Chapter 8
Value of Travel Time Saved in Modal Shift from Bus to Metro Case Study: Rohini (West) Delhi Metro Station

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Introduction

The public transport plays a vital role in urban passenger movements. The majority of the city residents use public transport in their day-to-day travel. The choice between public transport and personalized mode is an individual decision that is further influenced by the government policies and the decisions of the urban local bodies. Recently, the availability and use of different modes such as metro, monorail, bus, bus rapid transport system, etc. have led to new choices, and the concept of "multimodal public transport system" in metropolitan cities in India has evolved. The multimodal transport system is an integrated approach that incorporates all components of urban transport into a single system for efficient use of available transport resources and infrastructure to ensure better mobility within a wide range of modal options for the commuters**.** In fact, multimodal public transport is a composite system of various modes. It provides access patterns by multiple modes by assuring integration, safety, and ease of use for all commuters, and hence requires adequate transport infrastructure at different levels to provide seamless mobility.

It is a difficult task for the commuters to choose one or more mode(s) among the available multiple modes of public transport. A commuter, while choosing either bus or metro as a mode, prefers to minimum travel time with maximum comfort, and wants proper connectivity to reach the desired destination. The options may be either a direct bus route from origin to destination or an integrated route of both bus and metro. The commuter has to make a choice. The commuter generally prefers the route that connects the destination directly in a complete journey chain. The commuter may prefer metro if the trip requires shorter waiting time, minimum effort for

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transfer at interchange, and provides greater comfort, even if its composite fare is higher. On the contrary, commuters may prefer bus, if services are available point to point within catchment areas and cost-affordable fare. In this context, there are multiple factors that affect the decision of modal shift from bus to metro. Therefore, it is imperative to assess the quantification of travel time saved due to modal shift for proper understanding of commuter's preferences and choices.

Value of Travel Time and Travel Time Saved

Travel time is defined as the cost of time spent on traveling from one point to another, including actual travel and waiting time. It includes cost of personal (unpaid) time spent and cost of business time (paid) spent in travel. Hence, the value of travel time saved due to reduced travel time has a significant share in transport costs. Generally, the cost of travel time and saved travel time depends on trip classification, travel conditions, traveler preferences, etc. The total travel time costs are the product of time spent in traveling multiplied by unit cost (Small et al. 2005).

Various studies have quantified travel time unit costs and the value of travel time savings, based on business costs, traveler surveys, and by measuring behavioral responses of the travelers faced with a trade-off between time and money (Mackie 2003). Generally, the value of travel time tends to increase with income, and is lower for children and the unemployed. However, the employed are often willing to pay more for travel time savings (Hymel et al. 2010). Under favorable conditions, public transit travel time can be productive. The findings of various surveys indicate that the captive users often spend time in working, reading, relaxing, etc. (Lyons et al. 2011). The saving in travel time is inversely proportional to trip length. It is estimated that carpools increase average trip distances by 10 %, buses by 15 %, and rail by 20 %, for automobile access (Delucchi 1998).

Various attributes such as speed, comfort, reliability, etc., affect commuters in choosing a particular mode. Generally, the commuters prefer metro as it has less congestion, fewer accidents, but more speed and more reliability, in comparison to bus (Kumar et al. 2009). The quantification of travel time saved uses wage rate method and revealed reference method. In the wage rate method, the monetary evaluation of travel time of passengers is determined by the average wage rate of the passenger and the same has been treated as the value of time. Generally, monthly wage rate based on 8 hours per working day is considered. The value of time for work journey and nonwork journey is different and hence separate monetary values for both journeys are considered (Srinivasan and Goel 1968).

Commuters are classified into various categories such as metro passengers, bus passengers, car passengers, etc., but time value for cycle traffic, two-wheelers, and pedestrians is also significant. The time involved in walking and waiting is valued at a different rate than the in-vehicle time. If the in-vehicle time is taken as 1, then value of walking time and waiting time is considered as 2 and 3, respectively. However, these values are based on European research (Harison 1974). Generally, data are collected by interviewing sample passengers of various categories and finding out their average monthly income. The sample interviewed should include nonwage earners such as the unemployed children and homemakers. Suitable accounts are made to arrive at the average wage rate for these categories. In the case of wage rate as a measure of value of time saved, the overheads borne by the employers are added to wages that the wage earners receive. The overheads include the employer's contribution towards provident fund, insurance, pension, and other fringe benefits. The UK uses a figure of 18 % as employer's overheads. Possibly a round figure of 20 % may be used in Indian conditions (Kadiyali 2007).

