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A Study on Efficient Comprehensive Package for Delhi Metro Commuters

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Abstract- Public vehicles provide significant benefits to society. It cuts vehicle ownership and operating costs, avoid road congestion and parking problems, and improv safety. However, the service used by the nation depends on the quality of service provided by the public transport provider and government, such as comfort, speed, safety, time discipline, connectivity from place to metro station, non-crowding, and speed. The users' needs and preferences determine the savings and benefits of public transportation, the number of transit users, and the service quality. For maintaining efficient public services, the services providers must earn sufficient revenues to sustain. The study's objective is to calculate the reasonable fare for passengers based on passing metro stations, increase the revenue of providers/ Delhi metro, and recommend the "Efficient Comprehensive package". This efficient, comprehensive package develops with the help of personal interviews with metro commuters. Given a metro line with stops, the study shows that the fare should be based on the number of metro stations passed by the traveller's boarding and arrival stops to maximize the benefit obtained from the sale of tickets to the travellers. The Paper presents a package that includes qualitative factors, such as comfort, convenience, travel time valuation, transit service quality and transit ridership. The Paper Contains 4 sections. Section I Includes the Introduction and objective of the Paper. Section II Covers a Review of the literature and methodology. Section III Contains calculations of Cost- Per passenger KM and a Comparison of Existing Fare with the Proposed Fare. Section IV contains "efficient comprehensive metro packag**e"** & Conclusions.

Key Words: Metro, Delhi, Fare, Efficient Comprehensive Package, Riders, Revenue and Cost

Section 1

1.1 Introduction

In a short period, the Delhi Metro has become a part of the daily life of the Delhiites. Commuters of Delhi are also proud to travel by metro compared to previous DTC buses in terms of cleanliness, punctuality and reliability. The Delhi metro is an important mode of transportation for the average-income society.Delhi Metro is an advanced mass transportation system. It connects the people of Delhi with Delhi and the cities of Gurgaon, Noida, Greater Noida, Ghaziabad, Faridabad, Bahadurgarh and Ballabhgarh in the Indian Metropolitan National Capital area. Currently, the Delhi Metro Network is operated by the Delhi Metro Rail Corporation (DMRC) consisting of 10 lines servicing 255 stations with a total length of 348.12 kilometres. DMRC further plans to expand to other NCR cities such as Sonipat and Meerut. Delhi metro provides significant benefits to the society. The use of Delhi metro by metro riders saves vehicle ownership costs, operating costs, and maintenance costs, avoids road and parking costs and insurance costs and improves safety.

Every day, approximately 27–30 lakhs people use the Delhi Metro. Despite this, as per the annual reports of 2019-2020 and, 2020-2021, Delhi metro has been incurring losses in past years.

The study suggests an "Efficient Comprehensive package ." for metro commuters. It would increase the revenue of DMRC generated by people's ridership without raising the overall travel fare and also saves the total per-ride cost for the metro commuters. The increase in daily commuters of Delhi depends on the service of the DMRC. The factors of services are comfort, speed, safety, time discipline, connectivity of metro stations, non-crowding, and speed. Metro commuters also use personal transport/automobiles/rickshaws to reach metro stations and incur high costs. This model considers all the above factors of services and cost.

An "Efficient Comprehensive package" for the users depends on several international studies conducted in the last 15 years about fare optimization worldwide of Metro and Transits systems. It develops with the help of personal interviews with metro commuters. The Efficient Comprehensive package considers only passenger fares and does not consider the revenue of Metro by advertisements, rental of properties and other interest or ancillary income. An increase in ridership will also increase advertisement revenue, which will further strengthen the revenues of the Metro.

1.2 Objective of the Study

1. To calculate and suggest the amount of reasonable fare to the passengers based on passing metro stations and increase the revenue of providers/ Delhi metro

