Effect of Introduction of Metro on Mode Choice Behaviour of Feeder Trips to Airport: A Case Study on NSCBI Airport, Kolkata.

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Abstract

Netaji Subhash Chandra Bose International Airport (NSCBI) in India stands out as a prominent airport in Asia region. Like other airports, NSCBI Airport has also experienced a surge in air travel demand. The rapid increase in air travel demand has created pressure on managing feeder trips to airports, resulting in increased congestion, delays, and environmental issues. To address these issues, the Kolkata city development authority and Kolkata metro rail authority has decided to connect NSCBI airport by existing metro system. The introduction of metro service will change the present mode choice behaviour for feeder trips to airport. This study analysed the present mode choice behaviour for airport feeder trips and the impact of the Kolkata metro on it. Based on preference survey data and with the help of statistical methods, present and future mode choice behaviour was investigated. The binary logit model was used to analyze present mode choice behaviour, and the multinomial logit model was used to examine future mode choice behaviour after the introduction of Kolkata Metro in NSCBI Airport. The outcomes of these models shows that present and future mode choice behaviour to access NSCBI Airport are significantly affected by trip-related attributes and socioeconomic characteristics of passengers. The result also revealed that more than 50% of passengers are willing to shift to metro in future to access airport. The findings of this research will help transport planners and Airport Authorities to make effective planning for metro and other access modes.

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Introduction

In the modern world, Air transportation plays a significant role in enhancing global mobility (Alhussein, 2011). Along with travel time saving air travel offers comfort and luxury. On the other hand, it has an impact on developing the economies of country by enhancing global connectivity, promoting tourism, and creating employment opportunities (Florida et al., 2015). After the COVID pandemic, air transportation is rapidly increasing all over the world. The International Air Transport Association (IATA) forecasted that the number of air transports will reach 7.8 billion per year at the end of 2040, with an annual growth rate of 3.3%. IATA also mentioned that the highest annual rate of increase in air transportation in Asia-Pacific countries is around 4.5% (International Air Transport Association, 2022). India, a prominent developing nation in the Asia-Pacific region, has experienced a notable increase in air transportation in recent years. The rapid advancement of technology in the aviation sector, the rise of various aviation companies, various government schemes regarding regional airports, and the increase in per capita income have fuelled the growth of the Indian aviation sector. In the financial year 2022–23, Indian airports managed 54.6 million international and 136 million domestic passengers, compared to 21.2 million international and 84.2 million domestic passengers in the previous fiscal year. Domestic passenger traffic shows a compound annual growth rate (CAGR) of 8.9% during the period 2012–13 to 2022–23, while international passenger traffic grew at 3.1% CAGR during the same period. Figure 1 shows the air transportation trend in India for the last few years (Directorate General of Civil Aviation, 2023).

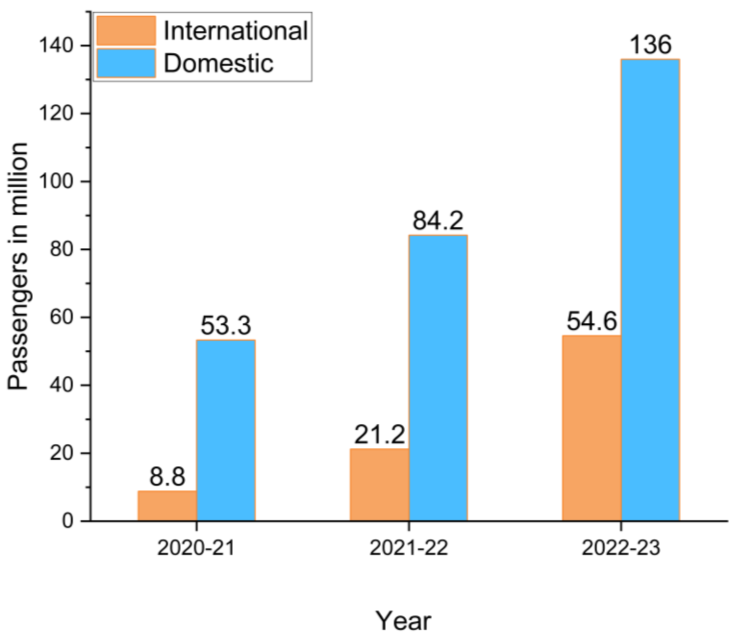

Figure 1: Air transportation trend in India
(Source: Directorate General of Civil Aviation, 2023)

Increasing demand for air transportation creates pressure on existing airport facilities. The Airport Authority of India (AAI) has started the upgradation of existing facilities like the construction of canopy, runway, terminal buildings, apron, hanger, etc. Along with these constructions, AAI initiated some new strategies to control the high volume of passengers: Digi yatra for the Biometric Boarding system and Air-Sewa for a convenient and hassle-free air travel experience (Airport Authority of India, 2023). The airport feeder system through the is the most important facility among them. The efficiency of the airport is correlated with the efficiency of the feeder system (Alhussein, 2011). As this is not controlled by the AAI, it often lags behind other airport infrastructure in terms of upgradation.

In Indian cities, the airport feeder system predominantly depends on private vehicles and low-occupancy paratransit vehicles. Therefore, to manage this increasing demand, a greater number of such types of vehicles operate, which contributes to increased congestion, vehicular emissions, congested parking spaces, and decreased air quality.

To resolve these issues, many metropolitan city development authorities like Kolkata, Bengaluru, Mumbai, and Hyderabad have started construction of metro connections between the airport and the central business district (CBD) areas of the city.

The introduction of this new sustainable, economical, and reliable travel mode to access airports will attract passengers to use it. Eventually, the introduction of the metro will change the mode choice behaviour of passengers.

In this context, it is important to evaluate the present mode choice behaviour of passengers to access airport and the impact of metro introduction on it, which would be helpful for effective transport planning for airport-surrounded cities and feeder system of airports.

The objectives of this study is to evaluates the mode choice behaviour of passengers to access airport and examines how introduction of metro will influence the mode choice behaviour of passengers.

Literature Review

To develop a foundation for understanding airport feeder trip mode choice behaviour of air passengers, studies of previous work are important. After a comprehensive study of the literature regarding airport feeder trips mode choice, it was found that most of the work regarding airport ground access mode choice was done in western cities and gulf counties.

First study regarding airport access mode choice was conducted by Ellis et al., in 1974. Based on survey data collected from Baltimore Washington Airport and using the multinomial logit

(MNL) model, the authors found that trip purpose, travel time, and travel cost were crucial factors for airport ground access mode choice [10].

