A Study of Indian Wholesalers for Mode Choice Decisions in Urban Goods Distribution

Pankaj Kant, Sanjay Gupta, and Ish Kumar

Abstract Shippers make key decisions about shipment size and mode selection to lower total logistics costs. In this study, discrete choice models are developed for the urban distribution of commodities from wholesalers to retailers in the Indian city of Jaipur. To analyse market variance, the freight mode choice model selects two wholesale markets: building hardware (BHM) and electronics (EM). A structured questionnaire and a face-to-face, pencil-and-paper survey were employed to gather primary data. For all wholesale markets, binary logit models comprised of non-mortised transport (NMT), three-wheel commercial vehicle (3W), four-wheel commercial vehicle (4W), and light commercial vehicle (LCV) modes were developed for various time, cost, and distance combinations. Tonne-kilometre travelled (TKT) across commodity distribution and vehice kilometres travelled (VKT) are more suitable variables for intracity good distribution.

Keywords Urban freight · Mode choice · Wholesalers

1 Introduction

Urban goods distribution's effects on traffic, externalities, the fragility of the infrastructure, and compatibility with land use are all very concerning. The primary policy goal of many nations is the sustainability of urban goods transit [1]. Freight mode choice modelling is vital for policymakers to perform policy actions like reducing

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externalities and congestion. Understanding and replicating urban freight stake-holder's behaviours and attributes is an essential research topic. Policy planners need to consider the effects of freight transportation on urban mobility from the perspective of sustainability [2]. The relationship between policy measures and stakeholder behaviours is still an area of investigation in the urban freight sector [3]. Associated urban freight traffic is significantly influenced by the flow of commodities and the frequency of shipments. The mode share and percentage of final commodities delivered by alternative transportation modes are determined by the type of infrastructure investment [4].

For the efficiency of the urban freight transport network and local sustainability, freight transport and urban freight strategies require better culmination. However, city planners procrastinated about the freight issues, transport operators and the last mile problem is often neglected to a large extent [5]. There are enough opportunities and scope to improve the efficiency of urban freight distribution as compared to long-haul freight (regional freight transport) without having additional costs to consumers and businesses [6]. Disaggregating models by commodity type can produce better estimates for freight mode choice [7]. Passenger transport is in a prime focus in cities of India in recent decades owing to National Urban Transport Policy, and urban freight is not adequately focused on in transport system development plan proposals in Indian cities [8]. Even the flagship smart cities mission programme of the Government of India, which has earmarked budgetary support for 100 smart cities to date has very limited priorities for urban freight transport proposals being taken up for implementation in these cities [9]. The explicit consideration of the urban commodities movement may help achieve the objectives of urban transportation. The goal of city planning, in particular, is to facilitate the efficient circulation of goods at targeted levels [10].

The diversity of urban freight stakeholders and the characteristics of urban goods movement present a significant barrier to policymakers seeking to implement interventions in city logistics. One of the topics that India hasn't covered enough is freight mode choice for intracity goods. The rest of the paper covers a literature review on mode choice for goods movement, research methodology, choice model formulation, characteristics of case city and wholesale markets, an overview of descriptive statistics of the data set, model estimation; and summing up with conclusions.

2 Literature Review

Econometric models such as discrete choice models are used at the shipment level for freight mode choice with modal attributes like cost, travel time, and distance [11]. To assess the variables impacting the selection of the freight modes, the probit with logit model was used for shipments among three zones in Maryland by revealing preference data. According to the findings, model choice decisions are critically influenced by mileage, the value of time, and fuel cost [12]. Microeconomic models are used to study how shippers select the size and mode of their shipments [13].

Time is the most critical variable for the shipper to determine freight mode choice for regional goods distribution [14]. For the shippers, the cost and quality factors of transport service, such as transit duration and damage rate, are significant, yet modality plays a significant part that is a fundamental aspect of their decision. For the end-shipper, a transport service's cost and quality factors like transit duration, dependability, and damage rate are important, but mode also has a non-negligible impact [15]. The taste characteristics of the shippers exhibit significant unobserved variation, according to the findings of multinomial logit models (MNL). Time and cost are subject to shipment size [16]. There is a greater need to analyse the changes in the firm's logistics for evaluating mode split and evaluation of transport infrastructure decisions [17].

