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Study of Performance Efficiencies for Jaipur Metro by Using Data Envelopment Analysis

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Abstract

Since the beginning of 21st century, most nations are involved with serious issues and challenges related to urbanization. Urbanization is due to increased prosperity, most of which goes in fulfilling the needs of increased mobility. People travel daily for different physical, psychological and economic needs like – work, shopping, leisure, recreational, etc. A collective outcome of increased population, high percentage of urbanization rate and rapid growth of private vehicles combined with increasing needs for mobility is a matter of great concern.

The aim is to find efficiencies in Jaipur metro transportation systemby using a non-parametric technique for e.g., DEA. The methodology was adopted by using a ratio of the weighted sum of outputs to the weighted sum of inputs. Various parameters like, in-vehicle travel time, out-of-vehicle travel time, ingress and egress time were calculated during the study. The resultscan be used by urban planners, municipal authorities, transport authorities, etc., for improving the efficiency of Jaipur Metro.It was observed that only a small portion of the data set was efficient. The inefficient units can analyse their weaknesses further toimprove their efficiencies.

Although the study was complete and exhaustive, still future prospects cannot be missed out. Various other factors like, land area, city population, etc. may vary from city-to-city which would again make the process of efficiency measurement a dynamic approach.

Keywords: Urban Public transportation Efficiency Data Envelopment Analysis

1. INTRODUCTION

1.1 General

The urban area of developing countries is striving with very high demands of growing population & choked infrastructural facilities. The responsibility of any city administration is to provide a decent quality of life to its citizen. Due to insufficient public financial resources and increased social requirements, sustaining and improving the quality of community transportation systems are important for future operation and expansion.

The city of Jaipur, popularly known as Pink City is fast growing both in terms of size,

population and vehicles. It is residence to about 31 lakhs (Census of India. 2011) extending to an area of around 400 square km. In the last decade the city's population has seen an annual growth rate of 2.83% per annum. The city has more than 8 lakhs registered vehicles (2004), of which more than two-third were two wheelers. It is predicted that in the next 30 years, the population inside the city will be more than 66 lakhs which would transform into more than 6 lakhs peak hour trips. This would be around twice the today's peak hour trips. This lead to implementation of Mass Transit Corridor for the city, along with assessment of alternative alignment possibilities and hence implementation of MRTS capability. The multimodal urban transportation system of Jaipur metro stations has been considered in this study.

A multi-modal metropolitan transportation structure consists of 4 stages: access, egress, line haul & transfer stages. Multi modal transport is the transportation in which movement of goods and people is done by at least two different modes of transportation are used. The trip is known as multimodal trip. In multimodal transit system, each mode provides "access" to the next mode. The "access" may be the "egress" for the previous mode. In this research work, the significance of performing a multi-modal effectiveness study by including metro stations as prime focus was more associated. Waiting time in the multi-modal trips are a factor of travel time delay. If the service level of a transit system is performing to a satisfactory level, then for shorter headways, time of waiting is almost half of headway time. In case of headways for longer distances, the commuter is expected to reach earlier than the planned time.

The desirability of the movement is ease, safety, time saving, cost and accessibility of transit system. For evaluation and assessment of the public transit system, it is essential to find the attributes that dampen and influence the commuters. In this study, the factors are wait time, access time, egress time, level of service, gender, income, purpose of travel and ownership of vehicle plays a key role. In this study, it is observed that the travelers had more readiness to use the public transport when integration of system, transfers, information and fare is better.

1.2 Scope of the Study:

The objective of this work is to determine the efficiencies and the slack of the Jaipur metro stations. This research work offers a platform for evolving a performance measurement indicator. If the metro rail system is not as effective as it could be (it delivers less and poor service than desired levels) it involves metro passengers to pay more than needed and eventually it affects the ridership also. As per the figures available the average ridership in Jaipur metro dropped from 49774 per day in the first month (June 2015) of its operations

to 19390 per day (December 2016). This also resulted in revenue loss from JMRC as it could earn Rs. 70.44 lakh per month after spending approximately Rs. 3.5 crore per month on its operations. In this study, we try to cover the reasons for the inefficiency and the strategies to improve the efficiency. The efficiency involves spatial competence, proximity proficiency, information and safety effectiveness, multi-modal effectiveness. This study gives the comparative appraisals. By this study, we can get the ranking of the efficient metro stations. When the metro is efficient then more people attract towards this system of transportation. The appeal of transfer might not be a problem if transfer from one mode to another is easy and the metro system deliver access to reach out to most of the public transportation system network. By improved integration of the network, reduced costs of transfers in between modes will lead to increased attractiveness. Ease of travel and security are other aspects that would greatly impact commuters' decisions.