In the revealed preference method, the value of time saved is determined by studying the travelers having different time and cost for the journey, according to choice of mode, route, destination, trip frequency, etc. This yields a result reflecting the revealed behavior or preference of the people and therefore is very near to the real value (Stubbs et al. 1980).

There is an estimation of the effect of building height limit on the spatial size of Indian cities and commuting cost. The building height limit is imposed by floor area ratio (FAR). A unit increase in FAR reduces city area (average of linear and semilog effects) by 20 % and hence there is significant saving in commuting cost. The findings of the study states that in the city of Bengaluru, the annual commuting cost per kilometer for a household is ₹ 969.00, but there is a reduction in the city's edge household commuting cost by ₹ 523.00 per kilometer per year due to unit increase in FAR. This relation reveals the saving in commuting cost by considering a marginal increase in height limit (Brueckner and Sridhar 2012).

In the Indian context, most of the researchers have derived value of travel time from the wage rate approach. By developing a disaggregated behavioral model based on household data for Ahmedabad city, the value of travel time for car, scooter, and bicycle users is ₹ 2.71/hr, ₹ 3.96/hr, and ₹ 0.36/hr, respectively, for employed persons (Raghavachari and Khanna 1976). The Central Road Research Institute (CRRI) (1982) conducted survey work on selected routes (trunk routes and secondary routes) as part of the Road User Cost Study in 1982. The results of the study stated that the average hourly income of bus passengers was ₹ 7.00 on trunk routes and ₹ 4.50 on secondary routes. However, these values pertain to 1980, but the same was updated in 1992. Based on values pertaining to 1990 prices, the value of travel time for bus passengers on trunk routes was ₹ 27/hr for work trip and ₹ 3/hr for nonwork trip. On secondary routes, the value of the same was ₹ 10/hr and ₹ 2/hr for work trip and nonwork trip, respectively. It was observed that about 40 % of trips were work oriented and 60 % of the trips were nonwork trips (Kadiyali et al. 1992).

Measurement of Value of Travel Time Saved

Background

Due to the operation of Delhi Metro Line-I, the commuters started to shift from road-based modes to the metro as road journey was congested, polluted, prone to

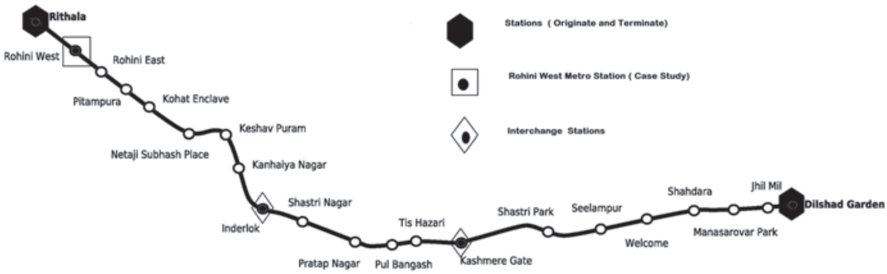

Fig. 8.1 Location of Rohini (West) Metro Station on Delhi Metro Line-I

accidents, increased travel time, etc. The study has been undertaken for assessing the saving in travel time due to the shift from bus to metro.

Survey Design

A primary survey was conducted to understand travel characteristics and to collect transport-related information among the metro commuters, before and after the use of Metro. Rohini (West) Metro Station on Delhi Metro Line-I was selected. The survey was conducted for a 12-h duration, i.e., from 8.00 a.m. to 8.00 p.m., on a normal working day at the station. A survey pro forma was designed to collect relevant socioeconomic profile and travel characteristics of the commuters. Figure 8.1 shows the location of Rohini (West) Metro Station, station (originate and terminate), and interchange stations on Delhi Metro Line-I also known as Red Line.

Aim of the Survey

The aim of the survey was to assess the time and cost saved due to modal shift from bus to metro at Rohini (West) Metro Station on Delhi Metro Line-I.

Methodology

In the study, "opinion survey approach" has been adopted. The commuters were asked to evaluate the value of travel time themselves. For rating of saving time, commuters depend generally on their wage rate. In other words, the quantification of time saved due to modal shift to metro based on hourly wage income has been adopted. The commuters were classified into various income groups and the average value of time for each group was judged by them. Around 200 random samples were collected at this station.