Shippers have a high preference for the mode's service. The firm's inventory cost increases with an increase in transit mode time. Disaggregate models provide more accurate analyses and user satisfaction with a particular mode but are subject to the availability of data [18, 19]. The variables that may affect whether to use a rented truck, a personal truck or the rail mode were assessed using linear logit models. Rail mode is preferred for the long haul, and trucks are preferred for the short haul. Transit time, reliability in transit time, and length of hauls as essential factors for freight mode choice [20]. Binary choice models, along with sensitivity analysis, were used to evaluate the choices between truck and rail modes. Shipment cost is a critical factor for rail, whereas haulage time is for road shipments. No significant change in modal shift is observed with an increase in fuel cost [21]. A discrete–continuous model was used to analyse joint shipment size and mode choice with parameters of freight rate, transit time, frequency, and reliability. Logistics patterns are disturbed with policy-induced modal shifts, and shipment size needs to be adjusted accordingly [22]. A discrete–continuous model was used for evaluating factors affecting freight mode choice. Study results suggest that small vehicles are chosen for the higher value of shipment commodities and large vehicles for long-haul shipments [23]. A discrete–continuous model, along with elasticity analysis, was used for the choice of truck type by transport operators. Changes in shipment size or cost have a negative impact on the mode share in the market. Imposing an axle load ban increases the number of trips and thus causes more congestion [24].

The Multinomial logit model was used to analyse shippers' preferred freight mode. Shippers do not tend to use hire-carrier for high-value goods but have a high tendency to use LTL due to speed and reliability [25]. The degree of heterogeneity for the small truck, large truck, and rail modes for various commodities was assessed using a mixed MNL model. There is significant heterogeneity among shippers regarding service attributes, quality, and flexibility [26].

An MNL model was used to evaluate the probability of mode share for shipment size. Shipping cost is the highest among other variables [27]. A logit model with stated preference data was used to evaluate freight mode choice by shippers and carriers. The cost of transportation is a crucial factor in determining how popular a new transport mode will be [28]. A utility-random regret mixed MNL model to assess the heterogeneity of LOS variables. Truck transportation can significantly

be improved by assigning dedicated routes, access control, and other freight infrastructure provision parking and loading–unloading facilities [29]. The mode choice model using elimination-by-aspect was used to evaluate the factors affecting mode choice between rail and manufacturers and non-manufacturers. Reliability is the most crucial attribute for manufacturers and freight rates for non-manufacturers [30]. The factors influencing French shippers' choice of freight method were evaluated using a nested logit model with revealed preference. An increase in shipment frequency and haulage distance would increase the probability of using both rail and combined modes. An increase in shipment size only leads to the probability of choosing rail only [31].

The factors influencing the decision for the shipper in Canada were evaluated using the logit mode choice model with data gathered from the stated preference survey. The choice of mode is positively impacted by an increase in reliability. An increase in cost and damage risk hurt the selection of mode [32]. To explore the variables influencing the allocation of truck size for transport operators, a discrete–continuous model (MNL) was utilised. The probability of choosing a heavy vehicle increases with the increase in haulage distance [33]. To account for the heterogeneity in shipment size choices for intracity shipments for the Tokyo metropolitan area, an empirical model was applied. Decisions on the size of the shipment and the operation of the vehicle must be made simultaneously [34].

The logit model was used to estimate freight transport demand for road and sea transport. The main determinants of mode choice are frequency of shipments, haulage cost, and transit time [35]. A mode choice model with service quality variables like price and speed was used to assess the shift in mode choice [36]. For truck transfers, a discrete shipment size selection model based on logistical costs was created. The findings imply that the choice of cargo sizes can be largely explained by commodity flows [37].

