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EVALUATING THE TIME AND COST EFFICIENCY OF PUBLIC TRANSPORT SYSTEM IN DELHI

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ABSTRACT

The National Capital Region of Delhi is ranked third as the largest built-up urban area in the world with a population density of about 14000 people per square kilometer. A complex system of public transit, paratransit and non-motorized transit system with last-mile connectivity is integral for such large areas to perform efficiently and promote sustainable transportation systems.

To understand these urban processes and related space-syntax, it is crucial to understand which mode of public transport is preferred by the user and why. The user choices for a particular mode of transportation are primarily dependent on the time-cost relation of the mode. The present paper evaluates the efficiency of four modes of public and para-transit transport systems in the city of Delhi. The key modes identified are a combination of metro, bus, auto and taxi systems. The data on travel time and travel costs is collected and compared for the three selected routes. This shall be done by comparing four modes on three routes to generate 12 permutations. The selected routes have varying origin and same destination with route length of 20 kms, 12 kms and 7.1 kms respectively. The efficiency of the transportation system is evaluated on 9 parameters - velocity, Cost of vehicle & infrastructure, Travel Cost, Travel Time, Capacity, Flexibility, Aesthetics, Comfort and Maintenance. The research identifies the travel distance and settlement density to be critical elements in the user decision-making process and hence are key parameters to be considered in planning for public transportation in complex metropolitan cities.

Keywords: Public Transport, Last-Mile Connectivity, Travel Time, Travel Cost, Delhi Metro

1. INTRODUCTION

The public transportation system is the nervous system for a city. It is the underlying factor in determining the location, growth pattern and density of a city or vice-versa. According to the DMRC (Delhi metro Rail Corporation), Delhi metro has transported over 369 crore passengers in the last 12 years. “This resulted in savings of 2.9 million tons of carbon-dioxide equivalent due to shift from other modes of travel, thus avoiding global warming and climate change” (Ashok, 2021) The Figure 1 below quantifies the time, fuel and money saved by the use of Metro instead to a private car.

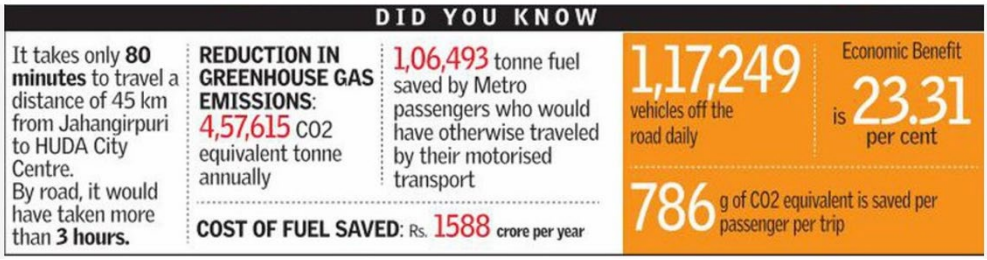

Figure 1 Infographics Showing the amount of time, fuel and money saved by Delhi Metro,
Source (Ashok, 2021)

The type and intensity of transportation network is both a cause and effect of Urbanization. The transport systems in cities are broadly categorized under four broad categories:

1) **Private motorized transport:** owned by individuals for personal use. Ply on public streets e.g., Motorcycles, Cars, etc.
2) **For-hire motorized transport:** Privately booked by individuals or groups, public in nature, offer door-to-door service. Suitable for destinations not served by public transport e.g., Taxi, Auto Rikshaw, Cycle Rikshaw, E-rickshaw, shared motorcycles, Ola, Uber etc.
3) **Public transport for masses:** owned by the state, buses are the most common system, varying capacities and may have an extensive network. Metro has the highest performance, capacity, speed & reliability, but routes are limited to fixed tracks and stations.
4) **Non-Motorized Transport:** Suitable for the narrow lanes and short distances within the neighborhood, e.g. Cycle, Rickshaw and Pedestrian are preferred.