Table 8.1 Modal shift from road-based modes to metro

S. N.	"Modes used" before using metro at present	No. of trips	Percentage of trips (%)	Total values (%)
A.	Public transport and intermediate public transport (IPT) modes			
	Bus/chartered bus/mini bus	130	65.0	80.50
	Auto rickshaw	31	15.5	
B.	Private modes			
	Scooters/motorcycles	14	7.0	10.50
	Car	7	3.5	
C.	Nonmotorized transport (NMT) modes			
	Walk	–		9.0
	Bicycles	5	2.5	
	Cycle rickshaws	13	6.5	
	Total	*200*	*100*	*100*

Table 8.2 Average travel time saved at Rohini (West) Metro Station

S. N.	No. of passengers	Journey time (before Metro) in minutes	Journey time (after Metro) in minutes	Saving of travel time in minutes	Average travel time saved per passenger in minutes
1	200	25,356	19,607	5,749	28.745 min = 29 min (say)

Modal Shift: Road-based Mode (Bus) to Metro

The commuters were asked about the "modes used" before using metro at present. The data are classified into three categories of road-based modes as shown in Table 8.1.

Table 8.1 states that 80.50 % of the road-based commuters on this route have shifted to metro. Similarly, 10.50 % private mode users have shifted to metro, due to park and ride facilities, comfort, safety, etc.

Travel Time Saved

The commuters were asked to inform about their travel time (origin to destination) by using metro. They were also asked to inform travel time if the journey was performed by bus. The difference between both values reveals saving in time as shown in Table 8.2.

Value of Travel Time

As per Opinion Survey, commuters evaluated the value of their reduced travel time of different durations. Table 8.3 shows the calculation of average value of time for the government employees and Table 8.4 for the private sector employees.

Table 8.3 Calculation of the average value of travel time for government sector employees

S. N.	Income group in ₹ (Monthly)	Sample size *(work trips)*	Mean monthly income (₹)	Hourly wage rate (₹/h)*	Average value of time (₹/min)
i.	< 15,000	19*(12)*	11,230	64.54	1.07
ii.	15,000–20,000	20*(11)*	16,430	94.42	1.57
iii.	20,000–25,000	30*(26)*	22,480	129.19	2.15
iv.	25,000–30,000	27*(26)*	27,991	160.86	2.68
v.	30,000–35,000	31*(28)*	31,190	179.25	2.98
vi	35,000–40,000	26*(21)*	37,679	216.54	3.60
vii.	40,000–45,000	23*(12)*	41,871	240.63	4.01
viii.	45,000–50,000	13*(7)*	45,934	263.98	4.39
ix.	> 50,000	*11(3)*	52,001	298.85	4.98
	Total	*200 (146)*			

*The mean monthly income under various income groups has been calculated from the primary survey sheets, and the values are shown in Table 8.3. The total working days for the government employees is derived by considering 5 working days in a week. Hence, the total working days in a year is 261 days (i.e., 365 days—52 Saturdays—52 Sundays = 261 days). The hourly wage rate is derived after assuming 8 working hours per day, for 261 working days in a year (i.e., 261 working days × 8 hours per working day = 2088 h). Further, the calculation follows the following steps: mean monthly income is multiplied by 12 months. It gives the annual income, which is further divided by the total number of working hours in a year (i.e., 2,088 h). It yields hourly wage rate, which is further divided by 60 min to get the average value of time per minute. For example,

For the 1st category of income group, i.e., income group < ₹ 15,000 as shown in Table 8.3

Mean monthly income	= ₹ 11,230.00
Annual income	= ₹ 11,230.00 × 12 months = ₹ 134,760.00
	= ₹ 134,760.00 is income for 261 working days in a year
	= ₹ 134,760.00 is income for 2,088 hours (261 days × 8 working hours/days)
Hourly wage	= ₹ 134,760.00 is divided by 2,088 hours = ₹ 64.54 per hour
Hourly wage rate (₹/hr)	= ₹ 64.54 per hour
Hourly wage rate (₹/min)	= ₹ 1.07 per minute, i.e., average value of time for the commuter of income group less than ₹ 15, 000 per month.
Average value of time (₹/min)	= ₹ 1.07

The same procedure may be applied for calculation of average value of travel time for other income groups as shown in Table 8.3.