2. To recommend the "Efficient Comprehensive package" for metro commuters.

Sections 2

2.1 Review Of Literature

Several studies have been conducted to study and suggest fare optimization. The objective of the studies was to maximize total revenue through transit improvements and comfort to commuters.
In 1980 Webster and Bly published a collaborative report on " identifying many factors which influence demand of travellers. This has been of great value to public transport operators and transport planners"[i].
The same year Cervelloanalyzed "the effect of flat rates versus differentiated ones"[ii] .
In particular, D. Fleishman, N. Shaw, A. Joshi, R. Freeze, and R. Oram studied "the impact of the variability of fares depending on the distance and time-of-day"[iii].
Moreover, V. R. Vuchic differentiated fares and it can be further subdivided into zonal fares, distance-based fares, sectional fares, and time-based fares"[iv] The objective functions in the above studies were to maximize either total profit and/or social welfare. In some of the cases elasticities in the demand of the transportation service were included. The solution of these problems was given by the maximization of certain profit function subject to certain restrictions.
In the same year, study conducted by Wener, Evans and Boately concluded "High-quality (safe, clean, comfortable and reliable) transit allows passengers to read, work and rest, so their unit costs are relatively low. If quality transit is available, travellers will select the mode that best meets their needs and preferences. This maximizes transport system increase efficiency and consumer benefits"[v]. "The problem of fare zone design for local public transportation networks using a graph theoretical approach" was considered by Hamacher and Schöbel[vi]. In the works, "the design is obtained in order to minimize either the maximal or average deviation between the fare zone system and the distance tariff for all the pairs of stops".[vii]
Arrington and Sloop also concluded "High quality transit requires an integrated system that includes attractive stops and stations surrounded by compact and mixed development, good walking and bicycling conditions, reduced parking supply, and more social acceptance of non-auto travel; together these are called Transit Oriented Development (TOD). Where these features exist, residents own fewer automobiles, drive less, and rely more on non-auto modes. Residents of transit-oriented developments tend to own about half as many vehicles, generate half as many vehicle trips, and rely on walking, cycling and public transit much more than in automobile-dependent communities"[viii]
Tomeret al. emphasised "Public transit is a critical part of the economic and social fabric of metropolitan areas. Nearly 30 million trips are made every day using public transit. Almost all of these trips occur in the nation's 100 largest metro areas, which account for over 95 percent of all transit passenger miles travelled. People take transit for any number of reasons, but one of the most common is to get to work. However, when it comes to the question of how effectively transit connects people and jobs within and across these metropolitan areas, strikingly little is known. With governments at all levels considering deep budget cuts, it is increasingly important to understand not just the location and frequency of transit service, but ultimately how well transit aligns with where people work and live. To better understand these issues, the Metropolitan Policy Program developed a comprehensive database that provides the first comparable, detailed look at transit coverage and connectivity across and within the nation's major metro areas. Nearly 70 percent of large metropolitan residents live in neighbourhoods with access to transit service of some kind.Inneighbourhoods covered by transit, morning rush hour service occurs about once every 10 minutes for the typical metropolitan commuter. The typical metropolitan resident can reach about 30 percent of jobs in their metropolitan area via transit in 90 minutes. About one-quarter of jobs in low- and middle-skill industries are accessible via transit within 90 minutes for the typical metropolitan commuter, compared to one-third of jobs in high-skill industries[ix].
H. Li, K. Gao, H. Tu concluded "The service quality of public transport could be measured by the attributes including in-vehicle travel time, waiting time, travel time reliability, cost, in-vehicle crowding, etc".[x]Litman,Wang and Zacharias

in 2020 concluded "Passenger travel choice utility mainly depends on some tangible factors such as travel time and cost . Increasing the number of passengers before vehicle capacity reaches saturation can reduce social costs, but ignoring the cost of passenger comfort . However, considering only time and cost is not enough to fully explain the passenger travel choice behavior, the cost of in-vehicle crowding needs to be taken into account in the travel choice model"[xi]

2.2 Scope & Methodology:-. Annual reports of Delhi metro for two years, i.e., 2020 and 2021, have been used for calculations of total expenditure. The data published by DMRC have been used for the daily metro commuters, the number of metro lines and stations. The data for efficient comprehensive package collected with the help of personal interviews with metro commuters.

Section 3

3.1Calculation of theCost Per Passenger KM

To develop an "Efficient Comprehensive package, " calculate a composite unit, i.e., Passenger – Kilometre[xii]

The cost per passenger KM = Total annual operating Costs for all metros lines / Total Passenger km travel in all metros lines*

Then accordingly, profit can added to the cost per unit.