Some researchers have utilized travel time and travel cost as primary factors in explaining access to the airport [5], [7], [8], [11], [12], [13]. Hess et al. in 2004, observed that travel cost was not a crucial factor for business class passengers [14]. On the other hand, Tsamboulas et al. in 2012, mentioned that the cost of travel was more important than travel a time for both car and taxi in the case of Athens air passengers [15]. In 1986, Harvey conducted a study regarding mode choice in San Francisco Bay Area Airports and found that travel time was a more crucial parameter for those air passengers who travel longer distances in flight[11]. M. Tam et al. in 2008, mentioned business travellers prioritized travel time more than other travellers while accessing the airport. Additionally, business travellers were willing to spend extra costs for travel time-saving[16].

Again M.-L. Tam & Lam (2011) examined the mode choice behaviours of air passengers at Hong Kong International Airport and measured travel time in terms of 'Safety margin'. The author explained the 'Safety margin' as the difference between the actual travel time to reach the airport and the expected travel time to reach the airport. The author also mentioned that business travellers were willing to pay more for the shortest safety time [7].

Trip purpose is another crucial factor that has been considered by many researchers for the analysis of airport mode choice. Most of the researchers classify trip purposes into two categories- Business category and Non-business Category [8], [11], [14], [16], [17], [18], [19], [20]. Harvey (1986) concluded that non-business travelers were more significantly affected by demographic variables. While business travellers gave more importance to travel time[11]. Mamdoohi et al. (2012) found that business travellers were more likely to choose private vehicles than public transportation to access the airport [19]. Psaraki & Abacoumkin (2002) conducted a mode choice survey at Athens International Airport. Their result showed that domestic business travellers were more inclined to choose private vehicles, while non-business international travellers were more likely to choose taxis or dropped-off, cabs to access the airport [17].

Some researchers have taken business and non-business travellers as categories of explanatory variable. Whereas Harvey (1986); Hess (2004); Gupta et al. (2008) made separate models for business and non-business passengers[11], [14], [18].

Socio-economical characteristics of passengers are an important variable for understanding the mode choice to access the airport. Age, gender, occupation, income, level of education, and nationality have been considered by most of the researchers. Alhussein (2011) found nationality and income were two significant factors for ground access mode choice for King Khaled International Airport [5]. Gender, monthly income, and vehicle ownership were considered by Mamdoohi et al. (2012) for the analysis of mode choice for IKIA airport [19]. Gupta et al. (2008) concluded age, gender, and income level had significant effects on airport access mode choice in New York City [18]. Sangho Choo & Lee (2013) found that age, gender, occupation, and income had a significant impact on mode choice in Korea [20]. Akar (2013) in her study considered age and income as demographic characteristics for air passengers[8]. Zaidan & Abulibdeh (2018) discovered nationality, income, employment status, vehicle ownership, and age as significant parameters for mode choice to access Hamad International Airport[9].

The number of luggage especially check-in luggage and group size were another important parameter for mode choice [9], [11], [21]. Passengers with more check-in luggage were more inclined to choose private vehicles rather than public transport [8], [9], [11]. Whereas Budd et al., (2011) found the opposite result in the UK where passengers with more check-in luggage preferred to choose public transportation[21]. In the case of group size, passengers with large group sizes preferred to choose private vehicles over public transportation [8], [9]. Vehicle ownership of passengers is also an essential parameter of mode choice modelling [19], [22].

Other parameters that have been considered by some of the researchers are parking fees, reimbursement of parking, and availability of parking space in the airport. Zaidan & Abulibdeh, (2018) experienced that if parking fees were fully reimbursed then the use of public transport would decrease by 48.6%[9]. Tsamboulas et al. (2012) mentioned that the use of public transportation increases if there is no parking facility available in the airport and toll subsidy is not available. More use of public transport as a main mode to access the airport can easily controlled by authorities [21]. Gokasar & Gunay (2017) in their study suggested that passengers were more willing to choose public transit if their trip origin was inside the influence area of that public transit[13].

In the case of discrete choice modelling, the logit model has been considered to be the most suitable method [12], [23], [24]. According to McFadden, (1973), the logit model is more straightforward and is capable of capturing the randomness of choice[23]. Additionally, Hess & Polak (2006)mentioned that the logit model can handle more complex situations than other models[12].

It is found from the literature survey that there is a lack of studies about airport feeder trips in South Asian countries. NSCBI Airport in India stands out as a pivotal airport in this region. Therefore, conducting a mode choice analysis for accessing the NSCBI Airport becomes imperative. Again, from literature survey, it was also discovered that no study has yet been incorporated the extension of the Kolkata metro to NSCBI airport. Therefore, this study empirically investigates the airport feeder trip mode choice behaviour for NSCBI Airport and examine how the introduction of the Kolkata metro influences this behaviour.

Study Area

Netaji Subhash Chandra Bose International Airport, located in Kolkata, the capital city of West Bengal, holds significant importance as a major airport in Eastern India (Figure 2). The airport plays a pivotal role in connecting eastern and northeastern India with many national and international destinations. The Airport is situated at a distance of 15 kilometres from the city centre. It has one integrated terminal for national and international flights and can handle 25 million passengers annually. The new terminal has several passengers boarding bridges, travelators, lifts, and biometric check-in facilities for the smooth movement of passengers along with a VIP lounge, food courts, duty-free shops, and parking facilities. There are no entry fees for any type of vehicle to access NSCBI Airport, but parking is chargeable, and parking charge increases with the duration of stay. NSCBI Airport has a cargo terminal with modern technology, capable of handling a wide range of goods including medicine.

