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Cycling, Walking, And Public Transport Versus Private Cars: An Empirical Investigation Of Travel Mode Choices For Shopping Trips In Mumbai Metropolitan Region

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ABSTRACT: This research delves into mode choice behavior for shopping-related excursions in the Mumbai Metropolitan Region (MMR), a rapidly expanding and socio-economically diverse urban area. The study seeks to identify key determinants influencing individuals' decisions between sustainable travel options, such as walking, cycling, and public transport, and private vehicles like cars. Utilizing empirical data from questionnaire surveys conducted on both weekdays and weekends, this study employed a binary logistic regression model to analyze the associations between mode preferences and pivotal factors, including car ownership, gender, income, age, walk score, and population density. Key findings underscored the prominence of sustainable transportation modes over private vehicles for shopping trips. Car ownership, gender, and income emerged as significant determinants shaping transportation decisions. The study emphasizes the need for policies prioritizing the enhancement of public transport infrastructure and services while promoting environmental sustainability. The research identifies areas for further investigation, suggesting a more nuanced approach to understand variations within demographic and built environment segments. Ultimately, the study provides insights to guide sustainable transportation policies, interventions, and urban planning in the MMR, advocating for a more sustainable and livable urban future.

KEYWORDS: Transport Policies; Individual Preferences; Socio-economic Characteristics; Travel Behavior; Shopping Mobility

1. INTRODUCTION

1.1 Rationale and Justification for the Research

Climate change and environmental degradation pose the foremost challenge to the global community. The combustion of fossil fuels significantly contributes to the emission of greenhouse gases, increasing global temperature (Fakana, 2020). The transportation sector plays a pivotal role in trade facilitation (Stopford, 2008). It not only demonstrates rapid growth in energy consumption on a global scale but also stands as a significant driver of worldwide climate change (Alkhathlan & Javid, 2015; Birago, Opoku Mensah, & Sharma, 2017; Jain & Tiwari, 2019). The World Health Organization's estimates indicate an annual global death toll of seven million due to air pollution (2014). Notably, India holds the highest air pollution-related mortality rate, as reported by (Dong & Harris, 2015).

Sustainable development, as defined by the Report (1987), aims to meet present needs while safeguarding the ability of future generations to meet their requirements. Aligned with the Brundtland Commission's definition of sustainable development this study characterizes sustainable modes of transportation as those with the least carbon emissions per individual, such as walking, cycling, or utilizing public transport. In comparison to other available options like motorized two-wheelers, motorized four-wheelers, or hired taxis, these modes compromise the least in meeting the needs of future generations. Globally, private cars dominate transportation choices (Publications Office of the EU, 2013). In India, motorized two-wheelers constituted approximately 81 % of total domestic automobile sales in 2018–2019 (Society of Indian Automobile Manufactures, 2018).

Modelling mode choice is an essential element within travel demand models, serving to elucidate the allocation of private and public transportation usage. This valuable insight informs policy decisions made by planners. The selection of transportation modes is significantly influenced by the purpose of the trip, as emphasized by Ortúzar & Willumsen (2011). In urban contexts, journeys related to work constitute a substantial portion of daily travel demand. Consequently, transportation planning and mode choice analysis have historically prioritized these obligatory trips. Nevertheless, given the dynamic socio-economic factors and evolving lifestyles of individuals, coupled with the mounting challenges of traffic congestion and pollution, it becomes imperative to explore travel behavior and mode preferences for other trip purposes. Shopping trips are the second most common type of travel in modern urban contexts, after work-related trips (Kikuchi, Felsen, Mangalpally, & Gupta, 2004; Sasidhar, Vineeth, Vineethreddy, & Subbarao, 2016; Shamim Al Razib & Ibna Rahman, 2017). Many of these trips are meant for shopping, which has flourished in major Indian cities over the past decade, changing the prevailing shopping culture. Shopping malls attract large numbers of people by offering a variety of amenities, such as supermarkets, movie theatres, restaurants, and entertainment zones, within a single location. As a result, shopping mall trips have increased significantly in frequency and have generated more vehicular traffic, as they act as main attraction hubs within urban areas.

The enactment of the Model Shops and Establishments (Regulation of Employment and Conditions of Services) Act 2015 by the Government of India represents a significant legislative measure aimed at regulating and standardizing the operation and working conditions of shops and establish-

ments (Ministry of Labour and Employment Government of India, 2016). This act serves as a comprehensive framework for ensuring the proper governance of various aspects related to employment and service conditions in shops and establishments across the country. By establishing clear guidelines and regulations, this legislation aims to promote fairness, safety, and compliance with labour laws within the retail and commercial sectors, thus contributing to the overall welfare and protection of employees in these establishments., which has brought about significant modifications pertaining to the functioning of diverse public amusement establishments employing a minimum of ten employees. This legislation grants permission to establishments, including restaurants, local markets, shopping malls, and movie theatres, to operate around the clock, thereby allowing for continuous operations. At the same time, the government has taken steps to ease the Foreign Direct Investment (FDI) policy and create a conducive industrial business environment. These efforts have helped India achieve the highest GDP growth rate among the major economies of the world in the 2015-2016 period (Pasupathi & Sakthi, 2019; Srinivasan & Duraichamy, 2020). Along with rising income, consumerism, government support, and capital inflow into the retail sector, these factors are likely to enhance India's role as a prominent retail market for international retailers. As a result, the country is anticipated to experience a surge in the presence of global brands that seek to benefit from this dynamic retail landscape

Mumbai, renowned as the financial capital of India, not only serves as a prominent center for commerce but also thrives as a bustling retail destination. In recent years, the city has experienced a remarkable proliferation of shopping malls, and this upward trajectory is anticipated to persist for the aforementioned reasons. The emergence of these malls contributes to an increased demand for transportation, as individuals travel to and from these establishments to engage in various socio-economic activities. However, Mumbai already grapples with significant traffic-related challenges, particularly during peak hours, and the presence of these popular attractions further exacerbates the transportation issues at hand. Consequently, it becomes imperative, from the standpoint of transportation planning, to thoroughly analyze the behavior of mode choice for these trips, with the ultimate objective of encouraging individuals to opt for public transportation alternatives instead of relying on private vehicles.

Existing transportation planning and mode choice analysis have primarily focused on work-related trips, and there is a need for more research on shopping trips, considering their increasing frequency and impact on urban transportation.

This research endeavours to explore the intrinsic determinants that influence individuals' selection of sustainable modes of transportation for shopping excursions in the Mumbai Metropolitan Region (MMR). By examining these factors, the study aims to gain insights into the decision-making processes involved in opting for environmentally friendly transportation options. Through the administration of a survey to a representative sample of individuals residing in Mumbai and the subsequent application of a binary logistic regression model, this study seeks to gain a comprehensive understanding of the mode choice behavior exhibited by individuals during their shopping excursions. Specifically, the research focuses on discerning the determinants that influence individuals' decisions to opt for cycling, walking, public transport, or private cars as their preferred mode of transportation. By effectively addressing this research objective, the study endeavours to furnish transportation planners and policymakers with invaluable insights and information. A comprehensive understanding of the factors influencing mode choices for shopping trips in the Mumbai Metropolitan Region (MMR) can significantly contribute to the promotion of sustainable transportation alternatives and the reduction of private vehicle dependency.

