Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 00 (2018) 000–000

Transportation Research Procedia

www.elsevier.com/locate/procedia

World Conference on Transport Research - WCTR 2019 Mumbai 26-31 May 2019

Comparative Performance Evaluation of Public Transport Services from City Perspective

Jitendra Gurjar[a], P.K. Jain[b] P.K. Agarwal[c],

[a]*Ph.D Scholars (Part Time), Department of Civil Engineering, Maulana Azad National Institute of Technology, Bhopal, 462003,India*
[a]*Assistant Professor, Department of Civil Engineering, Government Engineering College, Rewa, 486001,India*
[b]*Professor, Department of Civil Engineering, Maulana Azad National Institute of Technology, Bhopal, 462003,India*
[c]*Professor, Department of Civil Engineering, Maulana Azad National Institute of Technology, Bhopal, 462003,India*

Abstract

Now a day's public transport services encounter distinctive challenges in planning, maintaining and operating their services from user, operator and city perspective. Further, the alteration in transport technologies and infrastructure facilities requires a huge amount of funds. Hence prior to making investment in, public transport services the performance of existing service should be evaluated from different perspective i.e. user, city and operator. In this research particular attention has been given to the city perspective. It is concerned with the traffic flow pattern, social and economical development and reduction in environmental pollution in a city. A literature review indicated that most of the studies are not structured in a simple manner and cannot find significant comparative information which helps in diagnosing problems in relation to different aspects from city perspective. Therefore, in this study a simple methodology is developed for comparative performance evaluation of public transport service considering these aspects individually as well as combined. In order to demonstrate the application of the proposed methodology; BCLL bus system and Mini bus system in Bhopal city were selected. It is expected that this study will be useful to take appropriate decisions before implementation of new services, and performance improvement of existing public transport services.

Peer-review under responsibility of WORLD CONFERENCE ON TRANSPORT RESEARCH SOCIETY.

Keywords: Public transport service; Comparative performance evaluation; City perspective; Performance indicators; performance indices etc.

1. Introduction

Most of the population of world's lives in cities that act as centers of economic growth and productivity [Alonso et al., (2015)]. Public transport services provide a modern image of the city among other benefits like fast, regular, safe and comfortable services to the users. Therefore, there is a continued need to improve the performance of public transport services. However, the performance improvement of public transport system is a complicated process because it can be viewed through three different perspectives i.e. user, city and operator perspectives. The requirement of these three perspectives may be different or may affect each other. For instance user perspective is to have least travel cost, while operator perspective is to minimize expenses and maximize profit while city perspective

Corresponding author .Tel. +91-8989716185
E-mail address: jiten.manit@gmail.com

2352-1465
Peer-review under responsibility of WORLD CONFERENCE ON TRANSPORT RESEARCH SOCIETY

may be entirely different. City perspective reflects the impact of public transport service in a city which is concerned with the traffic flow pattern, social development, economical development and reduction in environmental pollution in the city. Some authors consider city perspective is helpful for development of sustainable transportation system [Alonso et al, (2015) Ramani et al. (2013), Black et al., (2012)]. While [Litman, (2007)] considered city perspective as decision-making tools which should reflect economic, social and environmental impacts of public transport service in a city. Consequently, the government has now realized the need for 100 smart cities in India in urban areas [MoUD, Draft report, 2016]. The public transport service develops in the wrong direction in these city can cause social inequalities; irreversibly harm the environment and huge economic loss. The requirements of satisfaction of a smart city for effective traffic operations are presented in Table 1.

Table 1: Requirements of City's Satisfaction from a Public Transport Service

S. No	City Requirement	Basic Requirements of Public transport service from City Perspective
1	Improved Travel Flow	• To integrate the various public transit system in terms of operational, physical and Institutional system. • To cover as much as possible areas of the city. • To serve more number of passengers transfer from origin to destination • To travel freely in the vehicle without congestion.
2	Reduced Environmental Emissions	• No adverse impact on city environment • No adverse impact on city due to noise generation. • To promote clean energy efficient vehicle and clean fuel technologies.
3	Improved Economic Benefits	• To support the new public transport projects that increase property values in the city. • To develop more employment in the city • To support local industries for development of economy.

Further, now a day, the percentage of the public transport service, particularly the bus service, is decreasing over the past few years in Indian cities. The expected decrease in the public transport share from year 2007 to 2031 in the cities of different categories is shown in Figure 1.