1.3 Objective of the Study:

JMRC has failed to get the targeted ridership in its phase-1 (Mansarovar to Chand pole). Wilbur smith, the consultants who conducted the ridership study, had projected more than 1, 20,000 travellers per day by March 2018. But in today's context, Jaipur metro is far behind in attaining this passenger ridership target. The object of this study is to know the reasons behind the fall of ridership. Some reasons are the higher passenger waiting time, non-availability of feeder to the metro, short distance route, awareness of the metro to the people. This study also gives the travel behaviour of the commuters. The strategies can be building up to increase the ridership of the metro. In this study six metro stations are taken for study. For different parameters, different station will have slack. On the basic of other efficient station, the strategies can be given to make them efficient. The primary objective of the study is measure the efficiency of the Jaipur metro stations at various parameters using the Data Envelopment Analysis (DEA) getting strategies and the planning for make it efficient.

2. Literature Review

Mansha Swami, ManoranjanParida, (2015), studied the Delhi Metro where they assessed the efficiency of its multimodal metropolitan public transportation system. The researchers used a linear optimization technique called Data Envelopment Analysis (DEA), which assess the comparative competences of its various policymaking units also called as decision-making units (DMUs) by using several of inputs and outputs. The researchers studied two networks of Delhi Metro (red and yellow line). Traveller based surveys were done to collect 1328 usable replies with respect to socio-demographic, time spent during commute, and service quality sensitivity factors. The study was further divided into seven network divisions and specific metro stations. Result showed competence marks and ineffectiveness value (slack) for which important approaches were suggested.

Donald et al. (2007), compared the competence of various mass transport sub-parts by assessing

them through DEA. The research provides a technique for evolving a performance index, and demonstrates its procedure with a use on the park-and-ride system of the Chicago transportation department. The recommended procedure used DEA technique to assess the efficiency value for each sub-parts. The study proves how the values can offer objective & effective indicator for all the sub-part's competence, while taking into consideration the important objectives & standards of internal & external stakeholders. The final values can be applied to some extent by a transportation organization to categorise its sub-part's incompetence, and as validated in various similar research works, these facts can be used as the source for modifications that will develop its sub-parts and as overall organisation performance.

Rahul Goel and GeetamTiwari (2016) studied the access, egress and various other travel related parameters of commuters of Delhi Metro and its adjoining regions. In 2011 they conducted an on board investigation of around 1100 metro travellers where passengers were asked on the usage of 7 diverse modes they use for accessing and egressing the metro station. Researchers used multimodal logistics regression techniques to comprehend the aspects related to the decisions made for access-egress modes, and the substitute modes. This study is very useful to know the travel behaviour of the Delhi Metro users.

Caulfield and Bailey (2013) studied the Dublin city rapid transit system by using the Data envelopment analysis to explore and recognise the most proficient transit solution. Owing to Ireland's deteriorating financial condition, the decision of infrastructure asset allocation has become very critical as compared to previous decades and therefore, huge costly ventures like under-ground metro network called Metro North Line were hugely criticised. The key objective of the study was to examine and recognise the most effective transportation solutions for the capital city centre-airport line. DEA was used to recognise the most effective clarification for the Dublin city-centre airport route and to find the causes for ineffectiveness. This study gave insights for implementing DEA in the area of public transit asset allocation study. DEA has also been useful to various other areas of transport study like comparison of different investment and mode options on the route.