Value of Travel Time Saved

The opportunity cost is a component of value of travel time saved. In fact, it is the economic value of the time that a commuter may get if that time is not spent in performing the journey. The CRRI (2007), New Delhi, has defined opportunity cost for different income groups based on number of trips performed by each occupational group. It is noted that the percentage values are obtained from the survey data and not necessarily true in all circumstances. The CRRI study states that opportunity

Table 8.4 Calculation of average value of travel time for private sector employees**

S. N.	Income group in ₹ (monthly)	Sample size *(work trips)*	Mean monthly income in ₹	Hourly wage rate (₹/hr)**	Average value of time (₹/min)
i.	< 15,000	19*(12)*	11,230	53.81	0.89
ii.	15,000–20,000	20*(11)*	16,430	78.73	1.31
iii.	20,000–25,000	30*(26)*	22,480	107.73	1.79
iv.	25,000–30,000	27*(26)*	27,991	134.14	2.23
v.	30,000–35,000	31*(28)*	31,190	149.47	2.49
vi.	35,000–40,000	26*(21)*	37,679	180.57	3.01
vii.	40,000–45,000	23*(12)*	41,871	200.65	3.34
viii.	45,000–50,000	13*(7)*	45,934	220.13	3.66
ix.	> 50,000	*11(3)*	52,001	249.20	4.15
	Total	*200 (146)*			

**The mean monthly income under various income groups has been calculated from the primary survey sheets and values are shown in Table 8.4. The total working days for the private sector employees is derived by considering 6 working days in a week. Hence, the total working days in a year is 313 days (i.e., 365 days—52 Sundays = 313 days). The hourly wage rate is derived after assuming 8 working hours per day for 313 working days in a year (i.e., 313 working days × 8 hours per working day = 2,504 h). Further, the calculation follows the following steps: mean monthly income is multiplied by 12 months. It gives the annual income, which is further divided by the total number of working hours in a year (i.e., 2,504 h). It yields the hourly wage rate, which is further divided by 60 min to get the average value of time per minute. For example

For 1st category on income group, i.e., income group <₹ 15,000 as shown in Table 8.4

Mean monthly income	= ₹ 11,230.00
Annual income	= ₹ 11,230.00 × 12 months = ₹ 134,760.00
	= ₹ 134,760.00 is income for 313 working days in a year
	= ₹ 134,760.00 is income for 2,504 h (313 days × 8 working hours/days)
Hourly wage	= ₹ 134,760.00 is divided by 2,504 hours = ₹ 53.81 per hour
Hourly wage rate (₹/hr)	= ₹ 53.81 per hour
Hourly wage rate (₹/min)	= ₹ 0.89 per minute i.e., average value of time for the commuter of income group less than ₹ 15,000 per month.
Average value of time (₹/min)	= ₹ 0.89

The same procedure may be applied for the calculation of average value of travel time for other income groups as shown in Table 8.4.

cost for income group (₹ 10,000–15,000) and income group (>₹ 50, 000) is 85 % and 91 %, respectively. However, the same relationship—range of opportunity cost from 85 % (income group <₹ 15, 000) to 91 % (income group >₹ 50,000)—has been used as a base to derive opportunity cost of different income groups for calculation of travel time.

Generally, it is believed that the opportunity costs of travel time saved are higher for higher income groups and hence suitable values have been assigned based on intuitive perception. For income group (<₹ 15,000), the opportunity cost is taken as

Table 8.5 Opportunity cost for different income groups. (The Central Road Research Institute, New Delhi (2007))

S. N.	Income groups in ₹ as assigned by CRRI (monthly)	Opportunity cost as assigned by CRRI (%)	Income groups adopted (monthly)	Opportunity cost adopted (%)
i.	Not specified	83		
ii.	<=3,000	93		
iii.	3,000>=5,000	96		
iv.	5,000>=10,000	91		
v.	10,000>=15,000	85	<15,000	85
vi.	15,000>=20,000	80	15,000–20,000	86
vii.	20,000>=25,000	85	20,000–25,000	86
viii.	25,000>=30,000	80	25,000–30,000	87
ix.	30,000>=40,000	79	30,000–35,000	87
x.			35,000–40,000	88
xi.	40,000>=50,000	89	40,000–45,000	89
xii.			45,000–50,000	90
xiii.	>50,000	91	>50,000	91