2. LITERATURE REVIEW

The study of travel behavior among urban residents has garnered considerable attention from researchers and planners owing to its profound impact on various aspects of urban development, such as land use transformations and the phenomenon of urban sprawl. By comprehending the factors that shape residents' travel choices, policymakers and urban planners can make informed decisions to steer urban development in a direction that aligns with sustainability objectives and minimizes the negative consequences associated with uncontrolled urban expansion (Salonen, Broberg, Kyttä, & Toivonen, 2014; Tight et al., 2011).

A study funded by the European Council (De Gennaro, Paffumi, & Martini, 2016) proposed that low-carbon or carbon-free fuels and improved fuel efficiency are essential to reduce greenhouse gas emissions from transport.

Furthermore, the advancement of cleaner fuel technologies and the promotion of fuel-efficient vehicles are potential measures to mitigate energy consumption, greenhouse gas emissions, and the detrimental impacts of environmental pollution in Indian cities (Andong & Sajor, 2017; Hachem, 2016).

In the realm of transportation, the criteria influencing individuals' modal choices can be bifurcated into two interlinked clusters: elements of the built environment and individual-specific variables (Papagiannakis, Baraklianos, & Spyridonidou, 2018). Numerous studies have probed into the ramifications of various facets of the built environment, such as urban road architecture, demographic density, multiplicity in land usage, ease of destination reachability, and nearness to public transit systems, on the travel conduct of individuals (Hess, Norton, Park, & Street, 2016; Zahabi, Miranda-Moreno, Patterson, & Barla, 2015). Ewing & Cervero (2001) posited that factors like accessibility to public transit, the density of road intersections, and the extent of road network connectivity are instrumental in shaping transportation modal selections.

On another hand, a considerable body of work has scrutinized the role of personal demographics and psychographics—ranging from age and gender to education, occupation, income, and even attitudes and lifestyles—in determining transportation choices (Chee & Fernandez, 2013; Joh, Nguyen, & Boarnet, 2011). For instance, Carse, Goodman, Mackett, Panter, & Ogilvie, (2013) identified that the availability of a car and lower educational attainment were key variables correlating with a preference for car usage in day-to-day commuting. Similarly, Ben-Elia & Ettema (2011) revealed that elements like educational background, ingrained habits, personal attitudes, and the accessibility of travel information collectively play a role in influencing changes in travel behavior.

The literature on travel mode choice for shopping trips paints a complex picture. Some studies found that online shopping reduces the frequency and distance of shopping trips (Le & Carrel, Reviews, 2021). However, others argue that e-commerce leads to more shopping trips as people take advantage of same-day delivery options (Luca & Mascia, 2021). When it comes to mode choice specifically, some studies found that characteristics of the built environment significantly impact whether people choose to drive, take public transit, walk or bike to stores, De Vos, Cheng, Kamruzzaman, & Witlox (2021) found that higher population density, proximity to transit stations and bike lanes make active transport and public transit more appealing.

However, the effects of urban form on mode choice may be indirect, mediated through factors like travel distance and attitudes. Other research suggests that habit and past experiences largely dictate how people choose to travel to stores (Havlícková & Zámecník, 2020).

A few studies take a broader perspective, reviewing research on travel mode choice for shopping trips over many years. These reviews find that research on this topic has grown substantially, with studies using increasingly advanced methods like structural equation modeling and social network analysis. However, research remains heavily focused on certain populations like university students, and lacks a comprehensive, integrated theoretical framework (Wu et al., 2020). In summary, while characteristics of the built environment and life events can influence travel mode choice for shopping trips, habit seems to be the dominant factor for most people. More research is still needed to develop an integrated understanding of mode choice for shopping trips.

In the context of shopping trips, early studies by Marjanen (1995) in Turku, Finland and Handy (1998) examined the influence of socio-economic and household characteristics on mode choice behavior. Both Marjanen and Handy found that income and family size positively influenced the preference for using a car during shopping trips. Similarly, El-Bany, Shahin, Hashim, & Serag (2014) used different models to compare the impact of modes for shopping trips in Port-Said City, Egypt. They identified income as the most influential factor affecting mode choice behavior in their study.

Substantial insights have been gleaned from prior research investigating the built environment and location attributes of shopping centers or malls. These studies have provided valuable knowledge and understanding regarding the physical features and spatial characteristics of shopping centers, contributing to our comprehension of their role within the urban fabric.

Popovich & Handy (2015) conducted a study investigating mode choice for shopping at various destinations within California. Their research highlighted the impact of factors such as the distance to the shopping destination and the individual's enjoyment of bicycling on the decision to use motorized modes of transportation. A separate study, Ng (2006) explored shoppers' perceptions of different public transport modes in Hong Kong, focusing on the influence of shopping center characteristics and trip purpose on mode choice. The findings underscored the significance of these factors in shaping individuals' decisions regarding the mode of travel.

Newmark, Plaut, & Garb (2004) conducted a comprehensive analysis of shopping travel behavior in Prague both before and following the introduction of new shopping malls. Their study aimed to investigate the impact of these new shopping establishments on individuals' travel patterns and preferences within the city. By examining the changes in shopping-related travel behavior, the researchers sought to provide valuable insights into the influence of the newly introduced malls on urban mobility and transportation choices. Their research revealed a decrease in the number of shopping trips but an increase in the duration of shopping visits. Additionally, they observed a shift from walking to motor vehicle use as a preferred mode of transportation.

Ding, Xie, Wang, & Lin (2014) utilized a cross-nested logit (CNL) model to investigate the interdependence between shopping destination and mode of travel in the Maryland-Washington, D.C. region. By employing this model, the researchers aimed to comprehensively understand the complex decision-making process involved in selecting both the shopping destination and the mode of transportation. The outcomes of their analysis underscored the substantial correlation between shopping destinations and individuals' choices of travel mode, shedding light on the intricate relationship between these factors and providing valuable insights into travel behavior in the studied region. Notably, the study indicated that parking costs at shopping centers had a substantial influence on the mode choice of individuals who rely on cars.

These studies collectively contribute to our understanding of mode choice behavior in shopping contexts. They shed light on the interplay between various factors such as distance, enjoyment, shopping center characteristics, trip purpose, and parking costs in shaping individuals' preferences for different modes of transportation.

The review of available literature reveals a noticeable gap in the research concerning mode choice behavior in shopping malls, particularly in the context of developing cities. This gap suggests a lack of comprehensive understanding and empirical investigation into the factors influencing individuals' transportation mode preferences when it comes to shopping malls in urban areas undergoing rapid development and transformation. While studies have explored mode choices for various land uses, such as hospitals and schools, there is a noticeable gap when it comes to understanding shopping mall mode choices in these urban contexts.