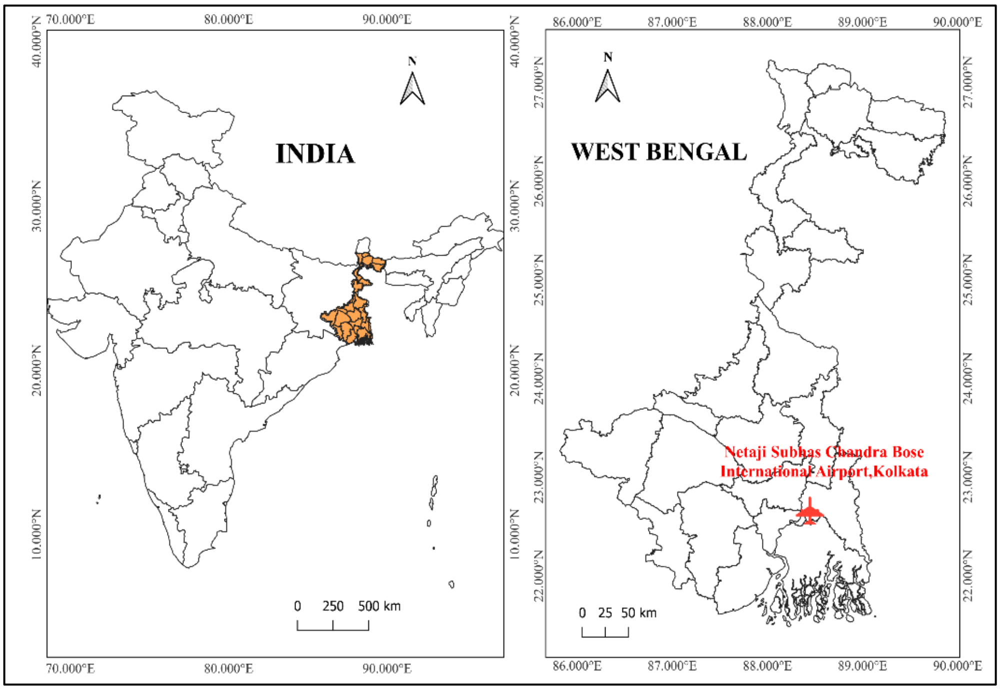

Figure 2: Location of NSCBI airport

In 2022-23 NSCBI Airport served 2.51 million international passengers, 16.9 million domestic passengers, 46 thousand metric tons of international freight, and 88 thousand metric tons of domestic freight. Figure 3 illustrates statistical data on passengers for the last few years.

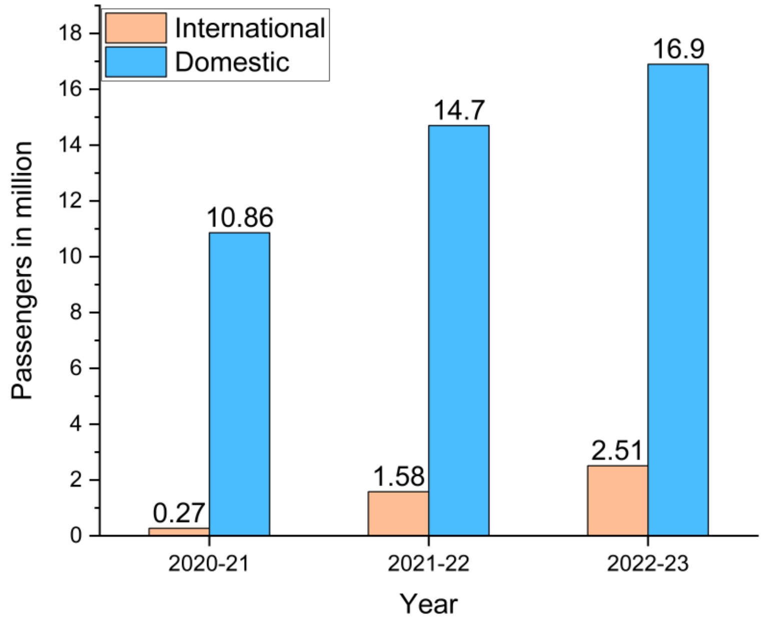

Figure 3: Air transportation trend in NSCBI Airport
(Source: Airport authority of India, traffic news)

NSCBI Airport is directly connected by only road transport. VIP Road and Jessore Road directly connect Airport with Kolkata metropolitan city and other surrounding city area. The two nearest rail stations, Dum Dum cantonment rail station, and Durganagar rail station are located 4.6 km and 5.3 km from NSCBI Airport respectively. Sealdah and Howrah, two major railway stations in Kolkata city are situated 15 km and 17 km away from NSCBI Airport. There is no railway station available that directly connects the airport. Presently three types of transport are used: private vehicles, paratransit vehicles like ride-sourcing services, traditional taxis, and city buses for accessing airport. City bus share is very low. Traditional taxis and city buses are controlled by the West Bengal Transport Department. And ride-sourcing services are controlled by various ride-hailing companies like Ola, Uber, In-drive, E-snap etc. Due to congestion and delay issues during access to the airport, passengers sought out alternative transportation methods that are sustainable, reliable, and economical. To solve these issues Kolkata Municipality Development Authority and Kolkata Metro Rail Corporation Limited decided to connect NSCBI Airport with metro. The proposed orange line and yellow line will directly connect airport with other parts of the city, as shown in Figure 4. The introduction of the Kolkata metro in the NSCBI Airport will change the present mode choice behaviour of airport access trips. Therefore, it is important to examine the change in airport access mode choice behaviour due to the introduction of metro. This study statistically evaluates present mode choice behaviour of NSCBI Passengers and the changes in mode choice behaviour due to introduction of metro by collecting data on socioeconomic characteristics of departing passengers and information regarding recent trips. The required number of data is collected from departing passengers in NSCBI Airport premises by questionnaire survey.

