A Methodology for the Performance Evaluation of City Bus Routes of Bhopal City

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Abstract— In most of the developing countries including India, the public transportation system is the primary mode of transportation. Public transport system improves the quality of life by providing safe, efficient, and economic transportation. However, in most of Indian cities performance of service of transport system is rapidly deteriorating because of the increasing travel demand and inadequate public transport system. There are various problems associated with public transport system in these countries such as overcrowding, traffic congestion, higher level of pollution, frequent stopping & starting, inefficient & uneconomic bus routes, irrational location of bus stop, frequency of service & schedule is not strictly adhered. Therefore, there is a need to evaluate the performance of existing city bus routes. In this study, a methodology is proposes for performance evaluation of public transport routes based on the identified performance indicators and this study also develops a hierarchical structure to identify performance indicators for evaluation of city bus routes. Relative weight for the performance indicators is identified on the basis of passenger opinion survey and rating given by them. The four routes of city bus has selected in Bhopal city, for which data have collected. The data collected from user of city bus service like comfort level, safety level, travel cost, travel time, reliability, accessibility etc. these data were analyzed by formulating index for travel cost, travel time, comfort, safety, reliability and accessibility. The outcome of this study is determination of indices for performance of existing city bus routes in Bhopal City.

Key words: City Bus Routes

I. INTRODUCTION

Transport situation in most Indian cities is rapidly deteriorating because of the increasing travel demand and inadequate public transportation system. Indian cities are facing the crisis of urban transport. Despite investment in road infrastructure and plans for land use and transport development, all facing the problem of congestion, traffic accident and air pollution and the problems continue to grow.

The developing countries like India have a great role of public transport in achieving higher growth. The cities of developing countries are also growing rapidly, and population density is increasing rapidly. In absence of effective and efficient public transport system passengers adopt self and private modes which are costly but convenient and reliable as compared to public transport. There are various problems associated with public transport system also in these countries such as overcrowding, traffic congestion, higher level of air and noise pollution, frequent stopping & starting, inefficient & uneconomic bus routes, irrational location of bus stop, less attractive and frequency of service and schedule is not strictly adhered. The shift of passengers to private modes increases the traffic levels, pollution, and fuel consumption to overcome these problems there is sincere need of some strategies which provide operational improvement to public transport system. Therefore, there is a need to improve the performance of existing public transportation system to retain the existing passengers and to discourage the use of private vehicles.

II. LITERATURE REVIEW

The following studies have been made from the literature reviews which are discussed below:

Agarwal et al. (2015) presented a rational methodology for evaluation of the impact of public transit services in a city. This paper indicated that improving the performance of public transit services is very difficult job and it is affected by many factors such as social factors, environmental, economic and political factors. Thus, the overall impact of city public transit service depends upon the four components namely impact on social development, impact on transport system effectiveness, on economic development and impact on quality of environment. These components were further decomposed to identify the 18 performance indicators. City public transit service index (CPSI) was developed by multiplication of relative weight with the indices of performance indicators which may be used to indicate the overall impact of public transport service in a city. It has also presented analysis and results for evaluating the impact of three public transit services i.e. City Bus service, mini bus service and magic service in Bhopal city.

Gupta et al. (2015) indicated that there is need to develop a comprehensive methodology which can evaluate the comparative performance of public transport system. The major reasons for evaluating the comparative performance of public transport system are to control operating and travelling cost, impact of systems in a city and justify the alteration in system before its implementation in a city. In this study, 14 different comparative performance indicators have been identified for the performance evaluation of public transport system. Further, condition indices have been developed for each of these comparative performance indicators individually. Later, relative weight of performance indices has been determined using an expert opinion survey and finally an overall comparative performance index has been developed considering the relative weights of the performance indicators. The approach proposed in this study was also illustrated using a comparative performance evaluation of BRTS system with mini bus service in Bhopal city.