Moreover, a predominant number of previous studies have predominantly utilized binary logit or multinomial logit models as their primary analytical framework, while alternative methodologies such as nested logit models or other advanced modeling approaches have been underutilized or neglected. This limited application of alternative modeling techniques highlights the potential for further exploration and adoption of innovative methodologies in investigating mode choice behavior in transportation research. To address these research gaps, the current study adopts a logistic regression model to examine mode choice behavior during shopping trips in Mumbai. Notably, this analysis considers socio-economic characteristics as influential factors that contribute to individuals' decision-making process regarding the mode of transportation. By employing this analytical framework, the study aims to provide valuable insights into mode choice behavior specifically within the context of shopping trips in Mumbai, thereby contributing to the existing literature on transportation mode preferences in urban settings.

Through a comprehensive analysis of the determinants that shape mode choice behavior during shopping trips, this study enhances our knowledge and comprehension of sustainable transportation planning and policy-making, with a specific emphasis on the unique context of developing cities. The findings of this study contribute to the existing body of knowledge in the field of transportation planning, establishing a solid foundation for evidence-based decision-making and enabling the development of targeted interventions that facilitate the adoption of sustainable transportation practices within developing urban areas. Ultimately, this study seeks to address the existing research gap about mode choice behavior in the context of shopping trips and make a significant contribution to the broader discourse on sustainable transportation planning and policy development, catering specifically to the unique challenges and opportunities prevalent in developing cities.

2.1 Objective and Motivation of the Study

The existing literature predominantly focuses on mode choice behavior for shopping trips in developed countries, leaving a research gap regarding economically developing regions like the Mumbai Metropolitan Region (MMR). Understanding mode choice behavior for shopping trips in the MMR is crucial due to potential differences, particularly in users' perceptions of available public transportation options. Therefore, research is needed to investigate mode choice behavior specifically in developing economies like the MMR, considering the unique

socio-economic and contextual factors influencing individuals' preferences and perceptions of public transportation facilities. This study aims to fill this research gap by exploring mode choice behavior for shopping trips in the MMR, contributing to the understanding of transportation preferences and effective policy design in developing urban regions.

In developed cities, efficient and convenient public transportation systems often make public transport more appealing for shopping trips. In contrast, shopping malls in developing regions like the MMR primarily cater to higher-end brands and specific socio-economic groups. Economic disparities and variations in consumer preferences further distinguish shopping malls in developed and developing regions, emphasizing the need for a comprehensive understanding of mode choice behavior and consumer behavior in these contexts.

Considering the socio-economic structure, built environment, and transportation infrastructure variations between developed and developing economies, it is essential to explore mode choice behavior specifically for shopping mall trips in the MMR. This research aims to bridge this gap by developing a comprehensive mode choice model that incorporates socio-demographic characteristics and travel mode attributes. By examining the interplay between socio-demographic factors and travel mode preferences, this study aims to elucidate mode choice dynamics for shopping trips in a developing urban area like Mumbai. The findings will contribute to the literature by shedding light on influential determinants that shape mode choice behavior in economically developing regions.

The primary objective of this study is to enhance our understanding of mode choice behavior for shopping trips in the MMR. By considering socio-economic attributes and individual travel mode preferences, this research aims to comprehensively understand the factors influencing mode selection in shopping activities. Through examining the interplay between socio-economic characteristics and travel mode preferences, the study provides valuable insights into the decision-making process associated with mode choice for shopping trips in the MMR.

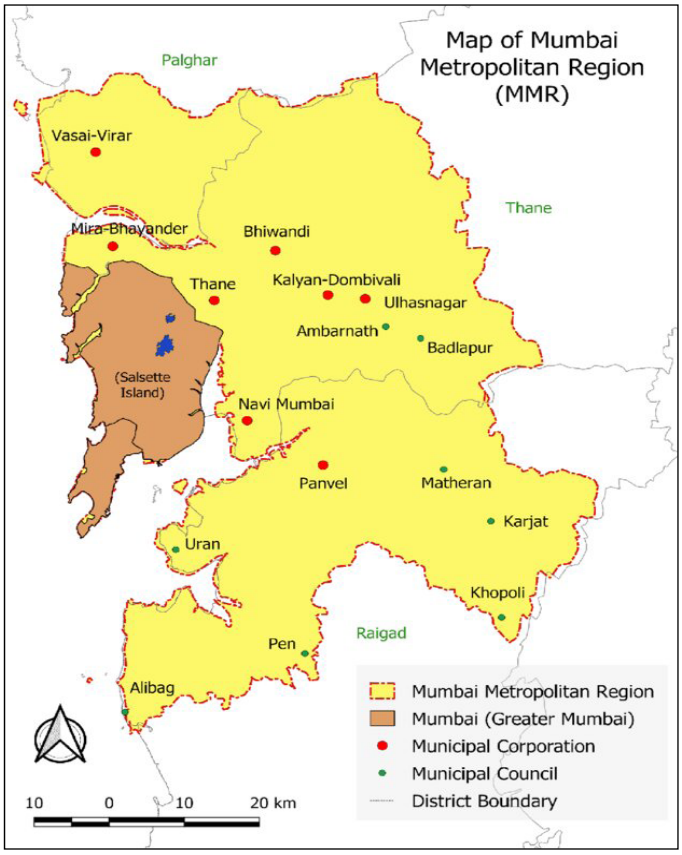


Figure 1. Illustration of the Mumbai Metropolitan Region, including the municipal corporations and councils, as depicted on the map.

3. MATERIALS AND METHODS

In this study, the socio-demographics and built environment variables (walk-score and population density) are tested following an empirical approach to characterize the walkability of urban neighbourhoods, which will address the three components of sustainability, which are: Environmental, Social, and Economic Sustainability (Sultana, Salon, & Kuby, 2017). The present study examines the Mumbai Metropolitan Region (MMR), India (Figure1), one of the nation's most rapidly expanding and economically vibrant metropolitan regions. It encompasses a diverse and complex socio-economic environment unparalleled in other parts of the world. The (MMR) comprises the districts of Mumbai City, Mumbai Suburban, and parts of Thane and Raigad. As per the 2011 Census, this region has a population of 21.3 million, which is anticipated to augment to approximately 34 million by 2031. Greater Mumbai, the region's centre, accommodates one-third of the MMR population. MMR has a population density of about 20500 inhabitants/m^2. The employment rate is projected to increase from 37 % in 2005 to 45 % by 2031.

3.1 Data and Measurements

Design of Survey Instrument: The survey instrument employed in this research, known as the Activity Travel Diary, was specifically crafted to capture a wide spectrum of activity and travel patterns associated with non-work trips, including walking trips. This diary-based approach was chosen to reduce errors and biases associated with recall, enhancing the reliability of data collection. Moreover, the inclusion of walking trips as part of tour activities, often overlooked in conventional surveys, is a distinctive feature of this approach. This survey instrument also facilitates interpersonal and temporal comparisons of walking trips, providing a more nuanced understanding of pedestrian behavior.