In the study undertaken by Barnum, et al. (2007), they observed that technical effectiveness is calculated by the comparing output and input. In public transportation system, various outputs are created by multiple inputs; so many efficiency ranks may develop depending on the precise

output/input ratio selected for investigation. In this study, a procedure is defined for matching the sub-parts efficiency, and validates its use for the park-and-ride lots initiated by the Chicago Transit Authority. These park-and-ride arrangements are tactical constituents of public mass transit structure, where it efficiently extends the service area and also attracts the potential commuters who till now have not the used public transit. One method to increase overall efficiency of the transit system is by improving the effectiveness of each of the public transportation system's sub-parts. Obviously, exploiting sub-parts effectiveness does not essentially get the most out of the overall system competence.

Krygsman and Martin (2003), proposed that access and egress are the profound associates with respect to the mass transit and regulate the accessibility and suitability of public transport. They investigated time of access and egress and the percentage of time to access and egress with respect to total journey time as factors of public transit accessibility and usage. In this study, they defined the interconnectivity ratio. They studied the relation between different accessibility time and egress time and modes for the entire trip time. This study states that both time of access and egress rises with increasing distance, though, the growth is not comparable to haul line time. Thus as a result, interconnectivity ratio drops as trip time increase. For maximum of the multi-modal trips, the interconnectivity ratio lies between 0.2-0.5. The outcome of the research study can be used in preparation of the catchment area of metro stations or bus stops & forecasting diverse mode sets for multi-modal trips.

Eboli and Mazzulla (2009), had considered the satisfaction index of a new customer. According to their conclusions, passengers who experience a good level of service with transit will possibly use transport service more often, while passengers who experience problem with transit may not use it again. To attract the commuters, service quality should be improved. In this study, different parameters responsible for transit service quality are deliberated: service scheduling and consistency, coverage, information, comfort, hygiene, and safety.

VenkateshBhagavath (2009), studied the technical efficiency dimensions of STUs (state transport undertaking) by performing a variable return to scale (VRS) model, where effectiveness marks were calculated for all the units. The research found that out of 44 units only eight were found to be efficient.

3. Jaipur City:

Jaipur, the Pink City, is the capital of Rajasthan India's largest state. As per 2011 census the city has population of more than 30 lacs making it the tenth most populated city in the country. Jaipur city covers an area of more than 400 km^2 hasthe fastest growth in registered vehicles in past decade. Despite being a tier-2 city, the number of vehicles per 1000 people in Jaipur is away above Delhi. The national capital has 332 cars per 1000 persons. Jaipur has 551 cars", report said. JCTSL (Jaipur City Transport Service Limited) has a fleet of 400 low floor buses. Of them 380 are non-AC low floor and 20 are AC low floor. The city also has the biggest fleet of privately owned buses with more than 1000 mini buses and serving more than 10 lakh passengers each year. The city bus transportation system operates more than 1500 bus stops in Jaipur region.

3.1 Jaipur Metro:

Jaipur Metro is presently operational on East-West Corridor which will be from BadiChoupar to Mansarovar. Its approximate length is around 12 km with 9.3 km elevated segment from Mansarover Station to Sindhi Camp Station and 2.789 kms of underground section from Chandpole Station to BadiChoupar Station. The consultant recommended two metro rail corridors for Jaipur. Construction work for Jaipur Metro started during February 2011. Jaipur Metro Rail Corporation consulted their counterparts in Delhi for guidance regarding operation & construction technique. Jaipur Metro became the sixth rapid transit system in India. The first stage of this mass transit project is anticipated to be accomplished by second half of 2018.

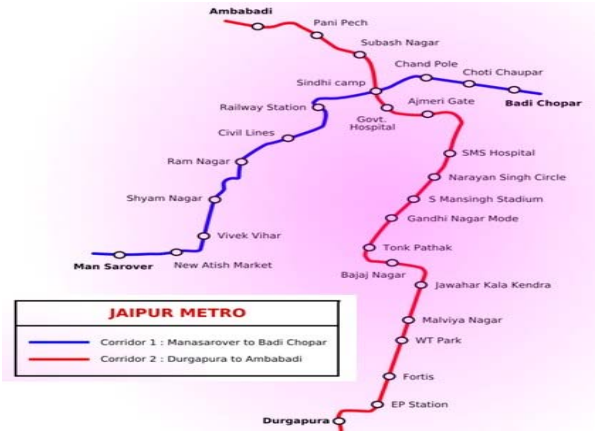

Figure: 1. Route map of Jaipur Metro

Table: 1. Corridor -1 (East West corridor) Metro Stations.