Each mode has its benefits as well as limitations, however the modal choices depend on several factors to determine the efficiency of transport modes. For the purpose of this research efficiency of the transportation system is evaluated on 9 parameters - velocity, Cost of vehicle & infrastructure, Travel Cost, Travel Time, Capacity, Flexibility, Aesthetics, Comfort and Maintenance. Out of these nine parameters it was found that the time and cost are the two major determinants of user choices.

Hence, The Aim of this research was to understand the relation between travel time, cost efficiency on the user preference of transportation mode. The three main objectives are – 1. To understand the nuisances and issues associated with the public transportation system in Delhi. 2. To evaluate the various modal combinations of transportations with respect to travel time and cost. 3. To analyze and identify the relation between user preference for transportation mode with respect to the travel time and cost efficiency in caser of Delhi.

2. LITERATURE REVIEW

2.1. NEED FOR PUBLIC TRANSPORT SYSTEM

The National Urban Transport Policy 2014 (Government of India, 2014), focuses on the movement of people rather than the vehicles and promotes multiple modes of transport. Integration of public transport systems and non-motorized systems in urban planning is highly advocated to ensure sustainable urban development as they align with three pillars of sustainability –

1) **Economic Viability:** Compared to the private systems, they provide a low-cost, fast, comfortable, and convenient intermodal transfer. They are widely used by the masses and enable transporting knowledge, labor, and skill across markets to instigate a series of economic growth.
2) **Low Environmental Impact:** Public transportation significantly reduces the number of private vehicles on streets and lower the per capita fuel consumption due to sharing of resources. This also means less pollution from vehicular emissions and leads to a healthier and livable urban environment.

3) **Social Inclusion:** Public Transportation provides immense opportunities for interacting with known and unknown people across the age, gender, and social status. This means a greater social inclusion in cities. Additionally, it gives the opportunity to walk for physical health and interact for mental well-being.

2.2. ISSUES AND OPPORTUNITIES WITH PUBLIC TRANSPORTATION IN DELHI NCR

The urban sprawl in Delhi can be attributed to the development of National Highways (NH) No. 8 and 24, passing through the south-west and the south direction respectively—connecting Gurugram and Faridabad—two newly developed cities along with a norther corridor near Narela. This Rapid development during 2010-2020 reveal that the transport corridors had strongest association with the built-up areas (Sharma & Abhay, 2021). 10 out of 20 most polluted cities in the world are located withing a range of 100 KMs of Delhi NCR. As per a 2018 study by ARAI and TERI, motor vehicles are the primary source of pollutants within Delhi and contribute to about 40 percent of PM 2.5 emissions — one of the key reasons for the city's toxic air (Bhatt, Half of Delhi pollution caused by vehicles! Here are three ways to clean the city's mobility system, 2021). Air Quality Index (AQI) is the index measuring the quality of Air with respect to its impact on human health. There have been several schemes by Government of Delhi to tackle hazardous high levels of AQI. Increased traffic density seems to have resulted into the worst air quality at ITO in the city amongst all the monitoring stations (Mohan & Kandya, 2007). The vehicular pollution have been identified as one of the key cause of this air pollution, hence government enforced restriction to the usage of private and polluting vehicles through odd-Even Scheme, Rahgiri Day, Work from home Scheme, Pollution Lockdown, Free Public Bus transport for women Riders, CNG Buses, restriction of truck movement within city for non-essential goods, prohibit the movement of diesel cars older than 10 years and petrol vehicles older than 15 years, check for PUC certificate, Metro to allow 30 standing passengers etc. These moves were indeed able to show considerable reduction on the air pollution levels till the regulations were in place. However, these regulations were criticized to be only temporary solution and ineffective when the public transportation was not efficient enough.

Public transportation systems account for 30 percent of trips in cities with populations between one and two million, 42 percent in cities with populations between two and five million, and 63 percent in cities with populations over five million (Census of India, 2011) (Figure 2). It is evident that the public transportation system for large urban agglomeration has greater demand and complex nature. This complexity results in large variation available for user choice and permutations of transportation modes. The Delhi itself relies on more than 10 broad modes of public transport that include- Metro, Buses, Mini-Buses, Auto Rikshaw, Taxi, shared for-hire service (taxi, autos and e-rikshaw), Phat-Phat Services, cycle rikshaw, E-rikshaw or Sunehri, Rented bikes, E-bikes etc. Often at the dense localities or areas with urban sprawl with pockets not serviced by popular public-transit modes a need based local and ad hoc systems develop.