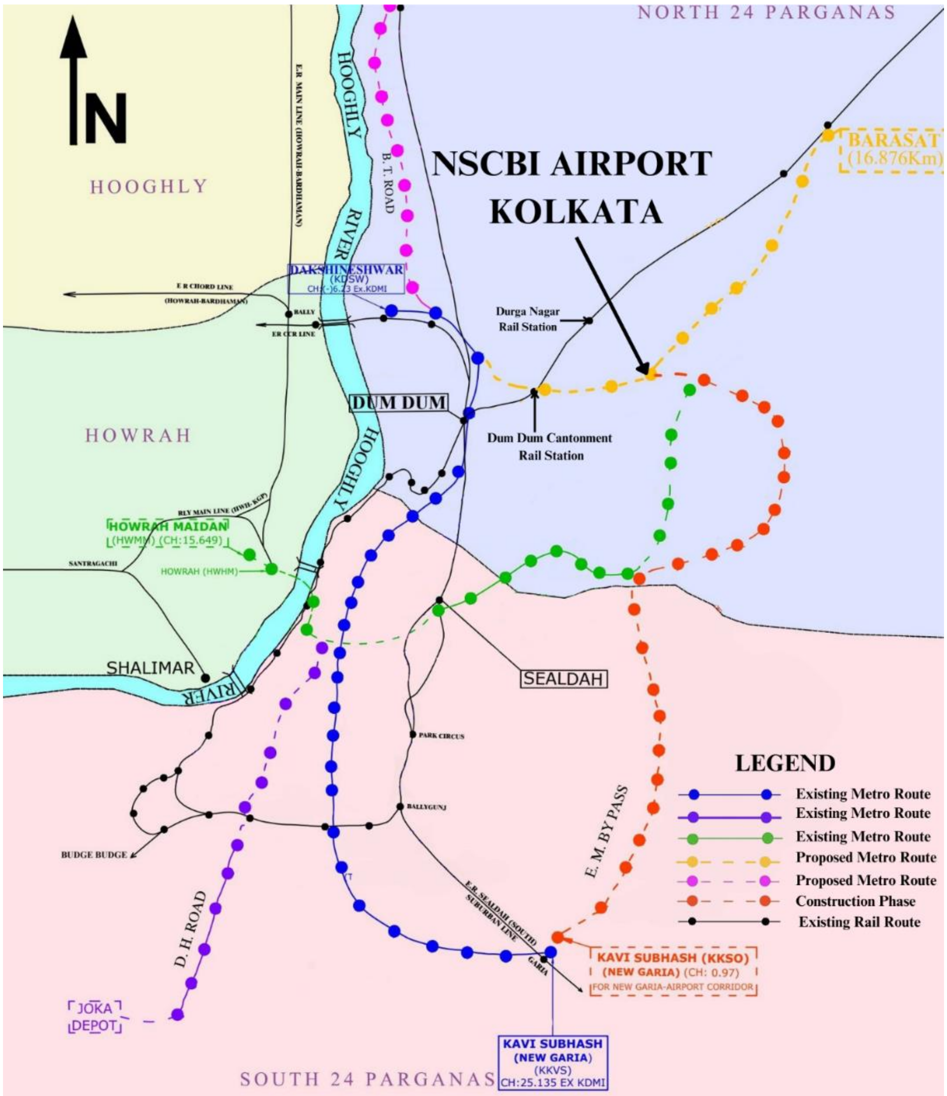

Figure 4: Metro and rail network in Kolkata (Source: Metro Railway Kolkata)

Data Collection

A reveal preference (RP) and stated preference (SP) face-to-face interview survey was conducted at NSCBI Airport to collect required data of departing passengers. After a comprehensive study of the literature regarding airport feeder trips mode choice, explanatory variables were selected and a questionnaire was designed. The questionnaire format was prepared in English and tried to be as simple as possible so that every respondence could understand easily. The RP questions were about the mode chosen to access NSCBI airport, information about the recent trip, and the socioeconomic characteristics of passengers. The SP questions were utilized for testing hypothetical situations. This section gathered information about the willingness of passengers to use the metro when it becomes operational and the primary reasons for using the metro as the main access mode. This data collection process was organized for 15 days (21st June – 5th July 2023). The face-to-face survey was conducted when the passengers were making queues to collect their boarding passes and before security checking. Each passenger in the queue was requested to participate in the interview. If anyone refused to participate then the next individual was invited to take part in this face-to-face interview. The Cochran equation [26], a well-established formula in many discrete choice studies, was employed to determine the necessary sample size for this study. Utilizing a Z-score of 1.96 for a 95% confidence interval, a population attribute distribution of 0.5, and assuming a margin of error of 0.5 in the Cochran equation, a calculated sample size of 384.16 was obtained. However, this study exceeds this requirement by collecting a substantial sample of 494 travellers through face-to-face interviews.

Methodology

The main focus of this study is to find out the effect of the introduction of the metro on the mode choice behaviour of feeder trips to NSCBI Airport, Kolkata. To evaluate the effect of the metro, analysis of the present modal preference to access the airport is important. The conceptual framework for this study is shown in Figure 5. The RP questions was designed to gather information regarding trip related characteristics (airport access mode, trip purpose, trip origin, travel length, travel time, travel cost, number of luggage, group size, and the primary reason for the used mode) and socioeconomic characteristics of passengers (age, gender, occupation, car ownership, annual income). Some service quality attributes like comfort, safety, reliability, convenience, and availability, are also used in this study. In the case of service quality attributes, the Likert scale (1 to 5) has been used. This RP survey data was utilized to evaluate present mode choice behaviour of passengers.

To investigate the impact of Kolkata metro on present mode choice behaviour SP data was used. The SP data were merged with RP data to analysis the future mode choice behaviour of passengers.

A binary logit model was employed to ascertain the current mode choice behaviour, while a multinomial logit model was utilized to assess the influence of the metro on present mode choice behaviour. Both models predict categorical dependent variables using a set of independent variables, employing odds ratios between the variables. Additionally, each logit model requires one dependent variable to be designated as the reference category.

Utility maximization theory is mostly used in mode choice analysis. A passenger chooses that alternative mode which can get maximum utility (Eq.1).

$$U_{i,n} \geq U_{j,n} \quad \ldots (1)$$

Here $U_{i,n}$ indicate the utility of i alternative for nth passenger. And $U_{j,n}$ indicate the utility of j alternative for nth passenger, Where $i \neq j$. Hence, for mode choice the difference between utility from various alternative is important. Determination of absolute utility is not relevant. This utility can be represented as function of socio-economic characteristics of passengers (S_n), trip, and mode-related attributes (X_i) as shown in equation 2.

$$U_{in} = f\,(S_n, X_i) \quad \ldots (2)$$

As per deterministic utility theory, individual with same characteristics choose same alternative for all time. But in real situation individual with same characteristics may choose different alternative depend upon situation. Therefore, there is an error term in utility function that describe the randomness of choosing alternative (Eq.3). V_{in} denoted the deterministic utility and ε_{in} is the error term. β_o, β_n represents a set of estimated coefficients associated with the variable (Xin). This (Xin) indicates the trip and mode related attribute and socio-economic characteristics of passengers.

$$U_{in} = f\,(S_n, X_i) = V_{in} + \varepsilon_{in} = \beta_0 + \beta n X_{in} + \varepsilon_{in} \quad \ldots (3)$$

To capture this randomness in choice making process, probabilistic choice theory is introduced (Eq.4).

$$P_{in} = \text{Prob}\ (U_{in} > U_{jn}) = \text{Prob}\ [(V_{in} + \varepsilon_{in}) > (V_{jn} + \varepsilon_{jn})] \quad \ldots (4)$$

If it is considered that the error term follows the gumble distribution, then the logit model can be used. Here, two types of logit model have used: binary logit model and multinomial logit model. Binary logit model has used for present mode choice. Here two alternative travel modes have involved: Private vehicle (PV) and Public transportation (PT).

Based on the survey, it was noted that the utilization of city buses was notably low, with some passengers resorting to a combination of transportation modes to reach the airport. Therefore, consolidating all modes of transportation except for private four-wheelers into a unified public transportation system would be more practical and direct.