Kanuganti S. et al (2013) Quality plays an important role in the market-oriented economy and the success of any transit system depends upon its quality of service. Since, the demand for transit is quite high in comparison with the supply in most of the Indian cities; quite often the level of service is

not given a priority by the service providers. However, to improve the quality of service, it is necessary to identify the parameters to be considered important by the commuters for knowing their satisfaction levels for the present service. This literature is focused on the results based on the observations made through reveled preference (RP) survey to evaluate the quality of service. The model uses various Multi criteria decision making tools such as Numerical rating approach; Fuzzy set approach, Analytic Hierarchy Process (AHP) and AHP Fuzzy. The results from different approaches are compared and justified for their appropriate use.

Jaiswal et al. (2012) assessed the public transport demand for Bhopal and identified the major factors for poor ridership. This study also estimated the probability that how much personal vehicle users are willing to shift towards public transport due to the increase in its level of service also identified the way to account for qualitative factors in the public transport project evaluation by adjusting travel time values to reflect comfort and convenience. For the better understanding of the travel behavior that affect the demand and trip generation some parameters were selected like trip length, comfort, level of service, travel cost and travel time. This study presents the impact of BRT System on Ahmadabad's transport sector and the changes that can be brought about by introduction of BRT System in other cities. They found that BRTS Ahmadabad has improved access for local riders and advanced public transportation systems while reducing the environmental impacts of transportation.

Mahmoud et al. (2011) have developed a methodological framework for the monitoring of bus service in the context of UK. The framework consists of traditional quality parameters (subjective parameters) and system performance parameters (objective parameters). The paper consists of two main sections, where first section investigated about the bus service quality concept related to user's behavior and the second part presented the framework for quality monitoring. This framework contained three combined models for integrated measurement of bus service quality including service quality, satisfaction and behavioral intention. This study concluded that the selection of appropriate indicators for performance evaluation of public transport system is a complicated task due to a variety of performance indicators are presented in the literature and the variation in description of different performance indicators.

Ali Zalina Mohd (2009)A study survey was carried out to investigate customer satisfaction level towards the public transportation services provided by Consortium Express Bus Company in Malaysia. 200 respondents consisting of 65 men and 135 women participated in the study survey. The survey was conducted in three bus stations in Kuala Lumpur and Selangor areas, namely Pudu Bus Station, Kajang Bus Station, and Putra Bus Station. Importance-Performance Analysis was used to identify customer perceived factors that needed to be prioritized for improvement. From this analysis, drivers and counter staffs were categorized as factors which needed to be given consideration. Customers were satisfied with the comfort, security, and ticket prices; thus, the kind of services given must be maintained. Customer Satisfaction Index was used to analyze customer satisfaction level and was found to be 64.1%.

A critical review of the literature indicated that there is a need to develop a methodology which can evaluate the performance of bus routes for Indian cities in comprehensive manner.Though the public transport sector has a major impact on the society and emerged as one of the important service providers, the literature shows that not enough research has been carried out. The models using algorithms and simulation have been employed for network design and evaluation of bus routes. Not many studies are reported in India on the study of bus routes and performance evaluation.The methodologies available may not be favourable due to absence of data base or incomplete data base or data is available but not in a comprehensive way.

III. METHODOLOGY

The methodological framework comprises four major stages for performance evaluation of City Bus Routes is as follows:

