are parking at the stations and using metro might shift to another mode if the parking spaces at the stations are removed. This would affect the ridership of the metro.
- Because of the safety and security at the parking spaces, high parking prices and shortage of space for parking, many people who are using metro do not use parking though they own vehicles and have access to it. If these issues are sorted it would encourage them to use their personal vehicle as their access mode.
- Even after staying in the influence area of metro, few people do not use metro for various reasons. High parking and metro prices is one among them. If these prices are reduced, it can drag many people and encourage them to use metro.
- From the parking study at Yelachenahalli, it is also found that the parking spaces provided serve more than its capacity for which it is built for. According to the BMRCL portal, 473 is the capacity of the parking space including both two wheeler and cars, but from the study it is found that peak volume at the station has 699 and has parking volume of 731veh/day. So there is a need to improve the parking facilities to ensure proper parking management.

Overall, the parking demand at the metro stations is very high. This facility, if removed in future, would affect the ridership of the metro which may also affect the traffic condition of the city. Making changes in the price ranges of the parking, solving the issues regarding safety, providing more space for parking to provide proper space between vehicles to avoid damage to the vehicles would attract more users for the metro and would increase ridership.

Conflicts of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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