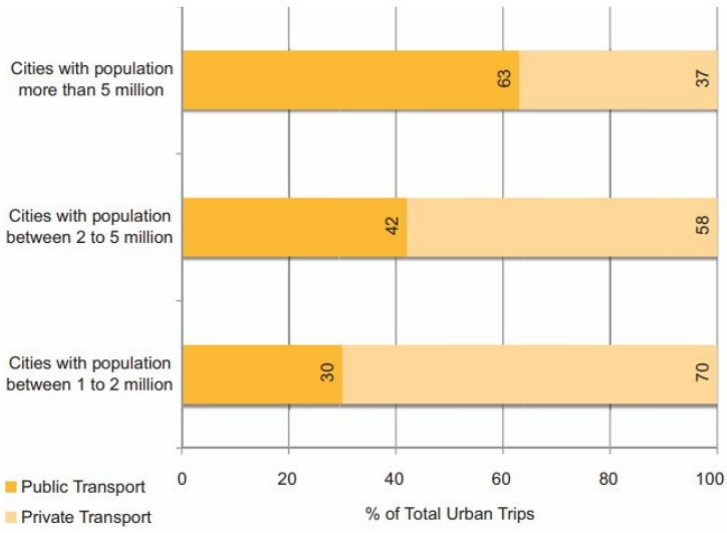

Figure 2 percentage of Urban Trips in Indian Cities based on population,
Source Census 2011

According to a Survey conducted by RITES over 80% of all the respondents travelled more than 10 kilometers of distance on metro (Goel & Tiwari, 2016). However, the average trip length of Delhi Metro user is around 16 kilometers. This means that Metro is preferred mode of transport for longer distance. (Bhatt, Metro vs bus: Integrated public transport system need of the hour, 2019). The convenience in using metro is greatly reduced as the distance reduces with large ridership, time to climb up or down to the metro concourse level and within the metro station or interchanges. This is where the buses find their niche, with very low fare and closer placement of the bus stops. However, when the routes are located at high densities and narrow road width with slow moving traffic the travel-time increases immensely. Also, sometimes the nearest bus stops are non-walkable distances the buses are not preferred and there is a need to improve last-mile connectivity for metro and buses. Which means walkable distances or integration of informal and non-motorized transportation connecting the nearest bust-stop or metro station to the destination (Figure 3). The lack of last mile connectivity reduces the public transportation ridership and increases the preference for private vehicles.

Figure 3: Last Mile Connectivity (Irani, 2022)

3. RESEARCH METHOD

The research intends to explore the determinant of user preferences for public transport and what kind of transit mode, or their combination have greater efficiency? For this purpose, an experimental study of 3 routes with different origin and same destination were evaluated based on time and cost efficiency of public transport modes, these routes were: (Figure 4)

1) Paschim Vihar to ITO (SPA Delhi Architecture Block, 4B IP Estate) – 20 Kms
2) Taimoor Nagar to ITO – 12 Kms
3) Mayur Vihar Phase-1 to ITO – 7.1 Kms