Description	Underground Segment	Elevated Segment	Total
Stage 1 (East-West Corridor) Mansarovar to BadiChoupar	2.789 km	9.278	12.067
No. of Stations – Stage I	3	8	11
Metro stations	BadiChoupar, Choti Choupar, Chandpole.	Sindhi Camp, Railway Station, Civil Lines, Ram Nagar, Shyam Nagar, VivekVihar, New Atish Market, Mansarovar.	11

3.2 DEA (Data Envelopment Analysis) Software:

Data Envelopment Analysis (DEA) is a very dominant facility management, ranking and performance measuring tool initially established by Chames, Cooper and Rhodes (1978) to appraise state and government administrations. A multi-stage DEA model can handle a multitude of inputs and outputs. In this research, numerous inputs were used. The outputs of each of the independent groups were single outputs. The total of inputs varied for each set of intentions. DEA analysis was performed by using output-oriented mode, which emphases on extension of output to attain results. This research work used the concept of constant returns to scale (CRS) where outputs were reviewed in the same proportion to inputs.

In this research work, various infrastructural components of the arrangement were in-changed though the operative factors or the outputs were changed; hence, the CRS is chosen here. DEAP software allowed for creation of inputs and outputs lists for stations of Jaipur Metro in Notepad file and later on it was combined with the model necessities independently in an required file format denoted by '.ins'. The result of the model can be attained in a Notepad file which will be suitably transformed into MS Excel file.

4. Passenger Survey

Passenger survey of Jaipur metro was performed on-board during February-March 2017. The study was done at six metro stations of Phase-I corridor. The survey was carried out at Sindhi Camp, Jaipur Railway Station, Civil lines, Ram Nagar, Shyam Nagar and New Atish Market. It was conducted during 10 PM to 5:30PM, respectively, by six volunteers. The surveyors includes of five males and one female who interviewed metro train commuters randomly, at the platform of metro stations. In survey the inquiry form was designed into three key segments. First segment data was related to socio-economic characteristics (eg: Gender, Age, Occupation, Smart Card Ownership, and Vehicle Ownership). The second section covers the travel habits (eg: Purpose of Travel, Access & Egress Time and Mode, Wait Time). The third part of the questionnaire covers the perception of the commuters about feeder services, security of metro station, information about the metro and passenger satisfaction rate. The total numbers of respondents in the survey were around 1200.

The survey inquiry form comprised of 17 questions, which comprises of question concerning to origin and destination, modes available for access-egress and time, wait time, purpose of travel, auto ownership, occupation, income and time travel by the other mode on the same route.

Table: 2. Categories of Socio-Economic Characteristics, Travel Habits & Suggestions

S. No.	Variable	Categories
1	Gender	1. Male; 2. Female.
2	Age	1. <20; 2. 20-30; 3. 30-40; 4. 40-50; 5. >50.
3	Occupation	1. Private job; 2. Govt. Job; 3. Self-employed; 4. Students; 5. Housewife.
4	Income (Monthly in '000)	1. <20; 2. 20-30; 3. 30-40; 4. 40-50; 5.>50
5	Smart Card	1. Yes; 2. No
6	Ownership of Vehicle	1. 4-W; 2. 2-W; 3. Bicycle.
7	User Frequency	1. Daily; 2. Twice or thrice a week; 3. Weekly, 4. Monthly; 5. Occasionally.
8	Purpose of Travel	1. Work; 2. Social; 3. Leisure; 4. Educational.
9	Perception about choosing Metro except other mode	1. Comfort; 2. Economical; 3. Safety; 4. Time Saving.
10	Access and Egress Time	Numerical (in minutes)
11	Mode of Transport used in access and Egress	1. Car; 2. Bike; 3. E-Rickshaw; 4. Cab; 5. Auto; 6. Walk.
12	Suggestions	1. Increase frequency. 2. Improve Feeder Services to Metro Stations. 3. Increase Route. 4. Extend Operational Hours. 5. Fare Improvement.