Table 8.6 Average value of travel time saved for government employees

S. N.	Income groups in ₹ (monthly)	Passenger trips	Rate of time (value in ₹/min)	Opportunity cost (%)	Total saved time (value in ₹/min)
i.	<15,000	19	1.07	85	17.28
ii.	15,000–20,000	20	1.57	86	27.00
iii.	20,000–25,000	30	2.15	86	55.47
iv.	25,000–30,000	27	2.68	87	62.95
v.	30,000–35,000	31	2.98	87	80.37
vi.	35,000–40,000	26	3.60	88	82.36
vii.	40,000–45,000	23	4.01	89	82.08
viii.	45,000–50,000	13	4.39	90	51.36
ix.	>50,000	*11*	4.98	91	49.84
	Total	*200*			*508.71*
	Average value				*₹ 2.54/min*

Calculation of Value of travel time saved per day

- Number of Metro passengers at Rohini West Station =15,000
- Average time saved by per passenger =29 min
- Average value of time =₹ 2.54/min
- Percentage of regular trips =60%
- Value of travel time saved per day =15,000×29 min × ₹ 2.54/min×0.60 =₹ 662,940.00

Table 8.7 Average value of travel time saved for private sector employees

S. N.	Income groups in ₹ (monthly)	Passenger trips	Rate of time (value in ₹/min)	Opportunity cost (%)	Total saved time (value in ₹/min
i.	<15,000	19	0.89	85	14.37
ii.	15,000–20,000	20	1.31	86	22.53
iii.	20,000–25,000	30	1.79	86	46.18
iv.	25,000–30,000	27	2.23	87	52.38
v.	30,000–35,000	31	2.49	87	67.15
vi.	35,000–40,000	26	3.01	88	68.86
vii.	40,000–45,000	23	3.34	89	68.36
viii.	45,000–50,000	13	3.66	90	42.82
ix.	>50,000	*11*	4.15	91	41.54
	Total	*200*			*424.19*
	Average value				*₹ 2.12/min*

Calculation of value of travel time saved per day

- Number of Metro passengers at Rohini West Station = 15,000
- Average time saved by per passenger = 29 min
- Average value of time = ₹ 2.12/min
- Percentage of regular trips = 60 %
- Value of travel time saved per day = 15,000 × 29 min × ₹ 2.12/min × 0.60 = ₹ 553,320.00

85 %, which is the same as assigned by CRRI for income group ₹ 10,000–15,000. Further, income groups ₹ 15,000–20,000 and ₹ 20,000–25,000 have given equal opportunity cost, i.e., 86 %, followed by 87 % for income group ₹ 25,000–30,000 and ₹ 30,000–35,000, due to less variations in sample size and majority of the trips belong to these income groups. Gradually, opportunity costs have been increased up to 91 % for income >₹ 50,000 which is the same as assigned by CRRI. Table 8.5 shows the opportunity cost of different income groups assigned by CRRI and adopted for the present study.

Based on the values shown in Table 8.5, average value of travel time saved is calculated for both the government employees and the private sector employees as shown in Tables 8.6 and 8.7, respectively.

Discussion

1. The saving in travel time is one of the reasons for modal shift from bus to metro along the Delhi Metro Corridor Line-I. The roads are saturated with all kinds of modes of transport. Both motorized and nonmotorized vehicles use the same right of ways. The congestion, accidents, pollution, and slow speed of the vehicles are common phenomena, which lead to increased travel time. In this context, shift of commuters from bus to metro is a healthy sign.