The Phoenix-Tucson mega-region used the joint shipment size and mode choice model, which was created with CFS Public Use Microdata. The shipment size and selection were evaluated using the nested model structure [38]. Externalities caused by trucks and rail were compared for their consideration. Externalities associated with trucks are three-time to rail mode. For the creation of comprehensive strategies, a more dependable analytical instrument is needed [39]. Eight cities in two different Indian states have undergone thorough establishment freight surveys. In terms of scope, the research project is unique and offers a plan for low-cost data gathering. According to research, the physical properties of goods and city demography are largely related to response rates from establishment surveys [40].

Freight mode choice variables have been extensively explored with disaggregated models. By and large, these studies are focused on intercity movement by various transport modes. A few studies have also looked at urban freight mobility and freight mode selection. A large research vacuum exists because urban freight and mode choice have not been examined in the Indian setting.

3 Research Methodology

This study covers electronics and building hardware wholesale markets in case city to identify the variables impacting the selection of freight modes in intracity goods distribution. The research study hypothesis is that freight mode selection factors differ in relevance and significance across two commodity distributions in the case city. Binary logit models based on revealed preference were used to assess choice variables for shippers (wholesalers). Selected variables for freight mode choice consideration are related to cost and time from the literature review. Various combinations of both time and cost variables have been modelled in IBM SPSS Statistics 21 software to arrive at the final utility equation of modes for both markets. Time and cost variables are significant factors since they are crucial to the efficiency and flow of freight in cities. Figure 1 shows the adopted framework for the mode choice model along with the combination of choice variables for this research study.

At wholesale markets, both for-hire and private carriers have been surveyed. Primary data was collected from wholesalers and truck operators (carriers) through in-person surveys. The quantum of samples collected from stakeholders is depicted in Tables 1 and 2.

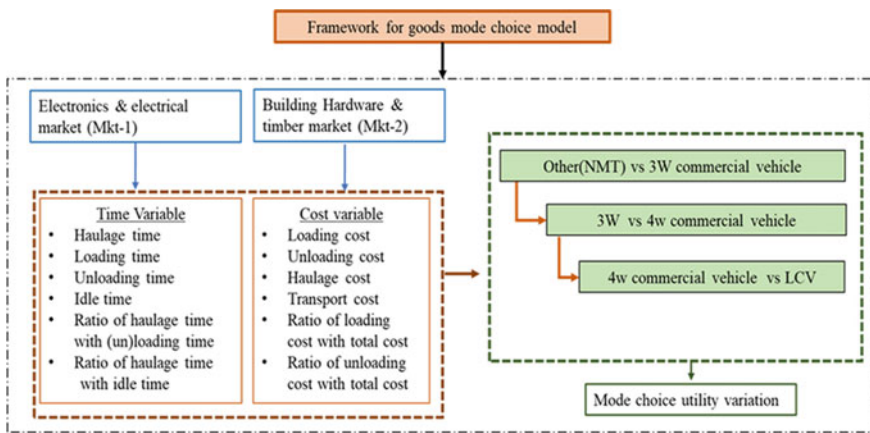**Fig. 1** The proposed framework for urban freight mode choice

Table 1 Quantum of samples

	Wholesalers	Carriers
Method of sampling	Stratified survey	Stratified survey
Samples collected	110	323

Source Author

Table 2 The sample size of transport operators

Mode	Electronics market	Building hard. market	Total sample size
Other (NMT)	35	30	65
3W	35	31	66
4W	32	35	67
LCV	31	30	61

Source Author

4 Case City Profile

The Indian state of Rajasthan's capital city is Jaipur. Jaipur covers a total area of 2939 km^2, of which the walled city (ancient area) takes up 17 km^2. Of the remaining 2650 square kilometres, the city of Jaipur is administered by the Jaipur Development Authority. 30.5 lac people are living in Jaipur city overall (yr. 2011). 44.8% of the city's land is used for residential purposes (13,825 ha), 6.7% for commercial purposes (2064 ha), 6.6% for industrial purposes (1862 ha), 2.6% for governmental purposes (602 ha), 3.3% for mixed purposes (1034 ha), 10.5% for public and semi-public use (3241 ha), 11.3% for recreational use (3461 ha), and 15.4% for circulation (4741 ha). The important wholesale markets at various location in Jaipur city including the walled city area along with intercity and intracity freight network is depicted in Fig. 2.