5. Definition of Parameters Used in DEA

The factors measured during the DEA study comprised of route features, service characteristic, service consistency, comfort, hygiene, availability of tariff related information, security, commuters' service, employees and environment factor. The descriptions of factors used in the outlining the inputs and their relevant outputs in the research are presented below in table 3.

Table: 3. Definitions of Parameters used in DEA

S. No.	Parameters	Description
1	Total Travel Time	Sum of Access, Egress, Wait Time and Haul Line
2	Travel Time Ratio	Proportion of Sum Total of Time spent in travel by Public Transport wrt Total Travel Time by Private Mode.
3	Interconnectivity Convenience(IC)	OVTT/IVTT (%)
4	Total Transfer Time	Access time + Wait time
5	Total Wait Time	Total Time Passenger has to wait for haul line
6	In Vehicle Travel Time (IVTT)	Total Time spends by passenger in haul line.
7	Out of Vehicle Travel Time (OVTT)	Total time spend outside main line transport. (in other modes)

8	Passenger Waiting Index (PWI)	Passenger Waiting Time/Frequency of Transport Service.
9	Interconnectivity Ratio(IR)	OVTT/Total Trip Travel Time
10	Running index	(IVTT+OVTT)/Total Travel Time. Inverse relation with system efficiency
11	Level of Service(LOS)	OVTT/IVTT
12	Penalty	Waiting time + Transfer time.

5.1 Definitions of Efficiencies

Effectiveness or efficiency of a system is the accomplishment with which an institute uses its resources to create outputs. It can also be defined as the amount by which the observed use of assets can be put to use to produce results of a specified value. It is to be seen that results matches the optimal use of resources to produce a desired level of quality. This can be evaluated in form of technical efficiency. Technical efficiency refers to the physical relation between resources and outcome.

5.1.1 Spatial Efficiency:

It contemplates the level of connectivity in spatial perspective. This parameter determines how efficient a metro station is according to its available space. This set deals with the number of passengers that a station can hold according to its space availability.

5.1.2 Proximity Efficiency

It relates the catchment area in terms of availability of access and egress modes. It deals with how easily feeder services is available to commuters to reach the station it includes fares charged, comfort and the frequency of transport. Less the time taken by the feeder transport more is the proximal efficiency.

5.1.3 Multimodal Efficiency

Multimodal efficiency finds the convenience level of the passengers who are able to switch between different modes of transport. This efficiency reflects connectivity from origin to destination. This is relevant in case of metro transit services because if the system is poor, performance of the system reduces drastically.

5.1.4 Information and Safety Efficiency

This efficiency evaluates facilities and how conveniently a commuter is able to make use of metro services and the amount of safety environment that is maintained by the metro department for *eg*: Installation of cameras, satisfactory checking of all the carriages and special provisions made for women. It also deals

with the easy access to information like announcements of stations, information boards indicating upcoming stations and destinations. This efficiency is equally important as it is equally efficient in saving commuters precious time.

5.2 DEA Result and Interpretations

5.2.1. Spatial Efficiency:

It reflects the connectivity with respect to spatial context. This section evaluates effectiveness in terms of spatial basis. Inputs were calculated from the 1178 response.

Table: 4. Inputs and Outputs Parameters for Evaluating Spatial Efficiency of the Metro Stations

Name of Efficiency	Inputs	Units	Outputs
Spatial Efficiency	Total Travel Time (TTT)	Min	Interconnectivity Convenience
	Passenger's sensitivity score for Access and egress facility.	Index #	
	Feeder availability in the vicinity.	#	
	Travel time Ratio	Ratio	

Table: 5. Summary of the Spatial Efficiency of the Metro Stations

Metro Station	Efficiency Score	Rank	Original value of Output	Projected value of Output	Slack values of Inputs	Projected value of Inputs	Difference between (original – projected)
Sindhi Camp	0.597	6	1.969	3.300	-4.909	35.033	1.331
					0	1.079	
					-1.859	6.590	
					-2.336	6.282	
Railway Station	0.881	3	3.203	3.636	-1.429	38.605	0.433
					0	1.189	
					-1.004	7.262	
					-1.353	6.923	
Civil Lines	1	1	3.442	3.442	0	34.771	0
					0	1.468	