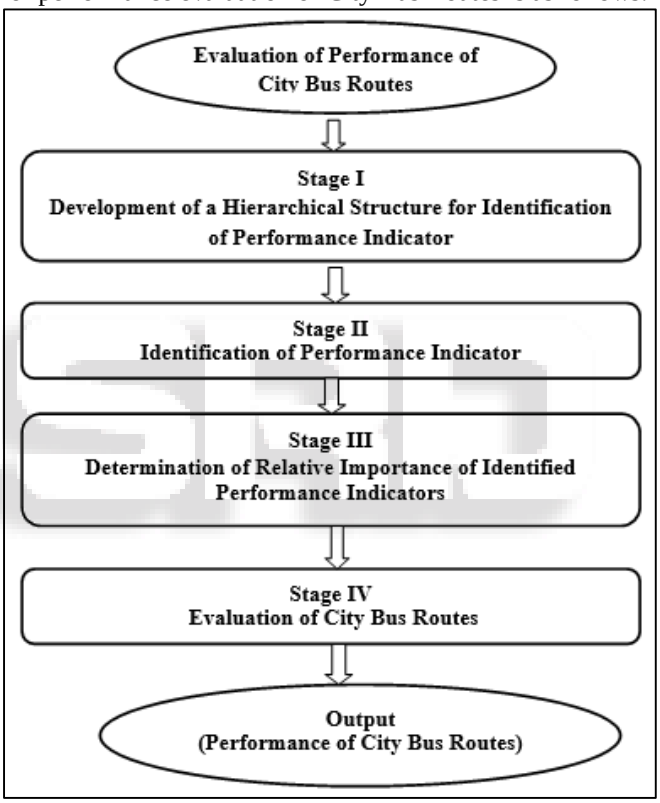


Fig. 1: A Framework of Proposed Methodology for Evaluation of Performance of City Bus Routes

A. Stage I: Development of a Hierarchical Structure for Identification of Performance Indicator

The first stage of this proposed methodology is to develop a hierarchical structure for identification of performance indicator. A hierarchical structure has been developed according to the conditions of the Indian public transport system. The hierarchical structure consists of six main criteria and nine sub-criteria. The major criteria selected for public transport route evaluation are total travel time, comfort, safety and security, accessibility, reliability and user cost of city bus routes.

B. Stage II: Identification of Performance Indicator

Performance Indicators are management tool which gives a clear indication of how well it is providing transit services so

that the selection of performance indicators is a very important task.

C. Stage III: Determination of Relative Importance of Identified performance Indicators

The performance indicators may not equally affect the performance of city bus routes. A system of weights therefore needs to be introduced to reflect the contribution to performance of city bus routes. The relative weights of the Performance factors are determined using passenger's opinion survey and the rating given by them.

D. Stage IV: Evaluation of City Bus Routes

The purpose of this stage is to develop a rational methodology of performance indices for each of the identified parameter for evaluation of city bus routes.Table 1 presents a methodology of formulation index for evaluating the performance of city bus routes.

Sr. No	Notation	Performance Indicators	Methodology for evaluating performance of city bus routes
1	OP_1	Total Travel Time Index (TTI)	TTI= TTC/ TTB TTC= Travel Time of Car = WTS + TTM TTB= Travel Time of Bus = WTS + TTM WTS= Waiting Time at Stop WTM= Travel Time inside Mode
		Waiting Time at Stop (WTS)	WTS = 60 / TNB TNB=Total No. of Transit
		Travel Time inside Mode (TTM)	TTM= TRL/ASP TRL = Total Route Length ASP = Average Speedof Transit
2	OP_2	Comfort Index (CFI)	CFI = W_{21}* CSI + W_{22}* CTI W_{21} = Relative weight of Comfort at Stop $W_{22=\text{ Relative}}$ weight of Comfort during journey CSI = Comfort at Passenger Stop index CTI = Comfort during Journey index
	OP_{21}	Comfort at Passenger Stop (CSI)	CSI = $\frac{(5*N1+4*N2+3*N3+4*N2+1*N5)}{(N1+N2+N3+N4+N5)*5}$ N_1= No of Passenger rated Extremely Important (5) N_2= No. of Passenger rated Very Important (4) N_3= No. of Passenger rated Important (3) N_4 = No. of Passenger rated Important to some Extent (2) N_5= No. of Passenger rated Not at all Important (1)
	OP_{22}	Comfort during Journey (CJI)	CJI = $\frac{(5*N1+4*N2+3*N3+4*N2+1*N5)}{(N1+N2+N3+N4+N5)*5}$ N_1= No of Passenger rated Extremely Important (5) N_2= No. of Passenger rated Very Important (4) N_3= No. of Passenger rated Important (3) N_4 = No. of Passenger rated Important to some Extent (2) N_5= No. of Passenger rated Not at all Important (1)
3	OP_3	Safety and Security (SSI)	SSI = W_{31} * SBI + W_{32} * RSI + W_{33} * SNI W_{31} = Relative weight of Safety at Stop W_{32} = Relative weight of Route Safety W_{33}= Relative weight of Route Safety SBI = Safety index at bus stop during boarding & alighting RSI = Route Safety Index SNI = Safety and Security index at bus stop at night
	OP_{31}	Safety at bus stop during boarding & alighting (SBI)	SBI= $\frac{(5*N1+4*N2+3*N3+4*N2+1*N5)}{(N1+N2+N3+N4+N5)*5}$ N_1= No of Passenger rated Extremely Important (5) N_2= No. of Passenger rated Very Important (4) N_3= No. of Passenger rated Important (3) N_4 = No. of Passenger rated Important to some Extent (2) N_5= No. of Passenger rated Not at all Important (1)
	OP_{32}	Route Safety (RSI)	RSI = TNA/CP TNA = Total Number of Accidents CP = City population in Lakhs