The building hardware market and electronics market was selected for the intracity mode choices exercised by wholesalers for respective commodities distribution. The Jaipur development authority recently created the building hardware market area. The building hardware industry bases the distribution of its goods based on weight. The electronics market is situated in a walled city area with restricted connectivity compared to the building hardware market. The electronics sector bases its distribution on the number of items.

5 Mode Choice Model Formulation

The likelihood that the shipper or wholesaler will select a particular mode of delivery for the consignment is determined by mode choice models. Mode choice models are disaggregate models with discrete dependent variables. The utility maximisation theory of economics is the fundamental behind discrete choice models. The decision made by the user maximises the utility gained from it. The choice mode is stated in probabilistic terms as an output from discrete choice models. Equation (1) depicts the utility equation of the binary discrete choice model. Equation (2) illustrates how the binary logit model framework yields the likelihood of selecting an option [41].

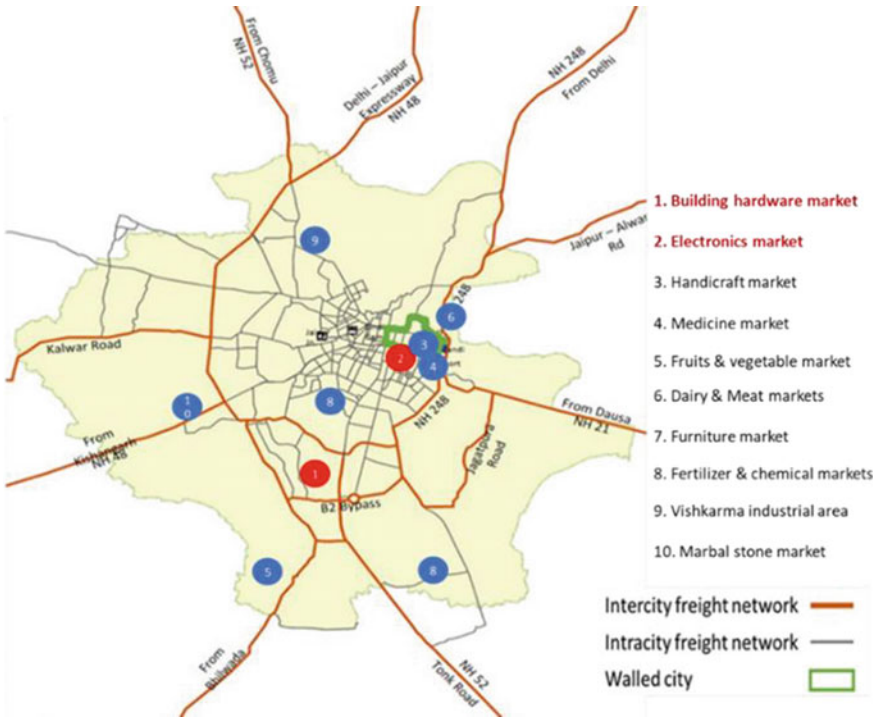$$U = (b0 + b1x1, i + ... + bkxk, i) \tag{1}$$

Fig. 2 Wholesale markets location (*Source* Author)

$$Pi = \frac{1}{1 + e^{-(b0 + b_{1,i} + \ldots + b_{kx k,i})}} \tag{2}$$

In equations:

- U denotes the utility of individual I for a specific choice.
- b0 is constant.
- b1, b2, …bk are parameters that need calibration.
- x1i, x2i, … xki are variables associated with the choice set.