The probability of choosing private vehicle (P_{PV}) and public transportation (P_{PT}) can be written as below. Here V_{PV} and V_{PT} indicate the deterministic utility of private vehicle and public transportation respectively.

$$P_{PV} = \frac{\exp^{V_{PV}}}{\exp^{V_{PV}}+\exp^{V_{PT}}} = \frac{1}{1+\exp^{V_{PT}-V_{PV}}} \quad \ldots (5)$$

$$P_{PT} = \frac{\exp^{V_{PT}}}{\exp^{V_{PV}}+\exp^{V_{PT}}} = \frac{\exp^{V_{PT}-V_{PV}}}{1+\exp^{V_{PT}-V_{PV}}} \quad \ldots (6)$$

If private vehicle is considered as reference mode, then the deterministic utility of private vehicle (V_{PV}) is converted to zero and equation 7 and 8 are formed.

$$P_{PT} = \frac{\exp^{V_{PT}}}{1+\exp^{V_{PT}}} = \frac{\exp^{\beta 0+\beta nXn}}{1+\exp^{\beta 0+\beta nXn}} \quad \ldots (7)$$

$$P_{PV} = \frac{1}{1+\exp^{V_{PT}}} = \frac{1}{1+\exp^{\beta 0+\beta nXn}} \quad \ldots (8)$$

By the help of Maximum likelihood estimator, the β coefficients are estimated. And the final binary model looks like equation 9.

$$\ln \left(\frac{P_{PT}}{P_{PV}}\right) = \beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+......+\beta_nX_n \quad \ldots (9)$$

For future mode choice, multinomial logit (MNL) model was used. Here Private vehicle (PV), Public transportation (PT) and Metro (M) were considered as alternative modes. The responses from SP data were merged with RP data to analyze the impact of metro on future mode choice behaviour.

In MNL model, probability of choosing private vehicle (P_{PV}), public transportation (P_{PT}) and metro (P_M) can written as-

$$P_{PV} = \frac{\exp^{V_{PV}}}{\exp^{V_{PV}}+\exp^{V_{PT}}+\exp^{V_M}} = \frac{\exp^{V_{PV}-V_M}}{1+\exp^{V_{PV}-V_M}+\exp^{V_{PT}-V_M}} \quad \ldots (10)$$

$$P_{PT} = \frac{e^{V_{PT}}}{\exp^{V_{PV}}+\exp^{V_{PT}}+\exp^{V_M}} = \frac{\exp^{V_{PT}-V_M}}{1+\exp^{V_{PV}-V_M}+\exp^{V_{PT}-V_M}} \quad \ldots (11)$$

$$P_M = \frac{e^{V_M}}{\exp^{V_{PV}}+\exp^{V_{PT}}+\exp^{V_M}} = \frac{1}{1+\exp^{V_{PV}-V_M}+\exp^{V_{PT}-V_M}} \quad \ldots (12)$$

V_{PV}, V_{PT} and V_M denoted as the deterministic utility of private vehicle, public transportation and metro respectively. If metro is considered as base mode, then V_M is converted to zero and equation 13, 14 and 15 are formed.

$$P_{PV} = \frac{\exp^{V_{PV}}}{1+\exp^{V_{PV}}+\exp^{V_{PT}}} = \frac{\exp^{\alpha_0+\alpha_n X_n}}{1+\exp^{\alpha_0+\alpha_n X_n}+\exp^{\beta_0+\beta_n X_n}} \quad \ldots (13)$$

$$P_{PT} = \frac{\exp^{V_{PT}}}{1+\exp^{V_{PV}}+\exp^{V_{PT}}} = \frac{\exp^{\beta_0+\beta_n X_n}}{1+\exp^{\alpha_0+\alpha_n X_n}+\exp^{\beta_0+\beta_n X_n}} \quad \ldots (14)$$

$$P_{M} = \frac{1}{1+\exp^{V_{PV}}+\exp^{V_{PT}}} = \frac{1}{1+\exp^{\alpha_0+\alpha_n X_n}+\exp^{\beta_0+\beta_n X_n}} \quad \ldots (15)$$

By using equation 13, 14, and 15 and maximum likelihood estimator, β and α coefficient are estimated. The parameters which give maximum value of this likelihood function are calculated by first derivative of this likelihood function and equating it to zero. Parameters of log likelihood function is easier to estimate than likelihood function, hence loglikelihood function is used. And due to complexity in calculation various software packages are used. Here SPSS software is used to estimate the β_0,β_n and α_0,α_n coefficients. Final MNL model looks like equation 16 and 17. For et al. (2006); K. Train, (2009) may be used for further information about logit models.

$$\ln \frac{P_{PV}}{P_M} = \beta+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_4X_4+\ldots\ldots\ldots.+\beta_nX_n \quad \ldots (16)$$

$$\ln \frac{P_{PT}}{P_M} = \alpha+\alpha_1X_1+\alpha_2X_2+\alpha_3X_3+\alpha_4X_4+\ldots\ldots\ldots+\alpha_nX_n \quad \ldots (17)$$