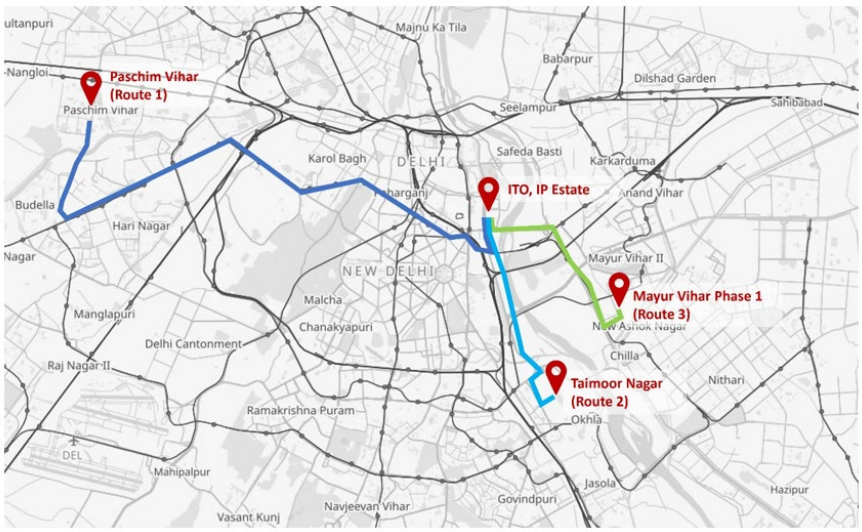

Figure 4 Identified movement Routes for Time-cost analysis,
Source Author

Further for each route for combination of transport modes were evaluated with a combination of walking and Auto rikshaw for last-mile connectivity. To avoid biases a set of four participants were required to test the selected three

routes and four modes of transport and were required to share their response. Additionally, the routes were evaluated for peak hour traffic conditions using google maps, to triangulate the findings. The four transit modes selected to be tested on each route were -

4) Bus Dominated
5) Metro
6) Taxi
7) Auto Rikshaw

Few limitations associated with the research were –

8) The Time and cost were calculated by taking random samples travelling on the same route on daily basis.
9) The distance up to 500 meters was considered walkable, beyond 500 meters the need for last mile connectivity was required, especially in harsh climatic conditions for most time of the year.
10) The findings are limited to the sample size, and time of study which was weekdays, morning 8am to 9am and early evening between 5pm to 6pm.

4. EVALUATION OF TIME-COST EFFICIENCY

Three routes were travelled and compared in the matric summarized below in Table 1.

Table 1 Evaluation Matrix of time-cost efficiency of selected routes

ROUTE NUMBER	**1**	**2**	**3**
ORIGIN	Paschim Vihar	Taimoor Nagar	Mayur Vihar ph-1
DESTINATION	ITO	ITO	ITO
Distance	20 KM	12 KM	7.1 KM
TRANSIT MODE COMBINATION 1 (BUS)	WALK – Sunder Apartment to Bus Stop 9 min - 0	WALK – SPA Hostel to Bharat Nagar Bus Stop 13 min - 0	WALK – Mayur Vihar Phase 1 to Samachar Apartment Bus Stop 5 min - 0
	BUS - Sunder Apartment to Peeragarhi – 761,805A,879B, 883A 6 min (2 stops) - 5	BUS – Bharat Nagar to ITO 420 cl Azadpur /274 30 min - 10	BUS – Samachar Apartment to IG Stadium 347 ISBT 30 min - 10
	BUS – Peeragarhi to Gandhi Darshan – 918 Delhi Sachivalaya 58 min - 15	WALK – Bus stand to SPA Campus 10 min - 0	WALK – Bus stand to SPA Campus 2 min - 0
	WALK – Bus stand to SPA Campus 8 min - 0		
TOTAL TIME - COST	90 min - 20	55 min - 10	35 min - 10
	WALK – Bus stand to Sunder Vihar Bus Stop 9 min - 0	E RIKSHAW – SPA Hostel to Sukhdev Vihar metro station	WALK – Mayur Vihar Phase 1 to Metro Station 5 min - 0

4.1. ROUTE 1

The metro required 2 changes, yet the travel time was comparable to taxi, as the roads have narrow bottlenecks and traffic congestion. The cost of bus service was lowest; however, it took almost, 1.5 hrs. time for a distance of 20 kms which means a speed of 13.33 kms per hour during peak traffic hours.