	OP_{33}	Safety and Security at bus stops at night (SNI)	$SNI = \frac{(5*N1+4*N2+3*N3+4*N2+1*N5)}{(N1+N2+N3+N4+N5)*5}$ N_1= No of Passenger rated Extremely Important (5) N_2= No. of Passenger rated Very Important (4) N_3= No. of Passenger rated Important (3) N_4 = No. of Passenger rated Important to some Extent (2) N_5 = No. of Passenger rated Not at all Important (1)
4	OP_4	Accessibility index(ASI)	ASI = 1/ ADP ADP = Avg. distance to the Nearest Passenger Stop
5	OP_5	Reliability Index (RBI)	RBI = NTT/ TNT NTT = Numbers of trips on time TNT = Total numbers of trips
6	OP_6	User Cost Index (UCI)	UCI =1- (UCB/ UCC) UCB = user cost of bus/ km = CS + CJ UCC = User cost of Car/ km = CC + CJ
	OP_{61}	Cost at stop (CS)	CS = PC/ TRL PC = Parking cost TRL = Total Route Length
	OP_{62}	Cost during journey (CJ)	CJ = TC/ TRL TC = Travel cost TRL = Total Route length

Table 1: Methodology for Evaluating the Performance of City Bus Routes

Further an overall performance index is also developed for evaluating the overall performance of city bus routes. Equation 1 presents the overall performance index for evaluating the overall performance of city bus routes.

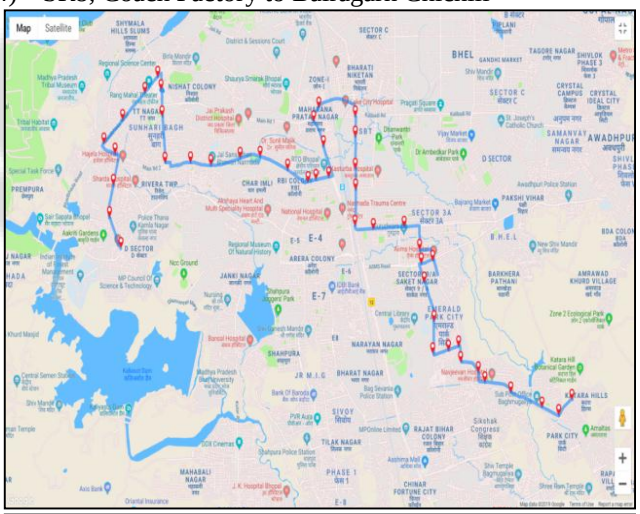
OPI = W1 * TTI + W2 * CFI + W3 * SSI + W4 * ASI + W5 * RBI + W6 * UCI Equation (1)

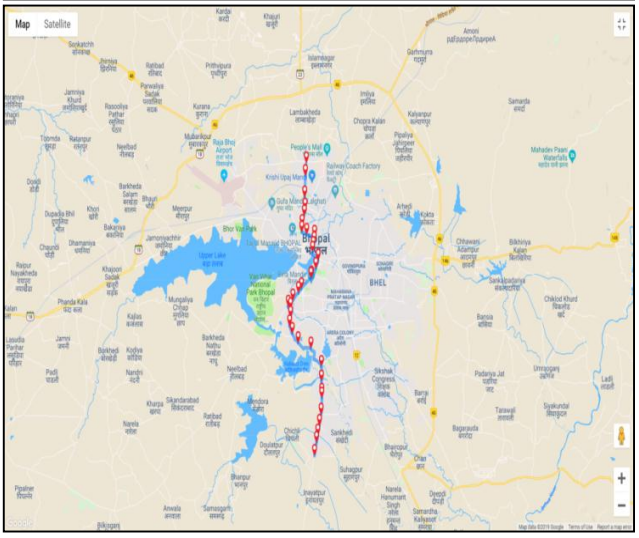
Where;
W1= Relative weight of Total Travel Time
TTI = Total Travel Time Index
W2 = Relative weight of Comfort
CFI = Comfort Index
W3 = Relative weight of Safety and Security
SSI = Safety and Security Index
W4 = Relative weight of Accessibility
ASI = Accessibility Index
W5 = Relative weight of Reliability
RBI = Reliability Index
W6 = Relative weight of User cost
UCI =User cost Index