Sampling Methodology Refinement: The 2010 Greater Mumbai Region Activity Travel Survey, spearheaded by Subbarao (2013) serves as the primary data source for our analysis. This fifteen-day survey encompassed approximately 126 households and collected detailed activity and travel information. To enhance clarity, we have expanded upon the rationale for selecting these households, emphasizing the focus on obtaining a comprehensive representation of high-density urban and suburban areas. The survey not only documented various activity episodes but also gathered essential socio-demographic and employment-related attributes, along with household vehicle ownership details.

Cleaning and Consistency Checks: The survey data, consisting of activity, person, and household files, underwent rigorous screening to rectify missing or inconsistent entries. Imputation was employed wherever possible to maintain data integrity. Records with unresolved issues were appropriately removed from further analysis.

Sample Extraction: A critical step involved ensuring complete information on walking trips undertaken by each household member. Houses lacking such comprehensive data were excluded from subsequent analysis. Through meticulous examination, we found that weekday and weekend walking behaviors exhibited minimal variability. As such, a subset of data representing a single weekday and weekend was randomly extracted from the overall cleaned dataset.

Activity-Type Classification: The classification of activities was refined, categorizing them as mandatory, maintenance, or discretionary. Mandatory activities, characterized by fixed attributes over time, were grouped under "work," while maintenance and discretionary activities were categorized as "non-

work." This classification holds for both weekdays and weekends. We also clarified that access/egress walk travel activity episodes for public transportation are considered walk trips.

Aggregation and Data Structuring: Data aggregation was performed at the individual and household levels, facilitating the identification of work and non-work walk travel activity choices. This process sets the stage for subsequent analyses.

In conclusion, the refined data and measurement methodology comprehensively capture activity and travel patterns, particularly walking trips, providing a solid foundation for the subsequent analysis of pedestrian behavior. These enhancements align with your valuable feedback, contributing to the clarity and specificity of our research approach.

3.2 Socio-economic Attributes of Respondents

Table 1 summarizes the respondents' socio-economic characteristics surveyed in MMR. The results showed that out of 346 respondents, 31.49 % had one car, 2.36 % had two cars, and 65.35 % had no cars. The sample consisted of 46.1 % women and 53.9 % males. The most common level of education was graduate (28.2 %). The largest occupational group was students (25.93 %), followed by managers (8.3 %). The income distribution was skewed towards the high end, with 17.64 % earning between 10000 and 20000 RS per month and 17.46 % earning more than 100000 RS per month. Figure 2 & 3 shows the portion of every mode of travel for seven days. Figure 4 illustrates the share of daily trips for shopping purposes compared to other types of trips.

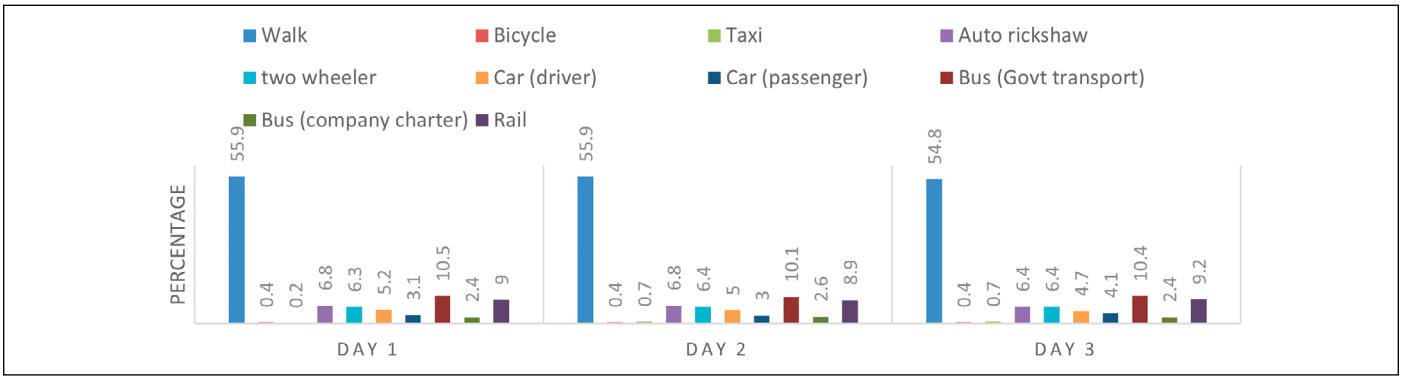
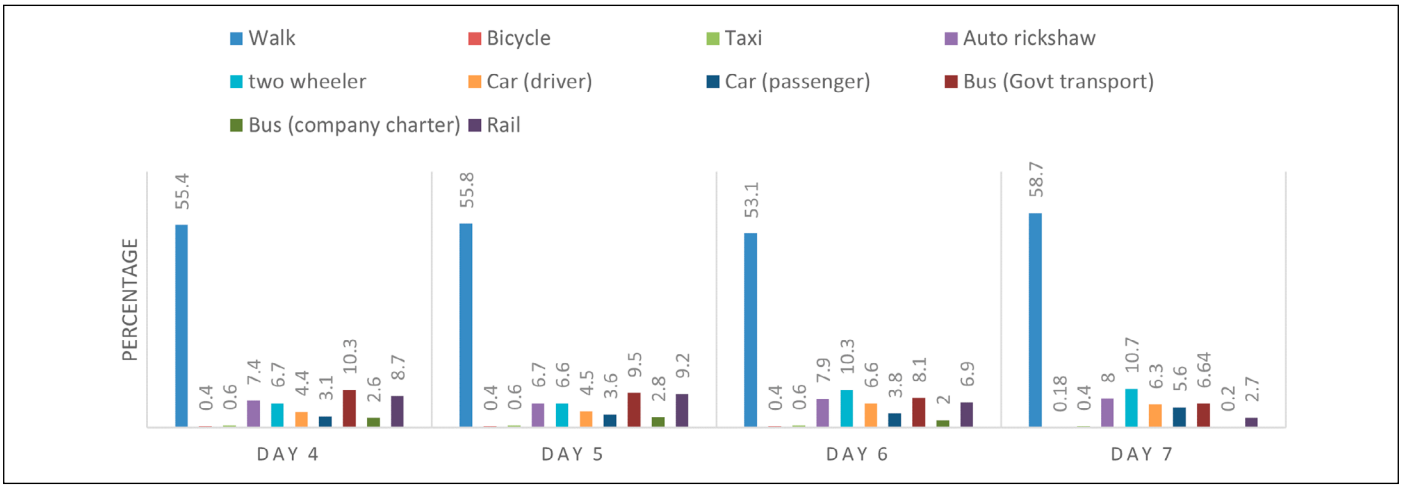


Figure 2. The proportion of every mode of travel during the survey period.