Delhi metro has a total of 10 metro lines in operation. Different colors represent these:

1. Red line - Dilshad Garden-Rithala
2. Yellow line- HUDA City Centre (Gurugram)- SamaypurBadli
3. Blue line- Dwarka Sector 21- Noida City Centre,
4. Blue line- Dwarka Sector 21- Vaishali
5. Violet line- Kashmiri Gate- Escorts Mujesar (Faridabad)
6. Pink line- Majlis Park- Durgabai Deshmukh South Campus
7. Magenta line- Janakpuri West- Botanical Garden (Noida)
8. Orange line -Airport Express Line- Dwarka Sector 21- New Delhi Railway Station
9. **Grey Line-** Dwarka – Najafgarh (4.295 km, 3 stations),
10. Green line- Inderlok/Kirti Nagar –Mundka

Passenger kilometers: Passenger kilometers are calculated as per the following formula:

(A)In Peak hours: Number of Metro Rides a day x No of average Passengers in one bogie of metro train x No. Of bogies in one metro x Average km metro run one-way x No. of days

(B) Number of Metro Ride in Non-Peak hours a day x No of average Passenger in one bogie of metro train x No of bogie in one metro x Average km metro run one-way x No. of days

(C) A+B=D

(1) No. Of bogies in one metro are 6 to 8. The average no. of bogies in one metro =7 bogies

(2) No. of Metro Rides in Peak hours a day-

8am to 11am (Morning) =3 hrs and 5pm to 10 pm (evening)= 5 hrs. Total Hrs are 8 hrs of peak hrs

Non-peak hrs

6am to 8am (Morning) = 2hrs , 11am to 5pm (Afternoon) =6 hrs and 10pm to 11 pm (evening)= 1hr.

Total Hrs are 9 hrs of non-peak hrs

(3) The average number of passengers in one bogie during peak hrs is 250 (50-passenger seated capacity and 200 standing capacity). Total capacity 250 passengers.

(4) Frequency of metro – Every 3 minutes (peak hrs) and 6 minutes (non-peak hrs).

Study considers only 7 main metro lines- Red line, Blue line, yellow line, green line, violet line, Pink line, and Magenta line. The airport line has different fares, and the Grey line has only four stations not considered for the study. There are two blue lines , both are counted as one.

Calculation of Total Passenger Kms of both rides in peak hrs of one day:

Total Peak Hrs = 8 hrs.
Frequency: One metro arrives every three minutes on both sides.
So the total number of one-side metro rides during peak hrs = 160 rides on one side (8hrsx60 minutes/3 minutes).
For calculation, we have divided it into two parts:
Ist Part:
(1) The passenger Kms of one ride during Peak hrs=1750 passengers. (No. of Passenger in each metro one way with 100% capacity- 250 x 7 bogies)
Maximum total km run one way of each metro – 45 km
(2+5+12+21+32+45)/6=average 20 km. (The sum of 2,5, 12,21,32 and 45 km is taken from the metro site. On this different Km differ prices.)
Total Passenger Km of one ride ,one side during Peak hrs= 56,00,000 Passenger km (1750passenger x 20 km x 160 rides)

(2) No. Of average passengers in one ride another side during Peak hrs in one metro=875 passengers (125, capacity is 50% x 7 bogies).
Total Passenger Km of one ride ,other side of Peak hrs = 28,00,000 (875 x20kms x160rides)
(3) Total Passenger Km of both rides of Peak hrs = 84,00,000 (Sum of both (1)and(2)5600000+28,00000)
(A) Total metro lines are 7 -
Hence,84000000 x 7 = 588,00,000 Passenger km during Peak hrs of 7 metro lines.
2nd Part:
Total Passenger Km of both rides in Non-Peak 9 hrs per day:
One metro arrives every six minutes on both sides.
So the Total no. of one side metro rides during Non-peak hrs = 90 rides on one side(9 hrsx60minutes/6minutes).
Considering both sides, the total number of rides will be=180 rides a day (90 ridesx2)
The passenger km of one ride of Non-Peak hrs:-
Assume 50% capacity of average passenger (50% of 250)
No. of Passenger in one metro-= 875 passengers(125 passenger x 7 bogies).
Total Passenger Km of both side during
non-peak hrs=31,50,000 Passenger (875passengers x 20km x 180rides)
(B) Total Passengers travel during non peak hrs a day in 7 metro lines=220,50,000 (31,50,000 x 7metro lines)
(C) Total Passenger km travel in 7 metros line of one day= 808,50,000{ (A)+(B) [588,00,000 + 220,50,000]}

(D)- Total Passenger km travel in 7 metros lines during a year =291,06,000,000 (80850000 x 360)

Annual Cost of operating for the year 2020:

Total annual cost in 2020 wasRs 595,687,63,000 and in 2021 was Rs. 557,298,89,000[xiii]

Cost per Km travel in 7 metros line during year 2020 and 2021(Table1)

Table1:Cost Per passenger KM

Particulars	2020 year	2021 year
Total Costs	595,687,63,000	557,298,89,000
Total Passenger travel in 7 metros lines	291,06,000,000	291,06,000,000
Cost Per Km(Total cost/Passenger km)	Rs 2.04 Per Km	Rs 1.91 Per km

In this study, we have not included any portion of the profit. Therefore the cost per passenger KM considers as fare per passenger KM.