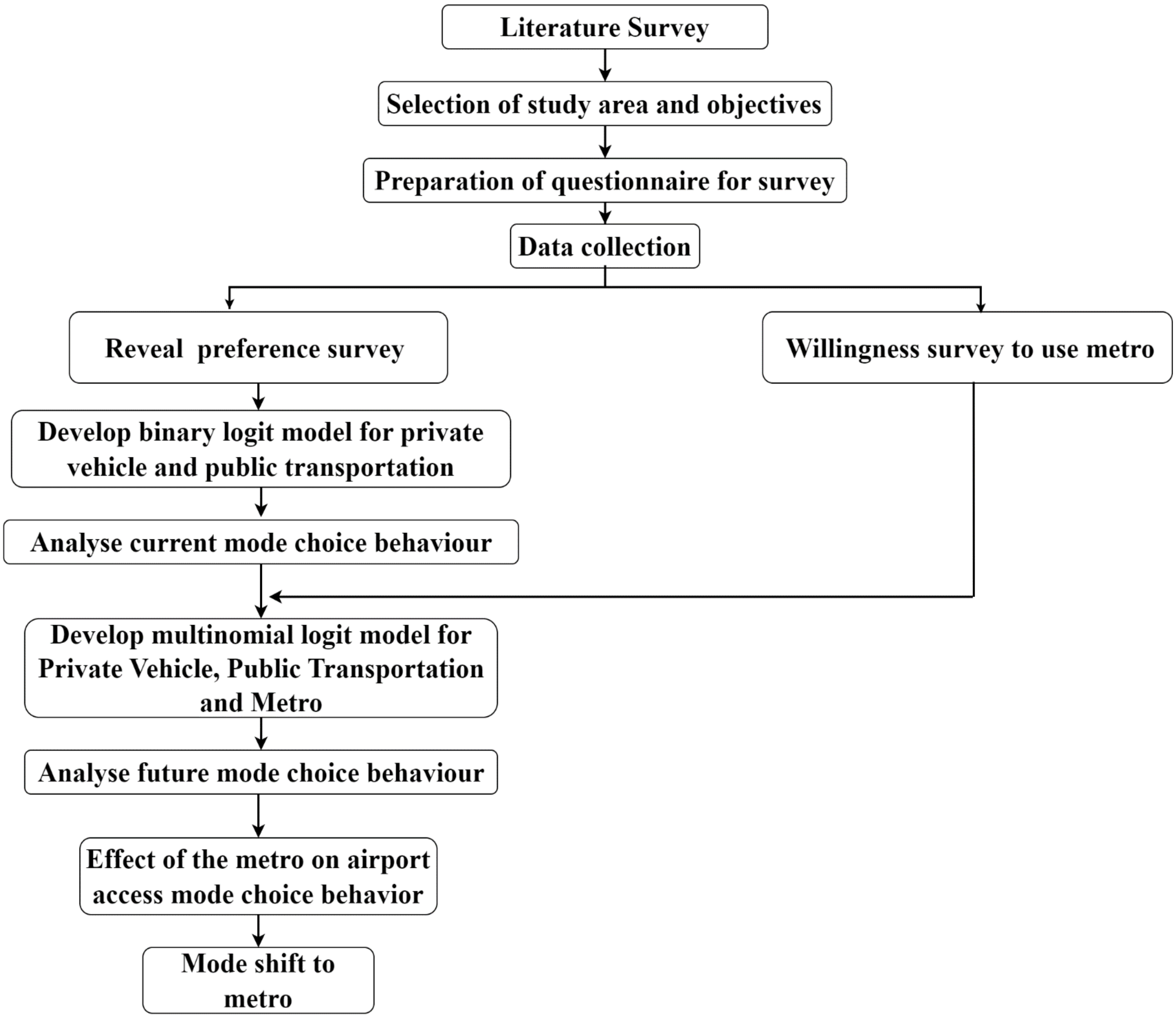

Figure 5: Methodology flowchart

Descriptive Statistics

The Survey data reveals that 56.28% of passengers were male, while 43.72% were female. Notably, the majority of passengers (43.72%) belong to the 30 to 45 age group, followed by 28.14% in the 15-30 age group and 22.67% in the 45 to 60 age group. As passengers get older, they are more likely to choose private vehicles as their preferred mode of transportation. Occupationally, private employees constitute the largest portion of passengers at 54.84%. It was found that 83.20%, of the passengers made their trip for non-business purposes and 78.54% of passengers made their journey from home. 58.91% of the passengers own a private car, but only 51.89% of them used private vehicle to access the airport. Income was another important parameter for mode choice. As income increased passengers were more inclined to private vehicle to access NSCBI Airport. 38.87% of passengers have an annual income in the range of 2-5 lakhs, 37.85% fall in the 5-10 lakhs range, 19.43% belong to the above 10 lakhs category, and the remaining fall in the income category of less than 2 lakhs per year. As mentioned above mainly three access modes are available to access NSCBI Airport. 38.66% of passengers use private vehicle (only 4- wheeler) while 60.12% use paratransit modes such as ride-sourcing services (ola, uber etc) traditional yellow taxis, and a combination of public transportation modes. The remaining passengers use city buses%. The share of city buses is relatively small, making it impractical to create a separate mode option for city buses. However, excluding city buses from the model would mean excluding a portion of passengers who want to switch to metro services. Additionally, some passengers choose to use multiple public transport mode to reach the airport. Therefore, combining all modes except private vehicles with public transportation makes the analysis more feasible and straightforward.

In terms of group size, the majority of passengers travelled alone, and regarding luggage, most passengers carried 2 to 4 pieces of check-in luggage.

The cost of travelling by city bus ranges from 10 to 50 rupees. Whereas for private vehicle and paratransit, the average cost of travel per km is almost same. Although travel cost in paratransit vehicles and availability vary with demand and time of day. A significant majority (62.35%) of passengers indicated a preference for using the metro as their main access mode for future trips to NSCBI Airport. Table 1 and 2 shows the overviews of descriptive statistics of socioeconomic characteristics of passengers and trip characteristics.

Table 1: Descriptive statistics of socioeconomical characteristics of passengers

Access mode	**Percentage**	**Primary reasons for choosing that mode**	**Percentage**
Private Vehicle	38.66%	Cost-effectiveness	9.41%
Paratransit Modes	60.12%	Travel time saving	21.96%
City Bus	1.21%	Luggage	25.49%
		Group Size	16.67%
Origin of trip		Quality of service	26.47%
Home	78.54%		
Hotel	21.46%		
Trip Purpose			
Non-business	83.20%		
Business	16.80%		

Table 2: Descriptive statistics of trip characteristics.

Gender	**Percentage**	**Occupation**	**Percentage**
Male	56.28%	Student/Unemployed	11.54%
Female	43.72%	Private Employee	54.85%
		Govt. Employee	17.81%
Age group		Business	11.74%
15-30	28.14%	Other	4.06%
30-45	43.72%		
45-60	22.67%		
Above 60	5.47%	**Annual income**	
		1-2 lakhs	3.85%
Car-ownership		2-5 lakhs	38.87%
Yes	58.91%	5-10 lakhs	37.85%
No	41.09%	Above 10 lakhs	19.43%

Data Analysis

Multicollinearity Analysis was conducted to check intercorrelation between independent variables. Variable with multicollinearity makes it difficult to estimate the coefficient of the independent variable. If the tolerance is less than 0.25 and VIF is greater than 5 then it can be concluded that there is an issue of multicollinearity. Here, tolerance values ranging from 0.345 to 0.957 and VIF values ranging from 1.045 to 2.896 indicate that there is no significant collinearity problem among the variables.

The main objective of this study is to find out the effect of the introduction of metro as airport feeder trips mode choice behaviour. To project future mode choices after introduction of metro, it is essential to estimate the present mode choice behavior for airport feeder trips. Next section discussed about present mode choice modelling.

Modeling present mode choice to access NSCBI Airport

The aim of this section is to formulate a statistical model (Binary Logit Model) for the present mode choice. Data collected from the questionnaire survey were coded with numeric values to import in SPSS software. The variables with numeric code shown in table 3.