					0	7.745	
					0	7.497	
Ram Nagar	1	2	3.722	3.722	0	39.514	0
					0	1.217	
					0	7.433	
					0	7.086	
Shyam Nagar	0.835	4	2.956	3.722	0	37.175	0.583
					0	1.234	
					-0.304	7.263	
					-0.350	6.949	
New Atish Market	0.651	5	2.193	3.539	-9.917	35.780	1.177
					0	1.102	
					-1.303	6.731	
					-1.264	6.416	

Here Civil Lines and Ram Nagar are the most spatially efficient metro stations. Sindhi camp carries the least rank in terms of spatial efficiency. The causes for poor spatial efficiency of metro stations are following – lack of availability of feeder services, long wait time and low frequency of metro these reasons are responsible for the increase of over-all travel time. Due to the above reasons and short route of metro IVTT is less compared to OVTT which is impeding interconnectivity accessibility and resulting in poor spatial efficiency.

Metro stations resulting in high ranks and efficiency score are the most spatially efficient metro station. These stations have very good feeder services and most of the commuters are accessing the metro station from the radius of one kilometre area. The factors that should be carried out to increase spatial efficiency of metro stations are-

1. Increase the frequency of the metro.
2. Improve the feeder services especially for metro.
3. Increase the route of the metro service.
4. For high ridership stations and at peak times increase the ticket windows for metro.
5. Encourage more usage of smart cards.

Table: 8. Improvement Strategies of Spatial Efficiency of Stations

Metro Station	Comment and Analysis	Improvement Strategies
Sindhi Camp, Railway Station, New	Negative slack value for input 1, 3, 4; i.e. total travel time is more	• To improve the total travel time frequency should be increased so that there is a decrease in wait time.

Atish Market	than desirable for this station.	• TO improve interconnectivity, added feeder services are required.
Shyam Nagar	Negative slack value for input 3, 4.	• Low customer perception score indicates that OVTT is greater than IVTT. So these metro stations require feeder services augmentation. • Access and egress time is more than IVTT which eventually affect travel time ratio. More temporal delay discourages passengers to use metro. • Good integration from near and far areas required to increase the feeder services to metro stations.

Spatial efficiency results shows that there is common concern for access and egress facilities for almost all the metro stations and consequently it reduces the interconnectivity convenience of commuters. For improving the access and egress facility, increasing the frequency and reach of feeder services is urgently required.

5.2.2Proximity Efficiency:

As the name indicates, this efficiency shows the ease of accessibility of each station. There are 9 metro stations on the green line. It compared the stations for accessibility such that each of the stations delivers a desired level of service in their respective catchment area. The output factor is the sum total of time taken by commuters for accessing and egressing the line haul mode. Data collected from the passenger survey are explained as inputs 1, 2, and 3.

Table: 6. Summary of the Proximity Efficiency of the Metro Stations

Name of Efficiency	Inputs	Units	Outputs
Proximity Efficiency	1. Total Transfer Time (TTRT)	Minutes	Access + Egress Time
	2. Total Waiting Time	Minutes	
	3. In-vehicle Travel Time (IVTT)	Minutes	

Table: 7. Summary of the Proximity Efficiency of the Metro Stations

Metro Station	Efficiency Score	Rank	Original value of Out	Projected value of Outp	Slack values of	Projected value of Input	Difference between (origi

			put	**ut**	**Inputs**	**s**	**nal – projected)**
Sindhi Camp	0.820	6	18.342	18.342	0	16.737	4.028
					-0.484	9.072	
					-3.898	8.146	
Railway Station	1	2	22.621	22.621	0	16.925	0
					0	9.174	
					0	8.238	
Civil Lines	1	3	20.717	20.717	0	17.747	0
					0	7.538	
					0	6.515	
Ram Nagar	1	1	23.834	23.834	0	21.883	0
					0	8.000	
					0	7.679	
Shyam Nagar	0.968	4	20.427	20.427	0	17.786	0.674
					0	7.736	
					-1.819	7.191	
New Atish Market	0.931	5	23.866	23.866	0	22.896	1.761
					0	8.862	
					-4.554	8.413	

As shown in table, the most efficient metro station among the 6 stations is Ram Nagar metro station. Result of the overall proximity efficiency test showed the existence of negative slack for many input parameters, signifying that such metro stations could progress their services in appropriate areas.