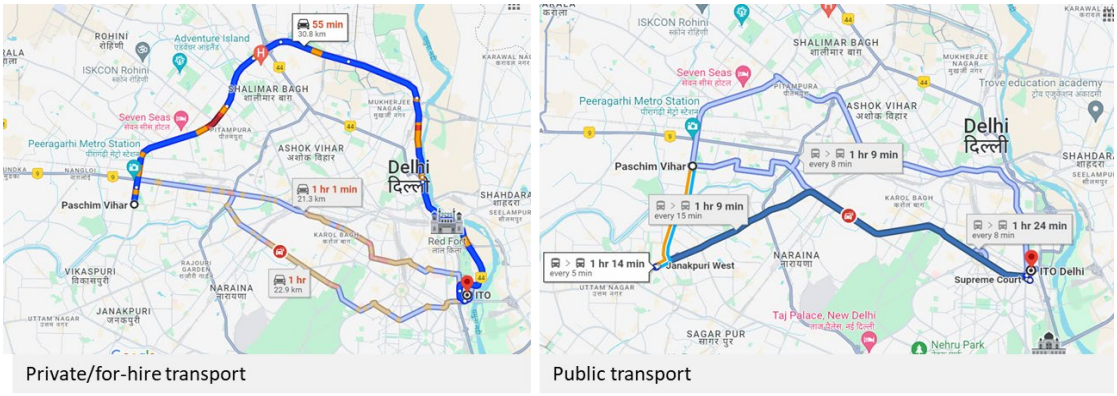

Figure 5 Route1 live traffic data comparison for private/for-hire versus public transport,
Source Google Maps (2024)

4.2. ROUTE 2

The distance was shorter but there was no direct connecting public transport route either by bus or metro. Hence, maximum efficiency in the travel cost and time was through shared auto rikshaw.

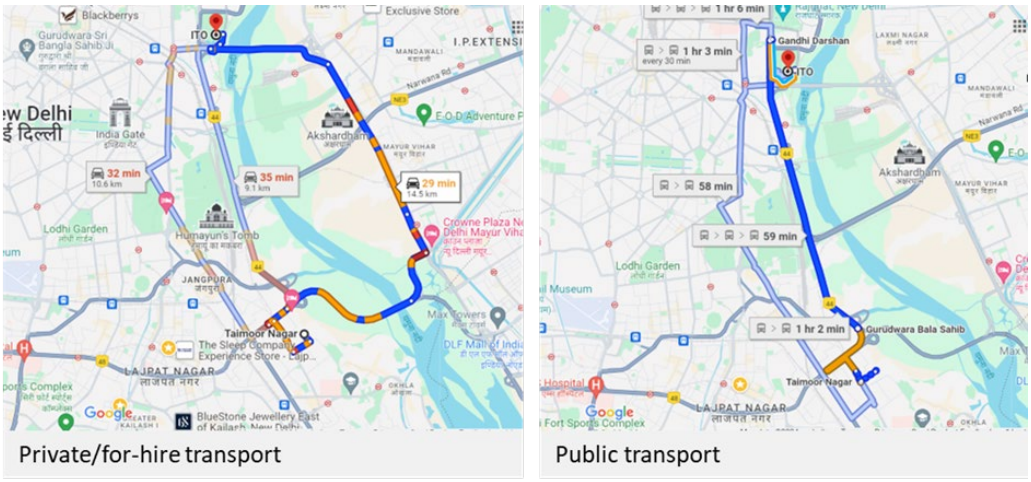

Figure 6 Route2 live traffic data comparison for private/for-hire versus public transport,
Source Google Maps (2024)

4.3. ROUTE 3

Bus service was equivalent to metro in terms of travel-time but 1/6th in terms of cost. Hence, it was the preferred public transport. This route was also, preferred for private transport as the travel time reduces to half and distance is less.

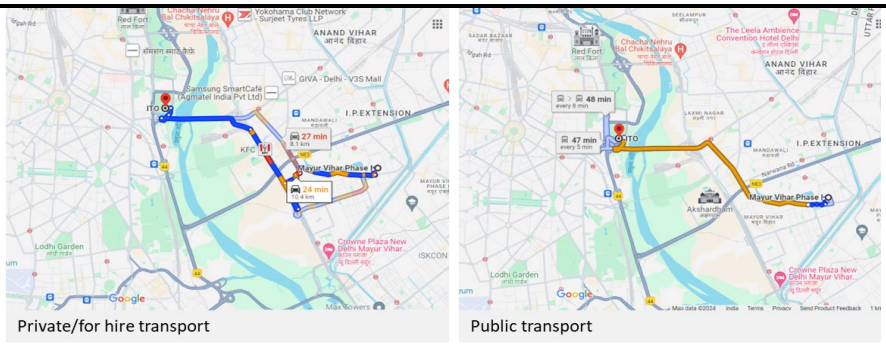

Figure 7 Route3 live traffic data comparison for private/for-hire versus public transport,
Source Retrieved from Google Maps (2024)