The initial universal set of variables for binary logistics regression taken into consideration for present freight mode choice modelling was based on the literature review, modal attributes, and case markets stakeholder's input. A total of 30 variables have been selected as possible predictors in mode choice across commodity distribution and modes. The final selection of modal attributes in the calibrated utility equations of modes is based on various statistical tests associated with binary logistics regression like the significance p-value of individual attributes of modes. The final utility equations incorporated the results of statistical tests such as the -2 Loglikelihood, Cox & Snell R Square, Nagelkrke R Square value, Hosmer and Lemeshow Test, and classification tables for several binary choice modes.

6 Descriptive Analysis

A descriptive analysis of the wholesaler's attributes is shown in Table 3. In the electronics market, the mean value of the shop area (square metres) is higher than in the building hardware market. The employment rate per 100 m^2 in the electronics market is 5, whereas it is 3 in the building hardware market. The total weekly tonnage handled in the building hardware market, including incoming and outgoing tonnage per 100 sqm, is 52.4 tonnes, whereas it is 26.6 tonnes in the electronics market. Total weekly trip frequency, including incoming and outgoing trips per 100 sqm of shop area, is 24 trips in the building hardware market and 27 trips in the electronics market. In the building hardware market, incoming weekly freight trips are nearly twice as high as in the electronics market. Compared to the building hardware market, the electronics market has more weekly outbound trips. As would be predicted, the building hardware sector has higher outgoing and entering tonnage than the electronics market.

Table 4 displays the descriptive analysis of transport operator characteristics. For all modes in both marketplaces, loading takes a little longer than unloading. For 3W and 4W modes, idle time is practically identical in both commodities, however, for LCV modes, the building hardware market (BHM) has longer idle times than the electronics market (EM).

There is not much significant difference in haulage cost for both markets except LCV modes. Compared to the electronics business, the haulage cost of LCV mode is higher in the building hardware sector. LCV is occasionally used for intercity (suburb) shipments. In both markets, the cost of loading and unloading an LCV does not significantly vary.

Table 3 Descriptive analysis of wholesalers

Variables	Unit	Electronics wholesalers			Building hardware wholesalers		
		M	Mdn	SD	M	Mdn	SD
Area of shops	Sq.m	140	149.5	67.7	89.1	80	62.5
Employment	Per 100 sqm	5	4	2.1	3.1	3	1.5
Incoming trips	weekly	4.1	4	1.4	9	9	2.7
Incoming tonnes	weekly	14.1	15	3.04	27.6	23	15.5
Outgoing trips	weekly	22.1	23	4.1	14.9	15	3.2
Outgoing tonnes	weekly	11.8	12	2.04	24.8	20	13.8

Source Author (M = mean, Mdn = median, SD = standard deviation)

Table 4 Descriptive statistics of transport carriers

Mode	Wholesale market	Haulage time (Hour)		Loading time (Hour)		Unloading time (Hour)	
		M	Sdn	M	Sdn	M	Sdn
NMT	EM	0.8	0.4	0.2	0.05	0.18	0.04
	BHM	0.9	0.3	0.2	0.04	0.19	0.04
3W	EM	0.7	0.2	0.3	0.05	0.27	0.06
	BHM	0.7	0.4	0.6	0.2	0.51	0.07
4W	EM	0.7	0.2	0.4	0.08	0.34	0.09
	BHM	0.8	0.3	0.6	0.17	0.49	0.15
LCV	EM	0.9	0.4	0.7	0.07	0.66	0.07
	BHM	1.4	0.6	0.7	0.12	0.69	0.09

Idle time (Hour)		Haulage cost (INR)		Loading cost (INR)		Loading time (Hour)	
M	Sdn	M	Sdn	M	Sdn	M	Sdn
0.09	0.03	228	87	50.9	8.6	50.9	8.6
0.67	0.13	207	68	96	25.1	97.9	25.8
0.95	0.15	597	186	109	101	109	101
0.9	0.17	584	343	168	47	142	49.8
1.15	0.16	853	304	150	12.1	150	12.1
1.13	0.2	834	241	159	47.5	135.7	21.4
1.4	0.14	1856	692	197	21.3		21.3
1.85	0.22	2627	832	202	39.7	194.1	26.1

Source Author
Note EM = Electronics market
BHM = Building hardware market
INR = Indian national rupee

7 Results and Discussions

The final calibrated utility functions of freight modes for both wholesale markets (commodities) are shown in Table 5.