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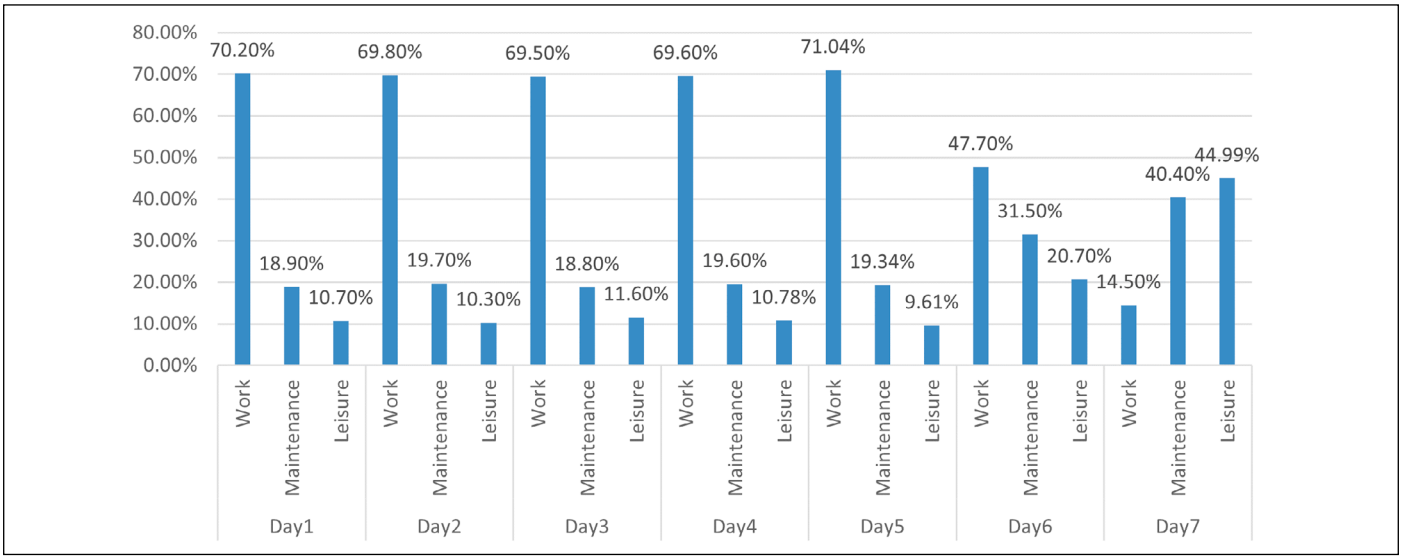

Figure. 4 The trip purpose share distribution.

Variable	Description
Car Ownership	Own a car (31.49 %)
	Own two cars (2.36 %)
	No vehicle (65.35 %)
Gender	Male (53.89 %)
	Female (46.1 %)
Age Group	<= 18 (20.10 %)
	19 – 30 (20.46 %)
	31 – 40 (25.07 %)
	41 – 50 (20.1 %)
	51 – 60 (9.79 %)
	> = 61 (4.3 %)
Education Level	Low (Illiterate, Primary 5th pass, Higher Secondary 12th pass) 59.1 %
	Middle (Graduation 28.2 %)
	High (Post-graduation and above 17.5 %)
Monthly Income	< 30000 (33.45 %)
	30001 - 100000 (35.65 %)
	>100000 (17.46 %)
No. Driving License	No (28.5 %)
	Yes (71.35 %)
Bicycle ownership	Yes (21.42 %)
	No (78.57 %)
Occupation	Student (25.93 %)
	Self-employed (5.40 %)
	Employed (public) (7.49 %)
	Employed (business) (5.76 %)
	Employed (managerial level) (8.3 %)
	Other (32.61 %)

Table 1. Socio-economic attributes of the sample population (n=346).

3.3 Neighborhood Characteristics

Walk-Score

Walk Score® is a freely accessible online tool designed to compute a score concerning the accessibility of local destinations for a given geographical location. The calculation involves a decay function, initially assigning a raw score based on network distance to essential establishments like grocery stores, restaurants, bookstores, banks, schools, fitness centers, and parks located within a 1.6 km radius from the target area (Koohsari et al., 2018). These initial scores are then normalized on a 0 to 100 scale, incorporating two street network measures—intersection density and block length—surrounding each location to provide adjusted values (Nykiforuk, McGetrick, Crick, & Johnson, 2016). Elevated scores indicate proximity to a variety of local destinations, facilitating convenient walking for daily errands and shopping. Cartographic data from sources such as Google, Education.com, Open Street Map, and other open-source repositories are employed in the Walk Score computation process (Koohsari et al., 2018).

Numerous investigations have demonstrated the positive correlations between Walk Score and transport-related walking (Cole, Dunn, Hunter, Owen, & Sugiyama, 2015) as well as recreational physical activity in smaller communities (Thielman, Rosella, Copes, Lebenbaum, & Manson, 2015). Conversely, studies have reported inverse relationships between Walk Score and body mass index (Hirsch, Roux, Moore, Evenson, & Rodriguez, 2014). For instance, research conducted in Australia revealed that individuals residing in highly walkable regions, classified under the top Walk Score category, were twice as likely to engage in 30 minutes or more of walking for transportation daily compared to those in the least walkable areas (Cole et al., 2015). Similarly, a study in the USA found that relocating to a neighborhood with a higher Walk Score was linked to a reduction in body mass index (Hirsch et al., 2014). However, it is noteworthy that various investigations have indicated null (Chiu et al., 2015) or negative (Hajna, Ross, Joseph, Harper, & Dasgupta, 2015; Tuckel & Milczarski, 2015) associations between Walk Score and leisure physical activity, recreational walking, and daily step counts.

In our study, we adopted the Walk Score as an independent variable to evaluate neighborhood walkability. Widely accepted and employed, Walk Score objectively gauges neighborhood walkability by considering several influential factors in transportation mode choices. These factors encompass the availability and accessibility of diverse nearby amenities, such as grocery stores, restaurants, shopping centers, coffee shops, parks, and schools. Additionally, the analysis incorporates pedestrian-friendly characteristics like intersection density and average block length. This comprehensive approach enables a thorough understanding of how the built environment shapes individuals' transportation mode preferences (Walk Score, 2020).Through integration into our analysis, we quantitatively assess the impact of neighborhood walkability on our variables of interest, shedding light on the built environment's significance in shaping communal behavior.

Walk Score acts as an integrative index quantifying urban form by consolidating elements like destination density, diversity, accessibility to amenities (e.g., coffee shops, libraries, restaurants), block length, and street connectivity within a predetermined network distance (Kim, Won, & Kim, 2019; Lefebvre-Ropars, Morency, Singleton, & Clifton, 2017; Sultana et al., 2017). Serving as a composite metric, Walk Score offers a comprehensive evaluation of neighborhood walkability. Some studies exclusively deploy Walk Score to assess neighborhood characteristics (Boisjoly, Wasfi, & El-Geneidy, 2018; Reyer, Fina, Siedentop, & Schlicht, 2014), yielding insights into walkability and its implications for urban life. This framework aids in understanding how neighborhood attributes influence daily activities and travel patterns.