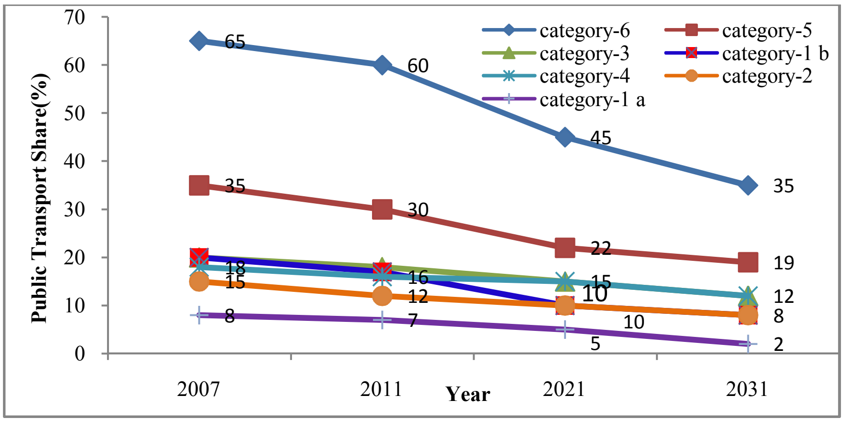

Figure 1: Expected decline in public transport share in the Indian cities [*Source: Wilbur Smith Associates, (2008)*]

As a result, public transport service faces multiple challenges such as higher travel cost, severe traffic congestions, fuel resource depletion, environmental degradation and diminishing revenues. It clearly indicates that if the same situation prevails then transport and environment related problems in Indian cities would rise greatly in future. Hence, the approximate investment of Rs 4, 35,380 Crore Rs is required in transport facilities for the next 20 years in Indian cities to enable efficient traffic operations and prevent a decline in the use of public transport services. The required transport investments are presented in Table 2.

Table 2: Required investment in transport infrastructure in Indian cities for next 20 years

S. No.	Category of City	Required Investment (Crore)	Total investment (Crore)
1	Cities population <5 lakhs	9800/-	**4,35,380/-**
2	Cities population 5-10 lakhs	70700/-	
3	Cities population 10-40 lakhs	137680/-	
4	Cities population >40 lakhs	217200/-	

[*Source: Wilbur Smith Associates, (2008)*] It is believed that more investment in transport technologies and infrastructures facilities improves its performance but it is not completely true [Cascajo (2004), Gurjar et al., (2015)]. This is mainly due to the fact that most of the cities simply select inappropriate public transport services that are either based on developed country models. Kanuganti et al. (2013), Das and Pandit (2013), and Roux Y. (2012) argued that developing countries like India have completely different demographic, political, economic, and social conditions as compared to developed countries. The transport problems are remaining enormous because the improvements have been made based on developed countries in public transport services. Hence, for a given city, before coming to some conclusion, it should be examined, why the existing system is deteriorating or what are the deficiencies in implementing the corrective measures for improving its performance [Gurjar et al (2015)]. Thus, the specific needs of Indian cities should be considered as opposed to simply adopting the model used by developed countries. Hence, in this research particular attention has been given to development of a simple methodology for comparative performance evaluation of public transport services from city perspective in Indian context. The developed methodology comprises four stages. A hierarchical structural is developed in stage-I, for identification of most important performance indicators relevant to the city perspective. In sub stage II comparative performance indices are developed. The relative weights of identified performance indicators are determined in sub stage III. The overall city comparative performance is determined in sub stage IV. In order to demonstrate the application of the proposed methodology; BCLL bus system and Mini bus system in Bhopal city were selected. The relevant data was collected by performing field survey, literature, opinion of the experts and from the offices of the concerned bus systems and authorities.

2. Literature review

The previous methodologies are based on some performance indicators. Hence the literature review was mainly conducted on those methodologies which are based on performance indicators. It is observed that most of the researcher [Alonso et al., (2015), Ramani et al., (2013), Black et al., (2012), Litman (2007)] considered economic, social and environmental related performance indicators for development of sustainable transport system which are reflected to city perspective. Most of the researchers [Dodson et al., (2011), TRB (2010, 2003)] discussed that public transport service benefits the whole community or a city when it can contribute to social cohesion, reduction of air pollution, provide mobility to people without access to private automobile, reduction of traffic congestion, and job accessibility. The important performance indicators that are used worldwide for evaluating the performance of public transport services from city perspective are summarized in Table 3.