IV. STUDY AREA & DATA COLLECTION

The data is collected for all four routes selected for analysis. Four routes of city bus service have been selected for service connecting different important areas of Bhopal City. The data has been collected by survey conducted during peak hours. A team of four members is required to collect data first member note down the waiting time, boarding and alighting time, the second members note down the number of passengers boarding and alighting at each bus stop. The third and fourth members were engaged in collecting data from passengers about safety level, comfort level, service level. The information about number of trips per day, travel cost is collected by conductors. The selected city bus routes are:

1) SR2, Nehru Nagar to Katarahills
2) SR4, Karond Chouraha to Bairagarh Chinchli
3) SR5, Chirayu Hospital to Awadhpuri
4) SR8, Coach Factory to Bairagarh Chichili





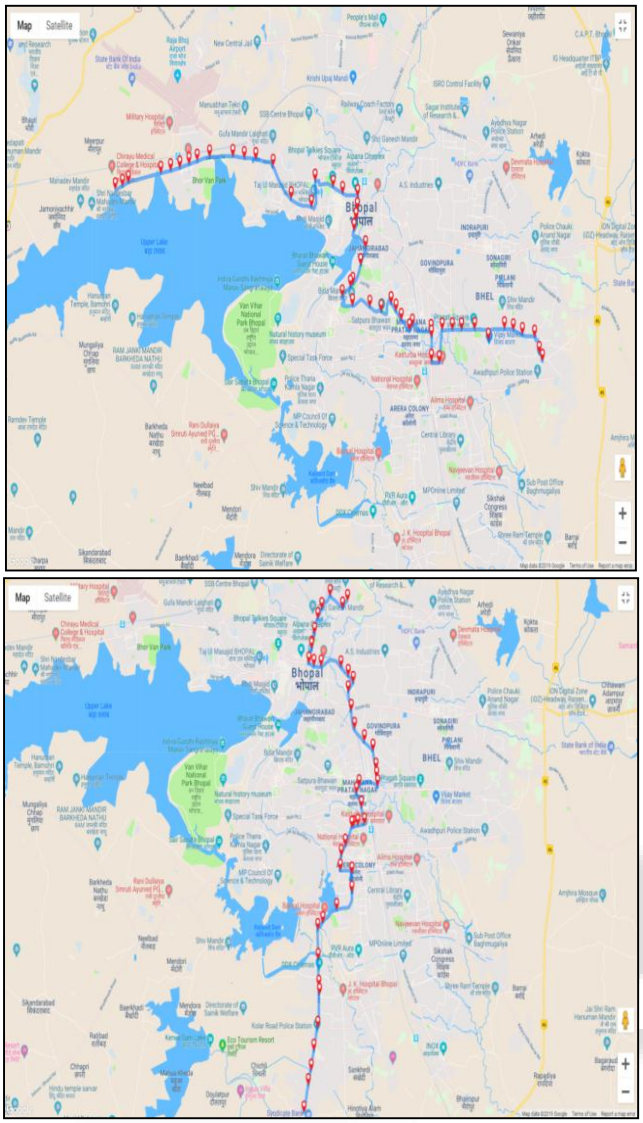


Fig. 1: Map of Bhopal selected City Bus Route SR-2, SR-4, SR-5 & SR-8 (Source: Google Maps 2019)

V. Analysis & Result

This section represents the analysis and results of performance of different city bus routes by analyzing the travel time, comfort, safety and security, accessibility, reliability, and user cost on selected four routes i.e. SR2, SR4, SR5 and SR8 in Bhopal city. Further these parameters are evaluated considering their performance indices and relative importance. Fig. 2 shows the performance index value of the respected performance indicators of city bus system which clearly indicates performance of selected city bus route.