Table 5 Calibrated utility equations

Mode	Market	Utility equation
NMT–3W	BHM	$U = -6.8$ (Total Time)-0.083 (Loading Cost) $+ 31.49$
	EM	$U = -14.8$ (Unloading Time)-0.03 (Transport Cost) $+ 13.7$
3W–4W	BHM	$U = -2.03$ (Travel Time)-0.15 (Loading & unloading Cost) $+ 4.99$
	EM	$U = -50.9$ (Total Time) $+ 0.002$ (Transport Cost) $+ 4.8$
4W–LCV	BHM	$U = 2.38$ (Travel Time) $+ 0.39$ (Unloading Cost)-15.8
	EM	$U = 1.91$ (Travel Time) $+ 0.001$ (Transport Cost)-16.7

Source Author

Among all the variables considered for modelling freight mode choice, the main variables affecting mode choice among various freight modes across commodity distribution are loading cost, transport cost, loading & unloading cost, total time, travel time, and unloading time. Variables are differing across commodities and modes.

In the case of building hardware distribution, the signs associated with total time and loading cost are negative indicating that an increase in travel time and loading cost would result in the stakeholder being less likely to use a 3W commercial vehicle. Further, the impact of the loading cost variable is higher compared to the travel time variable in the selection of mode between commercial NMT and commercial 3W in building hardware distribution.

In the case of electronics goods distribution, the signs associated with unloading time and transport cost are negative indicating that an increase in transport cost and unloading time would result in less likely to select a 3W commercial vehicle similar to building hardware distribution. When choosing between a 3W commercial vehicle and an NMT for the distribution of electronics items, the influence of the unloading time variable is greater than that of the transport cost variable.

The signs associated with travel time and loading–unloading cost are negative for a choice between 3 and 4W, less likely to select a 4W commercial vehicle with an increase in variables in building hardware distribution. Further, the impact of the loading–unloading cost variable is lesser compared to the travel time variable in the selection of mode between commercial 3W and commercial 4W for building industry goods distribution.

For mode selection between 3 and 4W modes in electronics goods distribution, the signs associated with total time are negative and transport cost is positive indicating that an increase in total travel time results in the stakeholder being less likely to use a 4W commercial vehicle and an increase in transport cost are more likely to use a 4W commercial vehicle. Further, the impact of the haulage cost or transport is higher compared to the total transport time in mode selection between commercial 3W and commercial 4W modes in electronic goods distribution.

It is observed that the signs associated with travel time and loading cost are positive for 4W and LCV mode selection in building hardware distribution. An increase in travel time and loading cost would result in the more likely use of LCV. Further, the impact of the unloading cost variable is less compared to the travel time variable in the selection of mode between 4W and LCV in building hardware distribution.

The signs associated with travel time and transport cost are positive for LCV and 4W in electronics goods distribution similar to building hardware distribution. An increase in travel time and transport cost would result in the stakeholder being more likely to use LCV. When choosing between the 4W commercial and LCV modes of transportation for the distribution of electronic goods, the influence of the transport cost variable is far less significant than that of the travel time variable.

Statistical results associated with calibrated utility functions are shown in Table 6. Related statistical test associated with the final calibrated utility equations of the binary logit models qualifies all tests for the robustness of models. Only Hosmer and L. test has a value of 0.67 for the choice between NMT and 3W, but it is retailed as the value is nearer to 0.7.

Sensitivity analysis for 3W, 4W, and LCV has been shown in Table 7. Sensitivity analysis of the freight mode choice has been performed by incrementally increasing and decreasing the variable's value by 10%. Sensitivity analysis results are based on the mean values of various variables of transport operators (carriers) involved in respective commodity distribution in Jaipur city.