Recent research by Kim et al. (2019) supports the validity of the Walkability Score as an effective gauge of urban walkability. Derived from the Walk Score algorithm, this score integrates nine crucial amenities, providing a comprehensive assessment of area walkability by considering the availability and proximity of these amenities, thereby promoting pedestrian mobility and fostering a sustainable urban environment. The computation involves determining network distances to amenities and assigning points accordingly. Amenities within 400 meters receive full points, those within 800 meters garner 75 %, those within 1.2 kilometers secure 40 %, and those within 1.6 kilometers earn 12.5 % (Kim et al., 2019). Aggregating accessibility measures from the nine utilitarian destinations standardizes the scores on a 0 to 100 scale, ensuring a precise representation of overall walkability and considering varying amenity accessibility levels.

Population Density

Research studies have consistently shown that higher population density in residential areas has a significant impact on travel behavior and mode choice. (Doddamani & Manoj, 2021) found that increased density reduces the likelihood of driving, emphasizing the importance of neighbourhood attractiveness and cleanliness in reducing household car and two-wheeler ownership. Furthermore, higher density supports the use of public transportation, as demonstrated by (Jasim, Al-Jaberi, Al-Maliki, Al-Ansari, & Al-Mamoori, 2022).

Contrastingly, individuals residing in suburban areas rely more heavily on private cars and tend to undertake a greater number of car trips compared to those living in densely populated neighbourhoods (Tana, Kwan, & Chai, 2015). In high-density environments, favourable infrastructural conditions and shorter average distances to destinations facilitate walking and cycling for both commuting and non-commuting purposes (Christiansen et al., 2016). To explore the neighbourhood characteristics in this study, the explanatory variables considered include the population density of the six surveyed regions and the walk score around each sampled household. These variables provide valuable insights into the relationship between density, walkability, and mode choice behavior, shedding light on the dynamics of travel behavior in different neighbourhood contexts.

Area	Pop density Per sqkm (2011)	Pop density (approximated to the nearest 1000)	Per cent distribution
Navi Mumbai	3500	4K	31.7
Kalyan-Dombivli	8700	9K	4.6
Thane	12000	12K	4.6
Western Suburbs	15000	15K	10.1
Eastern Suburbs	20000	20K	45.2
Island City	46000	45K	3.7
Total			100

Table 2. Percent Distribution of Area-wise population density.

Walk Score	Walking Condition	Description of Walking Condition	Per cent distribution
90–100	Walker's Paradise	Daily errands do not require a car	5.2
70–89	Very Walkable	Most errands can be accomplished on foot	53.9
50–69	Somewhat Walkable	Some errands can be accomplished on foot	36.9
25–49	Car-Dependent	Most errands require a car	4.0
0–24	Car-Dependent	Almost all errands require a car	0

Table 3. Relationship between Walk Score and Walking Condition.

A comprehensive set of 22 potential explanatory variables was gathered for each observation, as outlined in Table 4. These variables encompassed 20 socio-economic descriptors, capturing personal and household characteristics, along with two built environment variables representing neighbourhood characteristics. Specifically, the built-environment variable utilized the walk score as a measure of pedestrian accessibility within the study region. The walk score was determined by employing a geospatial information system (GIS) and leveraging the publicly available Walk Score™ website. This online tool estimates the walkability of neighbourhoods by considering their proximity to a range of 13 amenity categories, as detailed in the (Walk Score, 2020). By incorporating these variables, this study aimed to comprehensively evaluate the influence of socio-economic and built environment factors on mode choice behavior during shopping trips.

3.4 Model structure

To examine the impact of socio-economic factors on travel choices, a binary logistic regression analysis was utilized to investigate and comprehend the intricate relationships between these factors and the decision-making process associated with transportation modes (Liu, 2007; Nesheli, Ceder, & Estines, 2016). We divided the transport modes into two groups: 'sustainable' (cycling, walking, metro, and public transport) and 'non-sustainable' (private car «driving, sharing» and taxi). We used a binary logistic model to see which socio-economic characteristics were important for choosing between the two groups. The model predicts the probability (p) of selecting the sustainable group (1) or the non-sustainable group (0) with the probability ($p - 1$) based on a set of socio-economic features consisting of continuous and categorical variables (Ramos, Ollero, & Suárez-Llorens, 2017). Equation (1) shows the binary logistic model (Smallman-Raynor, Rafferty, & Cliff, 2017).

$$(1) \quad \ln\left[\frac{\hat{Y}}{1-\hat{Y}}\right] = \beta_0 + \sum_{r=1}^{n} \beta_r x_r$$

The equation helps us estimate the likelihood ($\hat{Y}$) of choosing a non-green way to work. The fixed number β_0 is the model's constant, and (x_r) is a variable that can vary or belong to different categories. The model has to find out the number of (β_r), which is the coefficient that shows how much x_r affects the likelihood.

4. RESULTS AND DISCUSSIONS

To explore the impact of socio-economic factors on transportation mode preferences during shopping trips, in this study, a binary logistic regression approach was employed to examine the association between socio-economic factors and transportation choices. The variables considered in this investigation included gender, age, educational attainment, occupation, and monthly income. The results of the binary logistic regression analysis, which focused on the selection between low-carbon and non-low-carbon modes of transportation, are displayed in Table 5.

The statistical fit of the models was found to be modest, as indicated by the Chi-square value of 220.370 (p = 0.000). However, the models exhibited a relatively low explanatory power, with the Nagelkerke R-squared value of 0.310, which suggests that there are other significant factors influencing transport mode choices that were not accounted for in the model.

The subsequent analysis encompassed the execution of significance tests, which unveiled noteworthy effects of car ownership and gender on transport mode preferences with a 99.9 % confidence level, while monthly income exhibited significance at a 99 % confidence level. These results suggest that individuals who possess cars and identify as male have a higher propensity to select non-low-carbon transport modes for their shopping excursions. Additionally, a positive correlation was observed between higher monthly income and the likelihood of opting for non-low-carbon transport modes during shopping activities.

These identified significant factors provide valuable insights into the underlying rationales contributing to the prevalence of conventional transport modes during shopping excursions. However, it is important to note that additional unaccounted factors may contribute to this phenomenon, emphasizing the need for further research to enhance the understanding of mode choice behavior in the context of sustainable transportation.