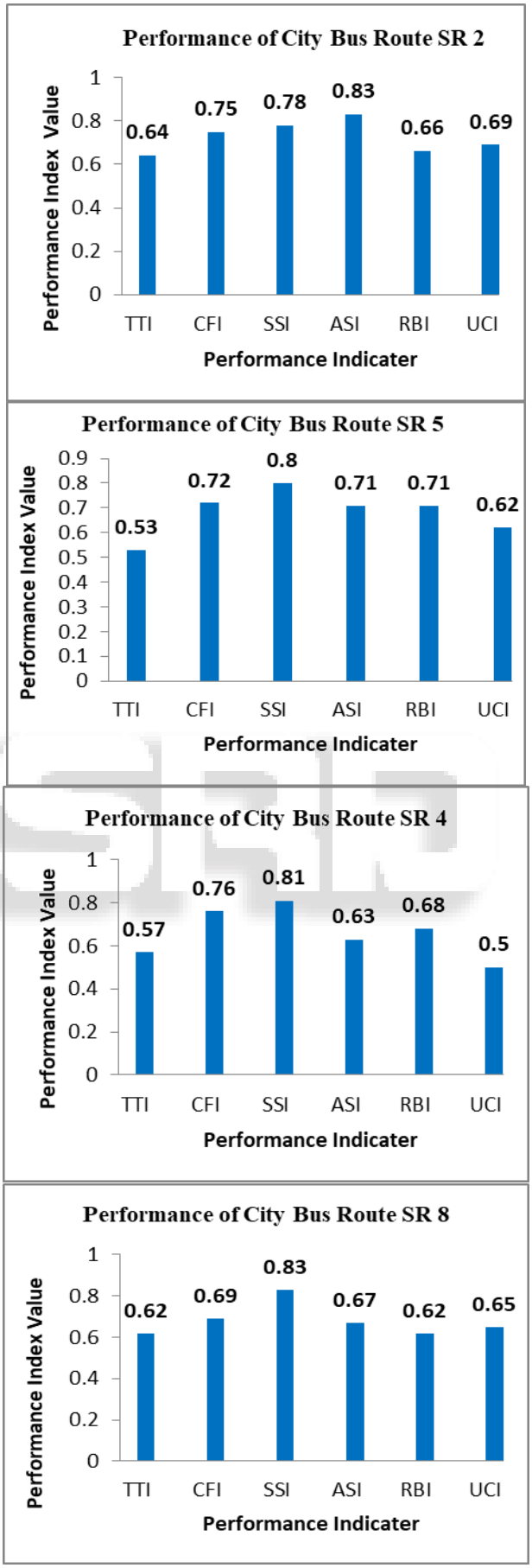
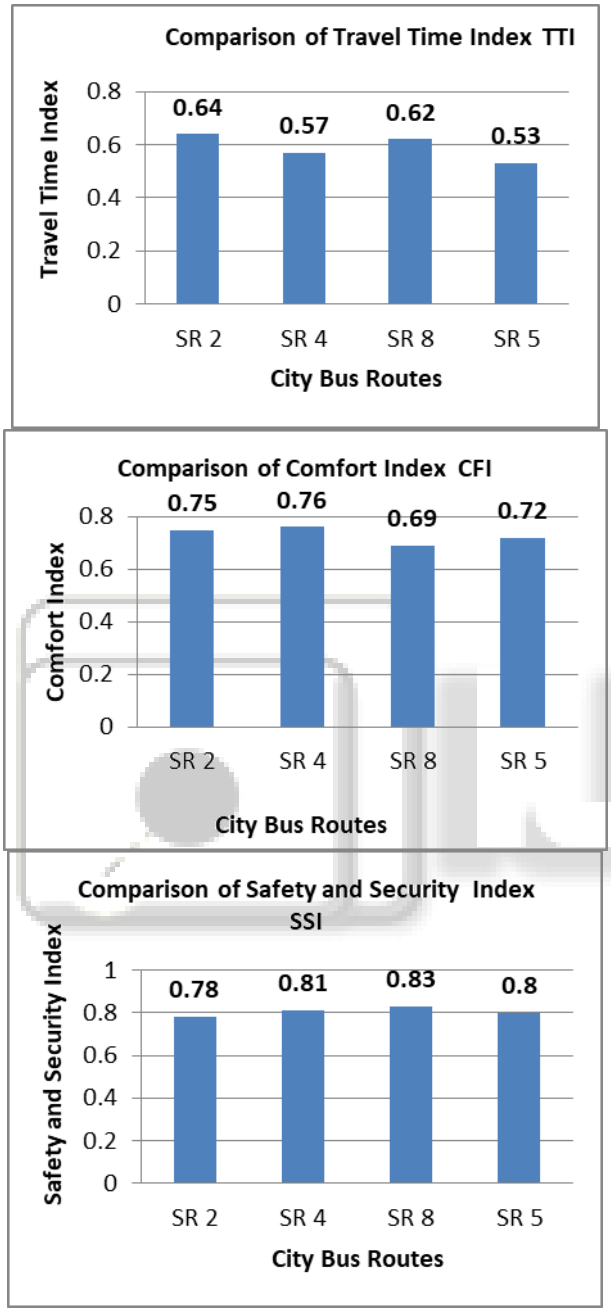