It is seen that loading and unloading cost is more sensitive in building hardware distribution as compared to electronics goods distribution, whereas time is more sensitive in electronics distribution compared to building hardware distribution in the selection of modes between 3 and 4W. The travel time variable is less sensitive compared to travel cost in the selection of modes between 3w, 4W, and LCV across commodity distribution in the case city. NMT mode is not considered in sensitivity analysis as there are various varieties of NMT modes ranging from a tricycle to a bullock cart, which makes it difficult to generalise NMT modal attributes.

Table 6 Statistical results

Mode	Market	–2 loglikelihood	Nagelkerke R square	Hosmer & L. test	Predicted (%)
NMT–3W	BHM	15.2	0.91	0.99	93
	EM	29.04	0.8	0.67	90
3W–4W	BHM	23.7	0.85	0.92	96
	EM	13.71	0.92	0.98	89
4W–LCV	BHM	13.05	0.92	0.98	98
	EM	9.88	0.94	0.97	95

Source Author

Table 7 Sensitivity analysis

Variable	Mode	Electronic market					
		-30(%)	-20(%)	-10(%)	10(%)	20(%)	30(%)
Cost	3W	-16	-10	-4	4	7	10
	4W	-18	-11	-5	4	8	11
Time	3W	1.3	0.9	0.4	-0.4	-0.9	-1.4
	4W	2.4	1.3	0.7	-0.7	-1.4	2.1
Cost	4W	-12	-7	-3	3	6	8
	LCV	-14	-8	-4	3	6	9
Time	4W	1	1	0	0	-1	-1
	LCV	2	1	-1	-1	-2	-3
Variable	Mode	Building hardware market					
		-30 (%)	-20(%)	-10(%)	10(%)	20(%)	30(%)
Cost	3W	-11	-6.7	-3.2	2.8	5.4	7.7
	4W	-11	-6.8	-3.2	2.8	5.3	7.5
Time	3W	0.3	0.2	0.1	-0.1	-0.2	-0.3
	4W	0.4	0.2	0.1	-0.1	-0.2	0.4
Cost	4W	-10	-6	-3	3	5	8
	LCV	-10	-6	-3	2	5	6
Time	4W	-0.1	-0.1	0.0	0.0	0.1	0.1
	LCV	-0.1	-0.1	0.0	0.0	0.1	0.1

Source Author

8   Conclusion

This study uses binary logit models to investigate the selection of road-based freight modes used in the distribution of urban goods in Jaipur city. The model incorporated several combinations of variables relating to time and the cost of intracity freight trips.

The key finding of the study suggests that mode choice variables differ from one commodity to another commodity distribution. Mode choice variables also differ according to mode due to the difference in tonnage carrying capacities. Travel time, unloading time, and transport cost variables are essential for electronics goods intracity shipment, whereas loading cost, unloading cost, and travel time are also crucial in building hardware shipments. Travel time and loading–unloading cost are the primary determinants in selecting 3W and 4W modes in building hardware distribution, whereas total time and transport cost are the key variables in the selection between 3 and 4W modes in electronics goods distribution. In the distribution of building hardware, the choice decision between 4W and LCV modes primarily depends upon unloading costs and travel time, whereas in the distribution of electronic items, the key concerns are travel time and transport cost. Variables that affect

the choice between a 3W and NMT mode in the electronics goods distribution are transport cost and unloading time, whereas it is loading cost and total time in the building hardware distribution. It is also observed that loading/unloading cost is relevant to building goods distribution whereas loading/unloading time in electronics goods distribution. Mode choice variables for intercity shipments are sensitive to VKT compared with TKT.

The appropriate modal share and parking-related infrastructure at wholesale marketplaces are directly impacted by the freight mode choice. For effective policy intervention for sustainable urban freight transportation, road-based urban freight mode choice variables are always for city planners and local policymakers. There is a further need to evaluate the freight mode choices within and across cities of different sizes, and more wholesale commodity markets need to be investigated.

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