Table 3: List of variables considered in the model with SPSS code

Variables	Categories	SPSS Code
Gender	Male	0
	Female	1
Car-ownership	Yes	1
	No	0
Trip origin	Home	0
	Hotel	1
Reliability	Extremely poor	1
	Somewhat poor	2
	Satisfactory	3
	Good	4
	Very good	5
Income Category	1-2 lakhs (1)	Dummy variable used (0 or 1)
	2-5 lakhs (2)	
	5-10 lakhs (3)	
	More than 10 lakhs (4)	
Primary reason for choosing mode	Cost-effectiveness (1)	Dummy variable used (0 or 1)
	Travel time saving (2)	
	Luggage (3)	
	Group size (4)	
	Quality of service (5)	
Mode of travel	Private vehicle	0
	Public transportation	1

This analysis focused on gender, car ownership, trip origin, trip length, reliability, luggage, income and primary reason for choosing mode. All of these variables are significant at $\alpha = 0.05$, except income category 3 and primary reason- travel time saving. Income category 3 and primary reason- travel time saving both are significant at $\alpha = 0.10$. Table 4 shows the model parameter estimate for the binary logit model. The calibrated model for present mode choice using the estimated co-efficient is indicated in eq-18

$$\ln\left(\frac{P_{PT}}{P_{PV}}\right) = 4.521 - 0.664\, X_1 - 1.078\, X_2 + 0.746\, X_3 - 0.08\, X_4 - 0.586\, X_5 - 0.180\, X_6 + 3.893\, X_7 + 2.569\, X_8 + 0.687\, X_9 + 3.135\, X_{10} - 0.701\, X_{11} \quad \ldots(18)$$

Where X_1 is gender, X_2 is car-ownership, X_3 is trip origin, X_4 is trip length, X_5 is reliability, X_6 is number of luggage, X_7 is income category-1, X_8 is income category-2, X_9 is income category 3, X_{10} is 'primary reason- cost effectiveness' and X_{11} is 'primary reason-travel time saving'. The omnibus test statistics indicate a significant decrease in the -2 log-likelihood value after incorporating these variables, indicating that the final model effectively fits in the data. In Hosmer and Lemeshow test, the significant value is more than 0.05, indicating that the model adequately fits in the data. Cox & Snell R2 and Nagelkerke R2 for this model are found to be 0.510 and 0.692 respectively, suggesting that 51% to 69.2% of the variation in the dependent variable can be explained by the model. This model predicts with an overall accuracy of 84.8%. Specifically, it achieves a correct prediction rate of 79.1% for private vehicles and 88.4% for public transportation.

The constant term is found to be 4,521 as shown in table 4. This implies that when all predictor variables are equal to zero, the logit of choosing public transportation is 4.521 times than private vehicle.

The negative coefficient for gender implies that if an individual is female, the probability of choosing public transportation is less than the probability of choosing private vehicle. The log odds of choosing public transportation over private vehicle for female passenger is - 0.664.

For car ownership, those individuals who have car, are less likely to choose public transportation. The logit for choosing public transportation over private vehicle for that individuals who have car is – 1.078.

In the case of trip origin, if individuals start their journey from a hotel, they are more inclined to choose public transportation over private vehicles to access the airport than those who are starting their journey from home. The log odds of choosing public transportation over private vehicles for those individuals whose trip origin hotel is 0.746 times than those passengers who start their journey from home.

A unit increase in travel length reduces the logit of choosing public transportation over private vehicle by a factor of 0.08. It is expected because after a certain distance the density of public transport like traditional taxi, paratransit services, city bus is reduced significantly. On the other hand, for passengers, it is often more convenient to travel in a private vehicle rather than using a combination of public transport modes to reach the airport.

The preference for public transportation is negatively influenced by reliability. A one-unit increase in reliability decreases the log odds of choosing a public transportation over a private vehicle by a factor of 0.586. It is expected because city buses may not have frequent departures, especially during off-peak hours. For a traditional taxi, it is more time-consuming to hail a taxi on the street. Sometimes the paratransit services are not present at the pickup spot at the scheduled time. It is more important for passengers to reach the airport on time.

Table 4: Model parameter estimate for present mode choice

Dependent Variables	**B**	**Sig.**
Gender	-0.664	0.026
Car Ownership	-1.078	0.001
Trip Origin	0.746	0.035
Trip Length	-0.080	0.000
Reliability	-0.586	0.000
Number of luggage	-0.180	0.028
Income category-1 (1-2 lakhs)	3.893	0.002
Income category- 2 (2-5 lakhs)	2.569	0.000
Income category-3 (5-10 lakhs)	0.687	0.054
Primary reason – Cost-effectiveness	3.135	0.000
Primary reason – Travel time saving	-0.701	0.054
Constant	4.521	0.000

(* Reference category: Private vehicle)

The coefficient for luggage is negative. It implies that a one unit increase in number of luggage reduce the logit of choosing public transportation over private vehicle by a factor of 0.180. This is because transporting luggage in a private vehicle is more convenient than public transportation. It is observed from Table 4 that, as income increases, the log odds of choosing a public transportation to access the airport decrease. In this case, a dummy variable for the income category is utilized.

In the case of the primary reason also dummy variable is employed. The first reason (cost-effectiveness) is found to be significant at a confidence interval of 95%, and the second reason (travel time saving) is significant at a confidence interval of 90%. Cost-effectiveness positively influences the log odds of choosing a public transportation, while travel time saving negatively influences the log odds of choosing a public transportation over private vehicle. Other primary reasons are not significantly affecting the present mode choice.

Effect of metro on airport feeder trip mode choice behaviour

The aim of this section is to examine the impact of the introduction of the metro on the mode choice behaviour of feeder trips to NSCBI Airport using a multinomial logit (MNL)model. The same explanatory variables that significantly affects the present mode choice behaviour are utilized in this section. The data obtained from SP survey is merged with RP data for analysis of future mode choice behaviour. Here the metro has inserted as an alternative mode along with previous modes and considered as reference category. Table 5 shows the result of multinomial logit model. Some variables are significant at 95% confidence interval and some are significant at 90% confidence interval. Hence, the calibrated model for future mode choice is as follows:

$$\ln\left(\frac{P_{PV}}{P_M}\right) = -1.633 + 0.101\,\beta_1 + 0.351\,\beta_3 + 0.952\,\beta_4 - 4.710\,\beta_5 - 2.359\,\beta_6 - 1.408\,\beta_7 - 3.135\,\beta_8 - 1.099\,\beta_9 \quad \ldots(19)$$

$$\ln\left(\frac{P_{PT}}{P_M}\right) = 0.139 - 0.320\,\beta_2 + 0.141\,\beta_3 - 0.820\,\beta_8 - 1.841\,\beta_9 \quad \ldots(20)$$

where β_1 is trip length, β_2 is reliability, β_3 is number of luggage, β_4 is gender, β_5 is income category- 1-2 lakhs, β_6 is income category- 2-5 lakhs, β_7 is income category- 5-10 lakhs, β_8 is primary reason- cost effectiveness, β_9 is primary reason- travel time saving.