Table 3: Reviews on important performance indicators used in worldwide

S. No	Performance Indicator	Studies Carried Out in Indian Context	Studies Carried in other Parts of the World
1	Mobility/ Congestion	Agarwal et al., (2015), Gandhi et al., (2013), Wilbur Smith Associates (2008)	Niyosenga (2012), Pticina (2011), TRB (2010,2003), Abreha (2007), Bhat et al., (2005), Sheth (2003),
2	Service Availability	Agarwal et al., (2015), DULT, (2013), MoUD (2009), Wilbur Smith Associates, (2008)	TRB (2010, 2003), Filipovic (2009)
3	Service Coverage	Agarwal et al., (2015,), Shukla(2012), DULT (2013), MoUD (2009)	Alonso et al., (2015), TRB (2010, 2003)
4	Crime Rate	Agarwal et al., (2015)	Kittelson and Associates (2010, 2003), Aidoo et al., (2013)
5	Air Quality	Agarwal et al., (2015), DULT (2013), MoUD (2009),	Alonso et al., (2015), Cascajo (2014), TRB (2010, 2003), Jakimavicius (2008), Litman (2007), Sheth (2003)
6	Noise Quality	Agarwal et al., (2015), MoUD (2009)	Cascajo (2014), TRB (2010, 2003), Jakimavicius (2008), Sheth (2003)
7	Water Quality	Agarwal et al., (2015)	TRB (2010, 2003), Jakimavicius (2008), Litman (2007)
8	Property Value	Agarwal et al., (2015)	TRB (2010, 2003)
9	Employment Generation	Agarwal et al., (2015)	Cascajo, (2014), TRB (2010, 2003), Iseki et al., (2007)
10	Fuel Consumption / Energy Consumption	Agarwal et al., (2015)	Alonso et al., (2015), TRB (2010, 2003), Feng and Hsieh (2009),
11	Service Equity	Agarwal et al., (2015)	Cascajo (2014), TRB (2010, 2003), Jakimavicius (2008), Abreha (2007)
12	Service Cohesion / Community Cohesion	Agarwal et al., (2015)	TRB (2010, 2003), Jakimavicius (2008), Litman (2007), Abreha (2007)

Further, most of the research studies developed simple performance indices but which are often relatively much more complicated due to non availability of data base or the process of data collection is more time consuming or difficult or expensive in Indian context. Some examples are Agarwal et al (2015) considered crime rate which is evaluated by the ratio of number of crimes in the public transit service and total crime in the city but both data are difficult to measure in Indian context. Similarly, for evaluation of service cohesion and service equity the data required are no. of low income household areas and key amenities are connected to public transit service is not available easily [Agarwal et al (2015)]. Alonso et al (2015) considered for evaluation of public transport service from environmental aspects by energy consumption per user and annual energy consumption by rail modes and buses both are difficult to obtain. The data such as accident costs per year and percentage of persons that are less affected by noise required are difficult to obtain in Indian context for evaluation of condition of safety improvement and noise respectively [Cascajo (2014)]. Further, most of the studies [Agarwal (2015), Alonso et al., (2015), DULT (2013), Gandhi et al., (2013), Ramani et al., (2009)] considered equal weights of key indicators for assessment of public transport services from city perspective. In summary, there are very few studies are available for overall comparative performance evaluation of public transport services from city perspective in Indian context. However, there is an absence of comprehensive methodology which can evaluate overall comparative performance of public transport service under city aspects.

3. Research Methodology

The different stages are step wise combined and to develop the proposed methodology which can evaluate the comparative performance of alternate public transport systems from city perspective in Indian context. Hence, the framework is helpful to explain the proposed methodology briefly as well as sequentially. The details of stages are presented in subsection of this section. A basic framework of proposed methodology is presented in Figure 2.

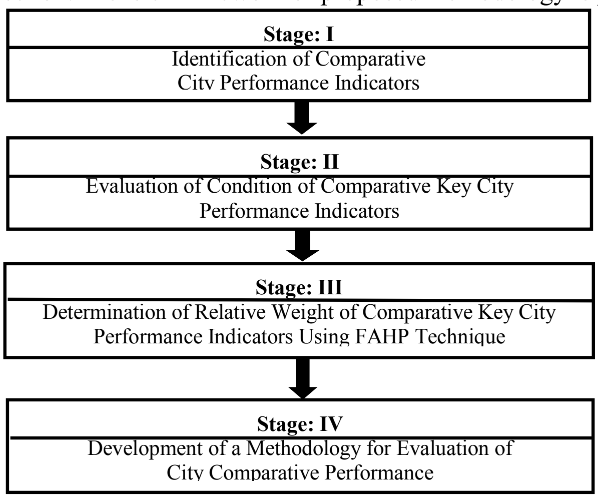

Figure 2: Framework of proposed methodology for comparative performance evaluation from city perspective

3.1 Stage-I: Identification of Comparative Key City Performance Indicators

The purpose of the Stage-I is to identify the most appropriate comparative key city performance indicators which are affecting the performance of public transport service. The classification of performance indicators from city perspective is a complicated task because many indicators are available in literature and there is no comprehensive classification. The selection of inappropriate performance indicators gives inadequate or wrong information about the public transport system, results in enormous amount of capital is used for implementation of new public transport services in a city. Therefore, the performance indicators are identified in such a manner that it includes all critical aspects that affect the performance of public transport services from city perspective. Total eight city performance indicators are preliminary identified logically on the basis of literature review and presented in Table 4.