Table: 8. Improvement Strategies for Proximity Efficiency of Stations

Metro Station	**Comment and Analysis**	**Improvement strategies**
Sindhi Camp	• Efficiency Score = 0.82 • 6th Rank • Negative Slack for Input 2 & Input 3. Reasons for this efficiency are that waiting time & IVTT is more. • Least performance.	• For input 2 (Total Wait Time): improve the frequency & increase the speeds of metro. • IVTT is very less compared to OVTT because distance between metro stations is less. • High Slag Value indicates that increase in the route distance is required.
Shyam Nagar	• Efficiency Score = 0.968 • 4th Rank • Slag Values are observed in	• Here IVTT is more; hence Speed/Frequency is to be increased. • Feeder facility is to be

	input 3 i.e., IVTT.	augmented.
New Atish Market	• Efficiency Score = 0.931 • 5th Rank • Negative Slag is observed in input 3 which is due to IVTT.	• Speed/Frequency is to be increased. • Availability of Feeder facility at RidhiSidhi&Triveni Nagar. • Increase in route, frequency and speed is required.

5.2.3. Multi-modal Efficiency:

It indicates the connectivity of the metro station with other transportation modes; it includes the passenger journey form passenger journey form origin to door of destination. In this calculation, the overall contribution of all the metro stations was considered. The entire data trip of the passenger was considered for the evaluation of the efficiency. The output taken here is the level of service which is observed form the input data. The input was calculated for passenger's time travel data.

Table: 9. Input and Output Parameters for Evaluating for Multimodal Efficiency of Metro Station

Name of Efficiency	Inputs	Units	Outputs
Multi-modal	1. Passenger Waiting Index (PWI)	Nil (Ratio)	Service Level
Efficiency	2. Running Index		
	3. Inter-connectivity Ratio (IR)		

Table: 10. Summary of the Multimodal Efficiency of the Metro Stations

Metro Station	Efficiency Score	Rank	Original value of Output	Projected value of Output	Slack values of Inputs	Projected value of Inputs	Difference between (original – projected)
Sindhi Camp	0.647	6	1.968	3.043	-.201	0.436	1.075
					0	0.583	
					-.109	0.635	
Railway Station	0.904	3	3.203	3.544	0	0.508	0.341
					-0.047	0.679	
					-0.027	0.740	
Civil Lines	0.982	2	3.441	3.505	-0.103	0.502	0.064
					-0.015	0.672	
					0	0.732	
Ram Nagar	1	1	3.721	3.721	0	0.533	0
					0	0.713	
					0	0.777	

Shyam Nagar	0.844	4	2.955	3.502	-0.0133 0 -0.0500	0.502 0.671 0.731	0.547
New Atish Market	0.684	5	2.193	3.204	-0.1311 0 -0.1266	0.459 0.614 0.669	1.011

It compares the performance with the other available modes of urban mass transit system that a commuter uses in course of his/her journey from origin to destination. In the above table, it is shown that the Ram Nagar metro station is technically efficient metro station among all stations. Sindhi camp metro station shows the very poor performance in multimodal efficiency. Ram Nagar metro station is situated near the Sodala. At the Sodala there availability of feeder is good.

Table: 11. Improvement Strategies for Multimodal Efficiency of Stations.

Metro Station	Comment and Analysis	Improvement strategies
Sindhi Camp, Shyam Nagar & New Atish Market	• Efficiency Score = 0.64 • Negative Slack for Input 1 & Input 3. Reasons for this efficiency are that PWI is more & I_R value shows negative slack.	• Frequency should be augmented. • Feeder services should be improved (both in terms of frequency and reach) so that OVTT becomes less than IVTT. • Level of service is also to be improved.
Railway Station	• Efficiency Score = 0.904 • 3rd Rank • A negative slack for input 1, 2. This shows that PWI is more than desired value. • Running Index shows negative slack.	• It affects overall Level of Service. • Improvement in access and egress facilities should improve OVTT value.
Civil Lines	• Efficiency Score = 0.982 • 2nd Rank • Negative Slag is observed for input 1 & 2. • Waiting time & Interconnectivity Ratio are towards lower value.	• Connectivity of feeder needs to be increased. • Frequency of feeder also needs to be increased.