Table 5: Model parameter estimate for future mode choice after introduction of metro

	Private Vehicle		Public Transportation	
	B	**Sig**	**B**	**Sig**
Intercept	-1.633	0.00	0.139	0.85
Trip length	0.101	0.00	0.012	0.42
Reliability	-0.192	0.27	-0.320	0.01
Number of luggage	0.341	0.00	0.141	0.07
Gender				
Gender= Female	0.952	0.00	0.314	0.24
Gender= Male	0		0	
Income category				
1-2 lakhs (INC_1)	-4.710	0.04	-0.992	0.26
2-5 lakhs (INC_2)	-2.359	0.00	0.219	0.58
5-10 lakhs (INC_3)	-1.408	0.00	-0.272	0.52
More than 10 lakhs (INC_4)	0		0	
Primary reason for choosing the mode				
Cost-effectiveness	-3.135	0.00	-0.820	0.03
Travel time saving	-1.099	0.00	-1.841	0.00
Luggage	0.542	0.42	0.512	0.33
Group size	-0.358	0.61	0.272	0.61
Quality of service	0		0	

* Cox and Snell R^2: 0.495, Nagelkarke R^2:0.589, McFadden R^2:0.371

Table 5 describes that the β coefficient is positive for trip length in both private vehicle and public transportation. This suggests that the introduction of the metro will not encourage travellers to choose the metro when the trip distance is more. A unit increase in trip length increases the logit of a private vehicle than metro by a factor of 0.101. This is expected because the metro network has certain limitations in terms of coverage, and the catchment area of NSCBI Airport exceeds the reach of the metro network. Therefore, passengers travelling from locations beyond the metro network's influence area tend to avoid selecting the metro as their mode of access.

The Table 5 also highlights that reliability is a key factor leading to a reduction in the share of both public transportation and private vehicles after the introduction of the metro. A unit increase in reliability reduces the odds of public transportation over metro by a factor of 0.320.

This is because both private and paratransit vehicles face road congestion in various locations within the city. whereas the metro, with its exclusive right of way, is more reliable than these modes.

Number of luggage is also a significant factor in influencing the future mode choice. The positive β coefficient indicates that travellers with luggage are more inclined to choose private vehicles and public transportation as their airport access mode compared to the metro, even after the introduction of metro. Many respondents with more than one piece of luggage recommended that the willingness to use the Kolkata metro for accessing the airport would increase if the metro incorporated facilities for luggage drop-off at boarding stations. A unit increase of number of luggage increase the logit of private vehicle and public transportation over metro by a factor of 0.351 and 0.141 respectively.

In terms of gender, female passengers exhibit a lower inclination to switch their airport access mode from private vehicles and public transportation to the metro compared to male passengers. The β coefficients for both private vehicles and public transportation are 0.952 and 0.314, respectively. However, gender is not a significant factor in future mode choice for public transportation passengers. A unit increase in female travellers increases the odds ratio of choosing private vehicles over the metro by a factor of 2.59 compared to the reference category. Here, the male category is considered a reference category. During the questionnaire survey, some female passengers mentioned that they might use the metro if a separate coach were available for female passengers.

Car ownership and trip origin were not found to be significant for future mode choice so they are excluded from model.

Income is a significant factor for private vehicle users to decide the future mode to access airport. Regardless of income category, private vehicle users are willing to use metro more than private vehicle. Whereas for public transportation user income is not a significant factor for future mode choice. The income category of more than 10 lakhs is treated as the reference category for various income categories. A one-unit increase in travellers belonging to the 1-2 lakhs income category decreases the logit of choosing private vehicles over the metro by a factor of 4.710 compared to the reference category. Similarly, for the 2-5 lakhs and 5-10 lakhs income categories, a one-unit increase in travellers of the respective categories decreases the logit of choosing private vehicles over the metro by factors of 2.359 and 1.408, respectively.

In terms of the primary reason for choosing a mode, both cost-effectiveness and travel time saving significantly influence the future mode choice behaviour for private vehicle and public transport users. The reason "quality of service" is considered as reference category.

When the number of passengers who choose their mode based on cost-effectiveness increases by one unit, the log odds of choosing a private vehicle or public transportation over metro decrease by a factor of 3.135 and 0.820, respectively. Similarly, when the number of passengers who choose their mode due to travel time savings increases by one unit, the log odds of choosing a private vehicle or public transportation over metro decrease by a factor of 1.099 and 1.841, respectively. This model predicts with an overall accuracy of 76.9%. Additionally, it correctly predicts private vehicle with 72.4% accuracy, public transportation with 18.5% accuracy, and metro with 93.8% accuracy.

Mode shift after introduction of metro

Table 6 describe mode shift comparison result between questionnaire data and model output. It is shown that from survey data, 62.3% passengers are willing to shift to metro. Whereas MNL model predicts 76.5 % passengers shift their mode to metro to access airport after introduction of metro.

Table 6: Comparison between questionnaire survey data and model output

Modes	Present mode choice	Shift	
		From survey data	From model
Private Vehicle	191 (38.7%)	105 (21.3%)	94 (19%)
Public Transportation	303 (61.3%)	81 (16.4%)	22 (4.5%)
Metro	-	308 (62.3%)	378 (76.5%)

Conclusion

In this study, present and future mode choice behaviour of NSCBI Passengers were studied. Two statistical models were used: Binary logit model between private vehicle and public transportation for present mode choice behaviour and multinomial logit model among private vehicle, public transportation and metro for future mode choice analysis. Socioeconomic characteristics of passengers such as gender, annual income, car ownership, and trip-related variables such as trip origin, travel length, reliability, number of luggage, and primary reasons such as cost-effectiveness and travel time savings, play a significant role in the present mode choice behavior of passengers. When it comes to choosing a mode for future trips, factors such as gender, trip length, reliability, luggage, annual income, and primary reasons for choosing the mode play an important role. The present mode choice model can predict the correct mode with an overall accuracy of 84.8%, whereas the future mode choice model can predict the correct choice with an overall accuracy of 76.9%. In case of mode shift, survey data shows that 62.34% passengers were willing to use metro in future. MNL model shows that 76.5% passengers may shift their mode in future to assess the airport. Another finding from this study is that most of the public transportation user (above 50%) willing to shift their mode to metro than private vehicle user. This study also reveals that male passengers are more willing to shift mode than female passengers. Additionally, passengers originating from their homes exhibit a notable inclination towards mode shifting. Individuals without car ownership express a preference for switching to metro for access to the airport. As income levels increase, there is a decrease in the propensity to utilize the metro. These findings in the study can help airport authority, and city development authority to design initiatives that encourage passengers to use the metro as the main mode to access the airport. Initiatives like luggage drop-off system in metro stations, separate coaches for females, increase in parking fees can encourage passengers to use the metro. This study only analyzed daytime airport access mode choice behavior. However, future research could explore egress and nighttime mode choice behaviors, which may differ from these findings. Additionally, exploring actual metro ridership data once the Kolkata metro is fully operational at NSCBI airport offers another opportunity for future research in this field.

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