Fig. 2: Results of Evaluation of City Bus Routes i.e.SR 2, SR4, SR5 and SR8

Comparative analysis is done for each identified parameter travel time, comfort, safety and security, accessibility, reliability, user cost on different routes for identification of better performance on identified routes. Fig. 3 represent the comparative analysis of different performance index on selected routes.



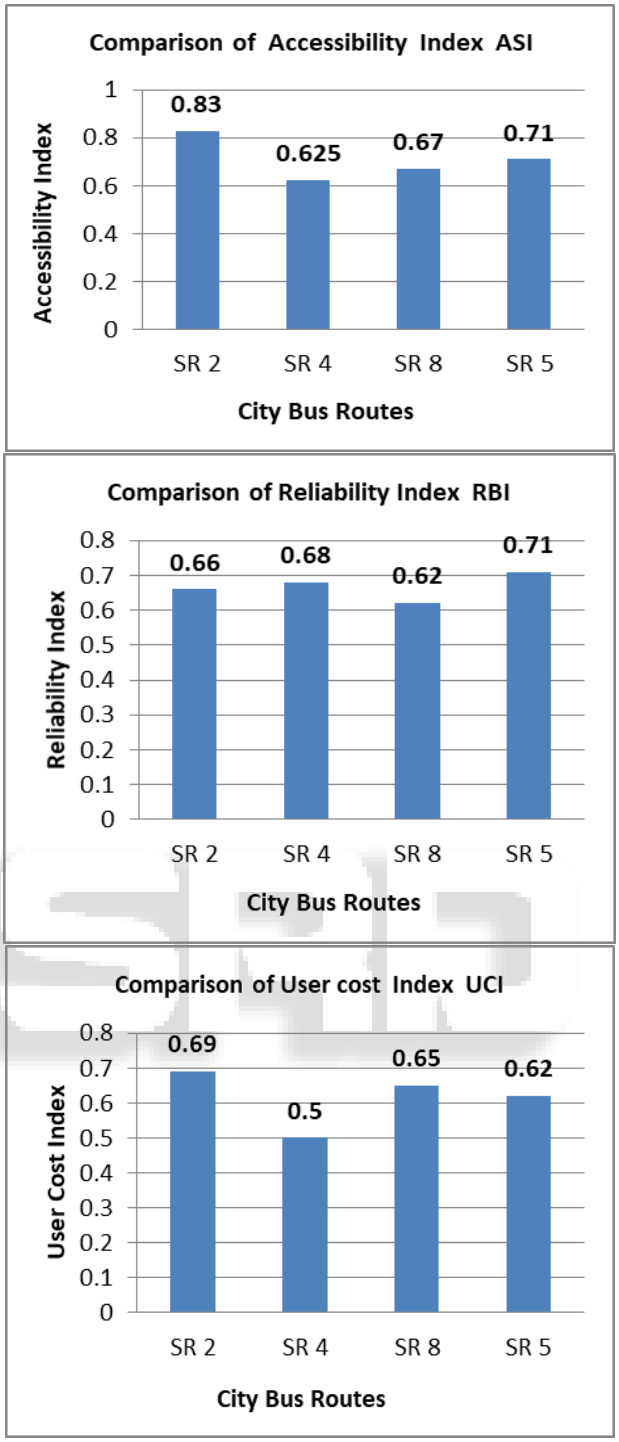


Fig. 3: Comparison of Different Performance Index on Selected City Bus Routes

The analysis of all identified routes has been carried out and the performance of routes is varying with each performance indicator. Fig. 4 represents the overall performance of identified city bus routes.

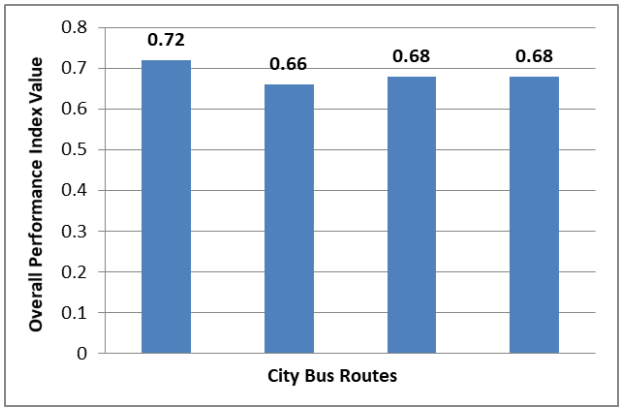


Fig. 4: Results of Overall Performance Index on City Bus Routes

VI. CONCLUSIONS

Some of the important conclusions drawn from the present study are:

- Travel time index values for respective routes are as SR 2, SR 4, SR5, SR8 are 0.64, 0.57, 0.53 and 0.62 respectively. Route SR 5 shows poor service than other routes i.e. 0.53 because route has total 26 no. of stop but during journey bus takes total 35 no. of stoppages.
- Comfort index values for respective routes are as SR 2, SR 4, SR5, SR8 are 0.75, 0.76, 0.72, and 0.69 respectively. Route SR 8 shows poor service than other routes i.e. 0.69 because route has total 18 no. of curves which affects the comfort level of the route.
- Safety and security index values for respective routes are as SR 2, SR 4, SR5, SR8 are 0.78, 0.81, 0.80 and 0.83. Route SR 2 shows poor service than other routes i.e. 0.78