For All three routes, Buses were most economically viable and were used by masses. The last-mile connectivity with metro was an issue as it required large distances to walked or to be covered by Auto. The Auto-rikshaw was a popular choice with students as the cost could be shared and when there are 3 people travelling the same route e.g., from hostel to college it was rated to be most efficient in terms of time as well as cost. For, longer travel distances and dense urban areas with narrow lanes, metro was highly time saving. To quantify the findings of above study a 4- point rating system was used to evaluate all the parameters that guides user's decision-making process. (Table 2), consider 1 as the lowest and 4 as the highest (positive attribute).

Table 2 Evaluation of various transit modes (combined with their last mile connectivity on the selected routes) on 4-point scale

S. No.	Parameter	Bus	Metro	Taxi	Auto
1	Velocity	1	3	4	3
2	Travel Cost	4	3	1	2
3	Travel Time	1	3	4	2
4	Capacity	3	4	1	2
5	Flexibility	3	1	4	4
6	Aesthetics	1	4	4	2
7	Comfort	1	3	4	2
	Total	14	21	22	17

5. RESULTS

The comparison of the 4 cases with one key public, semi-public mode of transport combined with the last mile connectivity gave interesting findings to understand user choices associated with public transport. The DTC bus service is widely spread over the city and is most economic choice but travel time is the highest due to traffic, low vehicle velocity, and lack of last mile connectivity options, need to walk long distances and to wait long durations without a certainty for the next bus and hence it ranks last with 14 points in the evaluation matrix. Although Last mile connectivity is a common issue with the metro, but travel time reduces due to no interference with the road traffic, certainty in terms of next available metro, travel time, comfort, aesthetics and travel cost. Metro ranks 2nd and is preferred mode wherever the service is available within walking distances. The last mile connectivity options of shared e- rikshaws have also popped near metro stations. The Private taxi is the most preferred mode with 22 points among the 4 combinations due to app-based availability that adds to flexibility, high velocity, Low travel time, comfort and aesthetics. The Auto rikshaw is third

with 17 points and is suitable for shorter distances in congested areas only. The flexibility associated with auto allows it to be an option for last mile connectivity along with bus and metro.

6. CONCLUSION

The findings of the study are based on the primary research and personal interviews of the co- travelers and taxi drivers during the experimental process. The responses are combined under the three parameters being studied in the research.

1) **Access and Egress Modes:** A large share of people prefer non-motorized transport of last mile connectivity of their metro along with auto and private cars. However, changing mode of transport is and indicator of inconvenience. Cycles are last used as a mode of last mile connectivity due to road safety. Walking in preferred only in ideal weather and footpath conditions.
2) **Travel Length:** The average trip length in Delhi is around 11 kilometers. The additional time taken in metro for entry and waiting is managed only when the distances are longer. For shorter trips buses were affordable and convenient when there is frequent bus service. Autos are preferred for shorter trip and low speed congested areas versus taxis are preferred for longer distances and wider streets.
3) **Affordability:** The affordability of buses is at least 6 times higher than any other mode of transport. With increasing metro tickets, the ridership has declined considerably.

This evaluation helps to develop an understanding of the factors influencing the user-choices of a transit mode. Although the bus service is lacking in several parameters, yet it is the most popular choice due to the sheer affordability of this mode. The Urban Density and road width determines the traffic and the transportation modes that are suitable for a city. The city form and affordability are also key component of urban transportation. Hence, for longer distances and people travelling across the densities and longer distances. It cannot be a single mode rather a combination of multiple mode and options for last mile connectivity. There are several emerging options that can be integrated with exiting bus and metro routes to enable list mile connectivity.

7. WAY FORWARD

The research must be tested on a greater number of modes and to areas where, the public transport access was limited. The routes with similar distance but varied last mile connectivity systems must be compared to identify possible shift in user choices. Also, it would be interesting to look at that how many modes of transport people can conveniently change on daily basis while taking a larger number of sample size.

CONFLICT OF INTERESTS

None.

ACKNOWLEDGMENTS

None.

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