The results regarding vehicle ownership indicate that individuals who do not have any vehicles had a 1.285 times higher probability of choosing environmentally friendly transportation options for their work-related trips, in contrast to those who own cars. These findings align with previous studies, reinforcing the notion that car availability significantly im-

Variables	Definition	Mean	Std. Dev. Dev.
Dependent Variables			
Weekday HB Shopping	Home-based sustainable shopping trips for weekday	1.01	1.27
Personal Characteristics			
Age	Individual's Age	34.02	15.76
Male	Male = 1, If not = 0	0.54	0.50
Education	Highest Degree (Graduate =1, = 0 Other)	0.46	0.50
Driving license status	(1 if available, otherwise 0)	0.35	0.48
Occupation level	full-time job = 1, otherwise 0	0.70	0.46
Travel Pass**	Travel Pass Ownership (Own a travel pass = 1, If not = 0)	0.24	0.43
Public mode***	Public Mode Usage (Using the public mode = 1, If not =0)	0.55	0.50
Workplace timing	Fixed Work Hours (Having fixed work hours = 1, If not = 0)	0.35	0.48
Household Characteristics			
Household Size	Number of Household Members	3.94	1.15
Residence type			
Apartment	1 if the residence type is Apartment, If not = 0	0.67	0.47
Independent house (Reference)	1 if the residence type is an independent house, If not = 0	0.03	0.18
Chawl*	1 if the residence type is Chawl, If not = 0	0.24	0.43
Slums (Informal settlements)	1 if the residence type is a slum, If not = 0	0.07	0.25
Ownership type			
Owned	Residence Type (Apartment = 1, If not = 0)	0.76	0.43
Rented	Ownership rented = 1, 0 = otherwise	0.19	0.39
Government Quarter	1 if the ownership type is government quarter, If not = 0	0.05	0.23
Accommodation level	Number of rooms in the household	3.48	1.43
Children	A household has children = 1, If not = 0	0.29	0.45
Students	Students number in the household	1.06	0.88
Workers	Workers number in the household	1.60	0.78
Vehicles	Vehicles number in the household	0.94	0.89
Car ownership	Household own a car = 1, If not = 0	0.31	0.46
Two-wheeler ownership	Household own a two-wheeler = 1, If not = 0	0.47	0.50
Bicycle ownership	Household own a bicycle = 1, If not = 0	0.03	0.18
Household Monthly Income Level	The monthly income of the household	4.27	1.84
Neighbourhood Characteristics			
Population Density per square km			
Population Density 4K (Reference)	If Population Density (4000-8999) = 1, If not = 0	0.32	0.47
Population Density 9K	If Population Density (9000-11999) = 1, If not = 0	0.05	0.21
Population Density 12K	If Population Density (12000-14999) = 1, If not = 0	0.05	0.21
Population Density 15K	If Population Density is (15000-19999) = 1, If not = 0	0.10	0.30
Population Density 20K	If Population Density is (20000-44999) = 1, If not = 0	0.45	0.50
Population Density 45K	If Population Density is 45000 or more = 1, If not = 0	0.04	0.19
Walk score	Walkability and Accessibility Index	70.61	12.25

* A Chawl is a large linear building divided into many separate tenements with a common corridor, offering cheap, basic accommodation to low-income residents

** A travel pass is a ticket that allows a passenger of a bus or transit service to take within a fixed period either a certain number of pre-purchased trips or unlimited trips.

*** Public mode indicates public transportation like local trains, buses etc...

Table 4. Description of the Dependent and exploratory variables for HBW sustainable shopping trips.

pacts residents' preference for transportation modes that are not environmentally friendly when it comes to shopping trips. Moreover, the findings regarding vehicle ownership reveal that individuals who possess their vehicles exhibited a 1.285-fold higher likelihood of opting for conventional transportation modes rather than low-carbon alternatives when undertaking shopping trips, as compared to those without car ownership.

Previous studies (Carse et al., 2013; Choi & Ahn, 2015; Plaut, 2005) consistently establishes a robust correlation between car ownership and a reduced propensity to select sustainable modes of transportation. Moreover, their studies indicate that households with a higher ratio of cars per adult exhibit a greater inclination toward conventional transportation options.

The findings from the analysis indicated that males exhibited a 1.08 times higher propensity to utilize transportation modes other than low-carbon options for shopping trips, in comparison to females. This observation underscores the importance of considering gender differences in travel mode

Explanatory Factors	B	S.E.	Wals	Exp (B)	95 % C.I. for Exp(B)	
					Lower	Upper
Car ownership (ref: no)	1.718***	0.108	107.715	1.285	2.101	7.671
Respondence Gender (ref: female)	0.637***	0.145	10.015	1.0 8	1.451	2.563
Monthly income (ref = >100000 INR)						
Monthly income (> 30000 INR)	−0.866**	0.303	8.154	0.305	0.232	0.762
Monthly income (30001 - 100000 INR)	−0.650**	0.207	9.872	0.721	0.348	0.783
Age (ref >= 61)						
Age (≤18)	−0.312	0.536	0.340	0.732	0.256	2.093
(19 – 30)	0.003	0.280	0.000	1.003	0.579	1.737
(31 – 40)	0.375	0.267	1.979	1.455	0.863	2.455
(41 – 50)	0.342	0.280	1.492	1.407	0.813	2.435
(51 – 60)	-1.071	0.115	1.156	2.04	0.814	1.913
Occupation (ref = retirement and unemployed)						
(public)	0.204	0.245	0.693	1.226	0.759	1.981
(business)	0.092	0.210	0.192	1.096	0.726	1.655
self-employed	0.106	0.230	0.214	1.112	0.709	1.745
Student	1.059***	0.501	1.05	1.15	2.015	1.09
managerial	-0.721**	2.013	3.164	0.91	0.513	2.019
Other	0.106	0.230	0.214	1.112	0.709	1.745
Education (High = ref)						
Education (Low)	0.142	0.426	0.111	1.153	0.500	2.655
Education (Middle)	0.629	0.382	2.707	1.876	0.887	3.970
Built environment Population density PD4K (Reference)						
PD9K	0.234	-1.03	-1.3077	2.1		1.981
PD12K	0.567	2.04	-0.704	0.08		1.655
PD15K	0.192	1.07	-0.042	1.13		1.745
PD20K	1.072	0.07	0.051	1.405		1.981
PD45K	-1.52	-1.29	-0.821	-0.17		1.655
Chawl	1.52**	1.07	0.39*	1.25		1.745
Walk score	2.103 ***	1.09	2.12***	0.24	2.09	1.981
Constant	−2.815 ***	0.455	38.227	0.060		1.655
PseudoR-Square (Nagelkerke)			0.310			
−2LogLikelihood			1351.411			
Chi-Square			220.370			

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 5. Outcomes of Binary Logistic Regression Investigating the Effects of Transportation Mode Selection on Shopping Excursions.

choice, a topic that has been extensively explored in previous literature. Notably, studies conducted by Cao (2015); Myers, Trang, & Crizzle (2011) have consistently highlighted a significant association between gender and travel mode preferences. Specifically, these studies have revealed that women tend to exhibit a significantly lower likelihood than men of selecting transportation modes that are not classified as low-carbon options.

These findings emphasize the significance of gender in shaping travel behavior and highlight the importance of considering gender-specific factors in the design of interventions and policies aimed at encouraging sustainable transportation choices. By acknowledging and addressing these gender-related dynamics, interventions and policies can be more effective in fostering sustainable transportation behaviors.