- Accessibility index values for respective routes are as SR 2, SR 4, SR5, SR8 are 0.83, 0.63, 0.71 and 0.67. Route SR 4 shows poor service than other routes i.e. 0.63 because route has irrational location of bus stop with more walking distance.
- Reliability index values for respective routes are as SR 2, SR 4, SR5, SR8 are 0.66, 0.68, 0.71 and 0.62. Route SR 8 shows poor service than other routes i.e. 0.62 because route has 30 trips/day out of which only 39 trips are on time which affects service reliability.
- User cost index values for respective routes are as SR 2, SR 4, SR5, SR8 are 0.69, 0.50, 0.62 and 0.65. Route SR 5 shows poor service than other routes i.e. 0.62
- The overall Performance of identified City Bus Route is as SR 2 – 0.72, SR 4 – 0.66, SR 5 – 0.68, SR 8 – 0.68.

The overall performance of city bus route SR 4 is poor than other identified routes. Route SR 4 has 26 number of stop but during journey bus takes total 35 number of stoppages, there are total 15 numbers of intersections out of which 7 intersections has signals. There are total 19 numbers of curves which affect travel time, comfort, safety and security and reliability of service. Route SR 4 has 16 numbers of speed breakers and 9 numbers of congested areas. The performance of route SR 4 is affected by more numbers of stoppages, large numbers of curves, speed breakers and intersections. So, the overall performance of SR 4 route is poor than other city bus routes.

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