3.2 Comparison of Existing Fare/ with Proposed Fare:

The existing method of fare employed by the metro is based on km[xiv].The study compares the existing method of Fare with the proposed method of Fare based on the number of stops. The Fare of a ticket depends on the number of stops a passenger crosses in his trip. That is called the "crossed station fare system". The fare system should be such that it gives benefits to the passenger and also to the company/Service provider. If a passenger crosses fewer stops, his Fare should be less than those who cross more stops. We can fix the fixed value of a certain distribution of stops into zones, which is applied to all the tickets as we want to get the optimal revenue for the metro company that supplies the service.

Suppose there are three passengers A, B and C. Their destination stop is Gokulpuri station. To reach Gokul puri station, there are three different routes. But the Fare for all three routes is Rs.50. However, A, B and C all start their journey from Janakpuri west to reach Gokul Puri. However, A follows the shortest route; he crosses 23 stations and takes 70 minutes (as per Delhi metro). But A has to interchange the train in four stations. B follows the longest route, the train crosses 34 stations and takes 99 minutes(as per Delhi metro), and he has to interchange the train at one station. C follows the average route; the train crosses 32 stations and takes 78 minutes (as per Delhi metro); he has to interchange the train at one station.

Presently, the Fare is the same for these three routesie.Rs 50.

Proposed fare;-

Particulars Route	Starting Station	No. of interchange	Station in between	Km covers (approx.)=1KM in between two station	Timeto Reach Destination Station (Minutes)As Per DMRC	Waiting Time During Inter Change Station (Aprox.) -10 Minutes per station	FARE (2020) Rs1.91 per stop	FARE (2021) Rs2.04 per stop
Shortest Route	JANAKPURI WEST	4	23	23	70minutes	40 min	Rs 44	Rs 46
Longest Route	JANAKPURI WEST	1	34	34	99 min	10 min	Rs 65	Rs68
Second longest route	JANAKPURI WEST	1	32	32	77 min	10 min	RS 61	Rs64

Result:-

The current metro fare is Rs 50 for allabove three routes. As per the calculation, the shortest route fare should be Rs 44 and Rs 46. As per the calculation, the Longest route fare should be Rs 65 and RS 68. The second largest route fare should be Rs. 61 and Rs 64 to benefit both metro/provider and passenger in 2020 and 2021, respectively.

Section4

4.1Efficient Comprehensive Metro Package

Metro Transit is an important travel mode for low- and middle-income non-drivers. For example, a household earning Rs. 20,000 per month spends about Rs.1250 monthly on transport. Similarly, many students depend on public transport for commuting to schools and colleges. Hence, reducing time spent on transit services can increase their future productivity and study time. As a city grows, these benefits become increasingly important as a cost-effective way to reduce traffic congestion and parking problems. These benefits increase if transit improvements and incentives are designed to attract discretionary riders.

In 2017, the metro fare was hiked after nearly 5 years owing to inflation costs and rising salaries of the employees. This study proposes that the fare may be formulated based on "Crossed Metro Station". DMRC needs to meet its costs, generate some profit for further expansion, and become self-dependent. The study also suggests the" **Comprehensive Metro Package "**aim to maximize the revenue of the metro without increasing the fare Per km".

"**Comprehensive Metro Package"-**The package has some common features and special features.

The common features are :

1. Last Mile Connectivity- The value door-to-door is included in the package**.**

2. **Reduce the waiting time** -The cost of connecting one metro station to another. Metro management can improve efficiency by synchronizing traffic signals and reducing waiting times at interchange stations.

3. **Comfort and security**-Strategies to provide users with comfort and safety The subway can build skywalks, move Walkways and connect walkways with escalators. It can improve last-mile connectivity. Construction costs of these facilities are offset by increased revenue from increased passenger numbers**.**

4. **Predictability, Punctuality and Reliability**-Strategies that improve access to transit, for example, by making it easier and safer to walk or by the availability of connecting transports like E-rickshaw or autos and more transit-oriented developments can also reduce travel time costs. Travelers switching from cars to public transport in response to public transport improvements and other positive incentives consider all implications and overall improvements, even if transit trips take more time.

The special feature is comprised of common features.