Income plays a significant role in shaping mode choice behavior in travel. The data and analysis conducted in this study revealed notable associations between income levels and the likelihood of selecting non-low-carbon modes for shopping trips. Specifically, residents with monthly incomes below INR 30,000 were found to be 0.305 times as likely to choose non-low-carbon modes compared to residents with higher incomes exceeding INR 100,000. Similarly, residents with monthly incomes ranging from INR 30,001 to INR 100,000 were 0.721 times as likely to opt for non-low-carbon modes compared to their higher-income counterparts.

These findings underscore the role of income as a key determinant of mode choice behavior, aligning with previous research highlighting the influence of socioeconomic factors on travel decisions. Individuals with lower incomes may face financial constraints that limit their ability to access and afford low-carbon modes of transportation. In contrast, higher-income individuals often possess greater resources and may have more options available to them, including the choice of environmentally friendly transportation alternatives. Understanding the relationship between income and mode choice can inform the development of targeted interventions and policies aimed at promoting equitable and sustainable transportation options across different income groups.

Age showed that it is positively connected to choosing sustainable transport modes, except above the age of 60. There could be several reasons for this. For instance, older individuals may have a heightened awareness of environmental issues and the impact of transportation on climate change. Another possibility is limited mobility, older adults above the age of 60 may experience reduced mobility, which could make it more difficult for them to use certain sustainable transport options like walking or biking. They may rely more on private vehicles or other modes of transportation that offer convenience and comfort.

The influence of population density on transportation mode choice exhibits nuances across different categories. Notably, individuals residing in low-population areas display a greater inclination towards sustainable transportation modes, a trend that aligns with expectations. In these areas, limited transportation infrastructure and options could naturally lead to a higher reliance on walking, cycling, and public transportation due to their convenience and availability. Furthermore, the relatively shorter travel distances in low-population areas render sustainable modes like walking and biking feasible and time-efficient for covering these distances.

However, the dynamics shift when considering individuals living in densely populated areas population D45K (Tanishita & van Wee, 2017). While one might intuitively expect a greater preference for walking and cycling due to improved facilities and shorter distances, the reality is more complex. In densely populated areas, there is indeed a higher availability of transportation infrastructure, including dedicated cycling lanes and pedestrian-friendly pathways. This availability can promote walking and cycling for shorter trips and can enhance the overall feasibility of these sustainable modes.

Yet, the prevalence of motorized modes in such areas can be attributed to multifaceted factors that extend beyond infrastructure provision. Despite having access to facilities for walking and cycling, individuals in densely populated areas might opt for motorized transportation due to several reasons. First, the sheer density of the population could lead to congestion and competition for limited road space, potentially diminishing the allure of cycling or walking. Moreover, the perception of time-saving becomes paramount in such areas where traffic congestion and longer travel distances are more common. Public transportation and private vehicles could offer faster options for covering substantial distances or navigating through crowded urban streets.

In essence, while infrastructure availability is a vital determinant, other contextual elements such as congestion, travel distances, and time-saving considerations play a significant role in shaping mode preferences in densely populated areas. Therefore, our findings underscore the need for a holistic approach to transportation planning, one that not only focuses on infrastructure development but also addresses the complex interplay of factors influencing individuals' mode choices.

The walk score has a positive effect on choosing a low-carbon commute mode. Living in a walkable neighbourhood tends to result in higher walking trips and more access to variance activities

The positive effect can be attributed to several factors. First, living in a walkable neighbourhood makes it more convenient and feasible for individuals to walk or bike to their destinations. The presence of pedestrian-friendly infrastructure, such as sidewalks, crosswalks, and bike lanes, encourages and facilitates active modes of transportation.

Second, the result indicates that individuals residing in walkable neighbourhoods have higher rates of walking trips. This suggests that they are more inclined to choose walking as a mode of transportation for various activities, including commuting. This behavior can be attributed to the proximity of amenities and services in walkable neighbourhoods, such as grocery stores, restaurants, parks, and shops, which makes walking a convenient and enjoyable option.

5. CONCLUSIONS AND LIMITATIONS

This study has examined mode choice behavior focusing on factors influencing the decision between private cars and sustainable modes of walking, cycling, and public transport for shopping-related mobility in the Mumbai Metropolitan Region. Valuable insights into travel behavior dynamics emerged from empirical data collected through questionnaire surveys on both weekdays and weekends. Sustainable modes, including walking, cycling, and public transport, were found to be more prevalent choices for shopping trips compared to non-sustainable options like private cars or motorcycles. Binary logistic regression analysis established associations between travel mode preferences and influential factors such as car ownership, gender, and income, significantly shaping transportation decisions. An essential insight underscores the importance of prioritizing environmentally sustainable alternatives over mere transport network expansion. Effective policies should address critical issues like seat availability, affordability, safety, accessibility, and reliability, with a focus on enhancing public transport infrastructure and services. Urban design must actively cultivate sustainable travel behavior and environmental consciousness, particularly among socio-economically diverse groups. Moreover, strategic investments in technological innovations to reduce vehicle emissions and fuel consumption, alongside behavioral incentives like taxes and congestion fees, can steer individuals towards eco-friendly choices. Integrating these insights into comprehensive policies that combine mode promotion, technology, and incentives could lead to a more sustainable and livable urban environment for present and future generations.

Based on insights from our study, we recognize the vital role of minimizing car use in moving toward eco-friendly transport solutions. To streamline this shift, we propose a multi-pronged approach that includes regulating vehicle ownership, enhancing the quality of public transport, and developing robust pedestrian and non-motorized transport facilities. We'll initiate the strategy by gathering data on the travel habits and preferences of our target audience through surveys or focus groups. This data will then inform a customized plan, guided by the psychological framework from Risser & Sucha (2020) aimed at addressing the unique barriers and incentives relevant to our target group. Key elements of the plan will include infrastructure improvements like additional sidewalks and bike lanes, informational campaigns outlining the health and environmental benefits of sustainable travel, and incentives such as discounts on public transport or free bike rentals to encourage adoption of greener travel options.

While this study contributes valuable insights, it has potential avenues for future research. A more nuanced investigation, considering different segments of independent variables, holds significant potential for enhancing our understanding of mode choice behaviors. Exploring variations within specific demographic and built environment segments could provide a deeper understanding.

Conducting a robust methodology such as mixed-effects binary logistic regression could be employed to identify distinct subgroups with varying relationships to mode choice could yield insights into how specific male car owner segments, age cohorts, income levels, urban/suburban contexts, or other relevant differentiators influence mode choice.

These refined insights could not only contribute to a better understanding but also offer targeted implications for sustainable transportation policies, tailored interventions, and urban planning strategies. As the field of transportation and urban studies continues to evolve, future research could build upon these insights to create more comprehensive and effective solutions for promoting sustainable mobility in urban areas, particularly in the context of the Mumbai Metropolitan Region (MMR).

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