5.2.4. Information and Security Score of Metro Station:

Safety and security information was obtained from individual metro station and was checked with caution. The overall perception score of the metro station was obtained from the individual commuters and result was drawn out using these two sets. The parameters used to evaluate safety information are baggage checked, cameras, guards, information, route map, sign boards, proper announcement on time and fare information which was found to be fine and constant at every metro station. The overall perception of the metro stations includes the cleanliness, seating and other facilities provided to the commuters to the metro services. This efficiency was calculated using excel worksheet. In the survey, most of the commuters have good perceptions about the information and security score. But most of the commuters have a bad perception about the hygiene aspect of the metro.

All the stations have a sufficient number of billboards and signage inside the station premises. Many of the suggestions were in the favour of security services. Each platform has two security guards. Many security standards that are needed to be enforced are:

- Separate compartments should be provided for women.
- At least one female security guard should be provided at every station. Eg. No female security was available at New Atish Market.
- Increase the no. of patrolling duties after increasing the route.
- The information boards should be expanded over the length of the station, to remove confusion among passengers.

6. Scope for Future Study

The survey's results about movement & value of service presented in this study allow finding a set of inferences that can be appropriate for future conclusions, regarding the public transport services in Jaipur.

- In overall, the metro's commuters are satisfied with overall performance of the service. The study observed good satisfaction rates in all aspects measured except the frequency and metro route. It was also emphasized the need of feeder service for first mile connectivity at Sindhi Camp and Railway Station. On the other hand, feeder system has to be enhanced for last mile connectivity at Mansarovar and New Atish Market metro stations. The Jaipur metro route is only 9 km so the trip of haul line is very less

for the passengers compared to OVTT. So, this factor affects the level of service of the metro.

- Station like New Atish market has poor connectivity of feeder services. Some passengers travelling from Triveni Nagar, Nirman Nagar, Shipra path and RidhiSidhi have difficulty in reaching the metro station.
- To increase the feeder connectivity of metro, the route for the specific catchment should be organised and the e-rickshaw feeder services especially for metro should be introduced.
- Mansarovar station shows numerous access and egress distance (or time) related issues. The reason for this is because passengers come from far-off places to avail metro services. This requires an extension of metro line and effective feeder connectivity to regions which are beyond the last stations (Mansarovar & Chandpole) for enhanced connectivity.

7. Conclusion

The result of the proficiency analysis which was performed on spatial characteristic of Jaipur Metro found that combined and specific characteristics of the whole network along with areas which need enhancement in over-all performance. Each of metro station has its individual conventional characteristics and therefore, for each metro station a diverse methodology is desirable to improve their influence on the multi-modal aspect of the mass transit system. The research led to following inferences:

- DEA is an operational instrument to match the comparative competences of all the decision making units (metro stations) by use of various responses and yields to evaluate a multi-modal mass transportation system.
- In addition to providing methodological competences by involving metro stations, DEA study also delivers the desired standards for responses and yields for all other metro stations to attain the corresponding effectiveness of the ideal metro station. Also, its investigation delivers precise slack standards, which help in defining the poor and robust associations amongst the various aspects of metro stations in the whole mass transit system.
- Amongst all the metro stations, Ram Nagar, Civil lines, Railway Stations were the worst performing stations.
- Access and egress facilities appeared to be very poor in terms of availability and accessibility for all the stations in the present research study. More than two-third of the passengers are accessing and egressing by walk. It also affects the ridership of the metro. This is because of meagre accessibility and poor planning of linking transit modes. Planned route

augmentation of feeder connectivity is essential.

- The user profile that dominates is adults most of them access metro by walk and use it for the work based trips. The survey also emphasized the need for strengthening and improving feeder services at some metro stations as 70% of passengers either walk or use public transport to reach metro station.

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