Metro presently offers discounted fares to travellers using metro cards instead of tokens. However, the metro may consider these additional special features to attract more travellers.

1. **Discounted fare pass** for regular metro users-A passenger with a round-trip ticket or return ticket between two stops is counted twice, once in each sense. These passengers pay twice the price of a single ticket and receive no discount. They should receive a discount if the passenger begins at one stop (A) and ends at another stop (B), and in the return journey if the passenger returns from the same stop (B) to where the passenger began his journey (A).

2. **Non-Peak Hrs Pass**: The metro may increase travel speeds or move faster during off-peak hours, which can attract low-income earners, Senior Citizen residents of big cities, Commuters of Adjoining areas or cities who commute to Delhi, commuters to major commercial centres, college and university students, or other public transits riders and those who are stressed by driving.

3**. Peak Hrs Pass:** Metro may increase service frequency and trips during rush hours. It attracts office goers for whom each minute is also very important.

4**. Privileged pass:** Transit should enable basic mobility such as medical services and assistance to senior citizens, people with disabilities and low-income households. . Demand for such services, and the benefits of providing public transit, tends to increase as the number of seniors, people with disabilities, and low-income households increases in a community. It is particularly true for those with moderate to severe disabilities that limit their mobility and often cannot use other travel options, such as walking, cycling or conventional taxis.

4.2 Conclusions

The cost of public transportation is a trade-off between time and money. The study looked at the overall impact of travel. The total impact incorporates both direct and indirect effects. When people switched from cars to public transportation, the direct impact was increased public transportation mobility and decreased personal vehicle use. When significant improvements in public transportation result in more accessible land use patterns and the use of transportation systems increases, the use of personal vehicles is reduced further. Quality metro transportation necessitates an integrated system with attractive stops and stations surrounded by compact and mixed-use developments, excellent sidewalks, and increased social acceptance of subway transportation. Commuters own fewer vehicles, drive less, and rely more on public transportation when these features are present.
The proposed metro system improvements will increase system efficiency. Reduce operating costs by increasing speed and frequency, as well as integrating with other modes of transportation. Because many transit costs are fixed, more commuters will result in lower unit costs. Metro services benefit from efficiencies and network effects as well.DMRC can attract more commuters by improving service frequency, coverage, operating hours, and features such as different types of passes. Users can compare such packages' "cost performance" to one-way and round-trip fares on the same system. The first metro ticket purchased influences commuter behaviour by comparing the average monetary cost per trip from previous travel patterns, and it also facilitates additional trips. However, A more thorough analysis will have a greater impactand be more accurate. Improving public transportation has far greater societal value than traditional models. 、

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[xii] As per Cost Accounting Standard 5 (CAS-5) issued by the Council of the Institute of Cost Accountants of India, Service Costing is also known as "operating Costing'. "It is that form of costing which applies where standardized services are provided either by an undertaking or a service cost center within an undertaking". Service costing includes transport costing also." Transport costing is a method of ascertaining the Cost of providing Service by a transport undertaking. It includes air, water, road and railways; motor transport includes private cars, carriers for owners, buses, taxis, carrier Lorries etc." In a transport company, a composite unit is used, i.e., Passenger – Kilometre

[xiii]Statement of total COST OF SERVICES OF DELHI METRO taken by annual report of Delhi Metro

S No	EXPENSES (LACS)	Year ended 31-03-2021 (Rs. Lacs)	Year ended 31-03-2020(Rs. Lacs)
1	Operating expenses including External Project Expenses	211,576.35	294,407.28
2	Employee benefits expenses	126,603.72	127,118.90
	Finance costs	45,210.83	45,189.32
3	Depreciation & amortisation expense	240,520.59	238,284.50
4	Other expenses	60,314.57	59,093.18
5	TOTAL EXPENSES (1+2+3+ 4)	684,226.06	764,093.18
6	(Less External Project Expenses)–	126,927.17	168,405.55
7	Total expenses related to operation of Delhi metro (after deduction of external project expenses) (5-6)	5,57,298.89	595687.63

Note: Because of Covid19 induced restrictions, the metro commuter services and operations were stalled or restricted from March 2020 to 7th September 2020 and again restricted on 19-04-2021 and resumed on 7th June 2021 with 50% seating capacity. Services finally resumed on 28/02/2022 with full passenger capacity.

[xiv]Existing method of fare is as follows:

Distance Slab(km)	Existing Fare(Rs)
0-2	10
2-6	20
6-12	30
12-18	40
18-24	50
24-44	60