2. The cost of travel time is a part of transport cost. Hence, the travel time saved has its own value, in terms of both money and time in journey chain. The study shows that the average time saved due to modal shift from bus to metro is 29 min. The saving in travel time highlights the improved transport infrastructure, better services in terms of punctuality, frequency, less congestion, etc. The saving in travel time can be further evaluated for other purposes by the different commuters in different travel conditions.
3. The monetary value of travel time saved may vary among different types of commuters having different socioeconomic backgrounds. The study shows that the value of travel time saved is ₹ 2.54/min and ₹ 2.12/min for government employees and private sector employees, respectively. Various holidays, such as gazetted holidays, restricted holidays, leaves, etc., are not taken into account. The variation in value is only due to the difference in number of working days in both sectors. In this study, the opportunity cost is taken to be the same for both, but depending on the quality of work delivered/output of work, it may vary significantly.
4. The average time saved is 29 min per passenger due to modal shift from bus to metro in a trip. In fact, the journey includes walking to a bus stop/metro station, waiting time, in-vehicle travel time (IVTT), etc., and each one has different unit costs. In this context, the saving in travel time is due to both out-vehicle travel time (OVTT) and IVTT apart from parking charge if park and ride facility is used at metro stations. Hence, value of travel time varies depending on commuter preferences and use of personalized modes at access points to the metro.
5. Time saving is not the only factor responsible for commuters switching to metro. There are many other factors that directly affect choice of metro in comparison to bus. The most important factors that motivate the commuters to use metro are comfort, reliability, safety, and security, followed by time saving and accessibility. Similarly, the facility for a separate ladies compartment (coach) also helps women to take the metro ride safely and comfortably. However, the role of feeder bus services and park and ride facilities at metro stations is crucial to increase metro ridership.

The observations are based on a single case study at Rohini (West) metro station on Delhi Metro Line-I. It is caveated that certain factors such as change in land uses, vehicle ownerships, road design, available right-of-ways, etc., can affect the modal shift on other corridors. Further, micro factors such as waiting environment at transfer points, availability of connecting modes, cleanness of stations/stops, and other amenities/facilities may be considered for assessing travel time saved in modal shift from bus to metro at the stations.

Conclusion

Delhi Metro Line-I is characterized by various interchanges such as Rail–Metro Interchange at Shahdara; Bus–Metro Interchange at Kashmere Gate, and Metro–Metro Interchange at Inderlok, but Rohini (West) is a station just near the hospitals, hotels, and malls, and shift is basically from bus to metro. Hence, the improvement in physical design at station areas, use of mechanized devices for connecting at various space levels, etc. may reduce transfer time. Similarly, unified ticketing system of both bus and metro can provide smooth transfer from one mode to another. Hence, transfer time is an important attribute that affects the saving of travel time. Further, the frequency of metro has significant impact on the commuters' mind, to choose metro as the main mode in their journey chain because the frequency of metro is at the interval of 4 min during peak hour and 5–15 min during off-peak hours on Line-I (Red Line). During peak hours, frequency at shorter interval provides less waiting time and hence may attract more modal shift. Generally, Delhi Metro runs on time and there is hardly any delay on the route except some unavoidable situations such as signaling problems, technical snags in heavy rains, software malfunction, unclaimed bags on the platforms, etc. The intelligent transport system applications also avoid line congestion and provide well-defined headways. Hence, less possibility in delays also favors more ridership of the metro.

In metropolitan Indian cities, one group of commuters (preferably government employees) may prefer to stay in the core area by paying higher rents but lower transport cost and hence saving both journey time and transfer cost. On the contrary, some of them may prefer to live away from the city (i.e., in satellite towns) by paying comparatively lower rent but higher transport cost and time. Hence, it is totally based on the choice and the willingness of the commuters to pay a higher price for either transport or house rent. In both cases, the value of travel time depends on affordability and paying capacity of the commuters by striking a balance between saving of travel time and paying of extra housing rent.

The findings of this research work support that there is always demand for connecting multinodes of employment centers, residential pockets, commercial areas, recreational centers, educational hubs, etc. with high capacity rapid transit for better mobility and less travel time, and hence city residents prefer to shift from bus to metro. Further, central business districts, housing areas, shopping centers, etc. may be encouraged to grow on mass rapid transit corridors, which further reduce transport demand. In this context, the concept of transit-oriented development is promoted. Transit-oriented development is a concept that aims at integrating high-trips-generating land uses with mass transit system in a city and its periphery. It reduces personalized modes, congestion on roads, air pollution, etc. by promoting mass transit and its ridership.

The policy recommendation for modal shift from bus to metro is a part of good governance that integrates all components of urban transport for sustainable transport system. The modal shift is not justified only based on travel time saved but due to indirect contribution in reduction of congestion, pollution, fuel consumption, and accidents on the roads. Similarly, bus-metro integration and multi mobility plan in station area is necessary which may further save travel time by reducing waiting and transfer time. Furthermore, planning efforts for all stops/stations with basic information, interchange points with real-time information, updated website, provisions of transfer facilities, etc. are more important to make modal shift more attractive with increased patronage and improved services.

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