Table 4 Preliminary selection of performance indicators from city perspective

S. No.	Performance Indicators based on literature review	Performance Indicators Considered in this study (Preliminary)
1	Traffic Congestion Mobility	Comparative City Mobility
2	Service Coverage	Comparative City Coverage
3	Total Ridership	Comparative Transport Capacity
4	Service Equity	Comparative Service Equity
5	Environmental emission	Comparative Air Quality
6	Noise Emission	Comparative Noise Quality
7	Property Value/Land development	Comparative Economic Activity
8	Employment Generation	Comparative City Employment

A questionnaire based survey was conducted to identification of importance level of comparative city performance indicators. The questionnaire survey form was structured into two sub sections from A-1 to A-2. The sub section A-1 are provided detail guideline for filling the questionnaire survey form. The sub section A-2 was to collect importance level of comparative city performance indicators rated by passengers, transport experts and academician. Total 286 response are collected i.e. more than 15 times the indicators according to thumb rule for factor analysis using SPSS tool are adopted. In factor analysis principal component analysis with orthogonal (varimax) rotation is performed on responses on identified eight performance indicators. From the analysis results of factor analysis out of eight performance indicator one indicator i.e. comparative service equity is eliminated on the basis of mean importance value, determinant value of correlation matrix, Kaiser-Meyer-Olkin Measure (KMO) value and Bartlett's test of sphericity of sampling adequacy. The correlations for remaining seven comparative city performance indicators are presented in Table 5.

Table 5: Analysis Results of EFA of Identified Comparative City Performance Indicators for Development of Correlation Matrix

S. No.	Performance Indicators	Comparative City Mobility	Comparative City Coverage	Comparative Transport Capacity	Comparative Air Quality	Comparative Noise Quality	Comparative Economic Activity	Comparative City Employment
1	Comparative City Mobility	1.000	.085	.367	.419	.331	.800	.129
2	Comparative City Coverage	.085	1.000	.468	.509	.535	.084	.841
3	Comparative Transport Capacity	.367	.468	1.000	.914	.902	.635	.635
4	Comparative Air Quality	.419	.509	.914	1.000	.907	.681	.676
5	Comparative Noise Quality	.331	.535	.902	.907	1.000	.619	.685
6	Comparative Economic Activity	.800	.084	.635	.681	.619	1.000	.211
7	Comparative City Employment	.129	.841	.635	.676	.685	.211	1.000

Determinant value = 0.025, KMO value = 0.831 and Bartlett's test of sphericity = 0.00 (within limit).

From the results of factor analysis three factors are extracted. These factors were labeled considering character of key performance indicators and tendency associated with them from city perspective. These are comparative travel performance, comparative environmental performance and comparative economic performance. The Cronbach's alpha was calculated to measure the internal consistency of performance indicators and presented in Table 6. The performance indicators with higher loading are more influence in explaining the corresponding extracted factor.

Table 6: Analysis Results of EFA of Comparative City Performance Indicators (Cronbach's Alpha value and Rotated Loading)

S. No.	Comparative City Performance Indicators	Rotated loading			% Variance Explained	Cronbach's Alpha value(□)
		Factor 1	Factor 2	Factor 3		
1	Comparative City Mobility	**0.896**	0.286	0.224	41.06	0.951
2	Comparative City Coverage	**0.858**	0.345	0.295		
3	Comparative Transport Capacity	**0.876**	0.360	0.198		
4	Comparative Air Quality	0.210	**0.950**	0.013	28.07	0.911
5	Comparative Noise Quality	0.444	**0.851**	0.016		
6	Comparative Economic Activity	0.126	0.063	**0.976**	25.10	0.828
7	Comparative City Employment	0.557	-0.062	**0.791**		

On the basis of the results of factor analysis structural models (hierarchical structure) were developed to selection of most significant performance indicators in context of Indian cities. A hierarchical structure is presented in Figure 3.

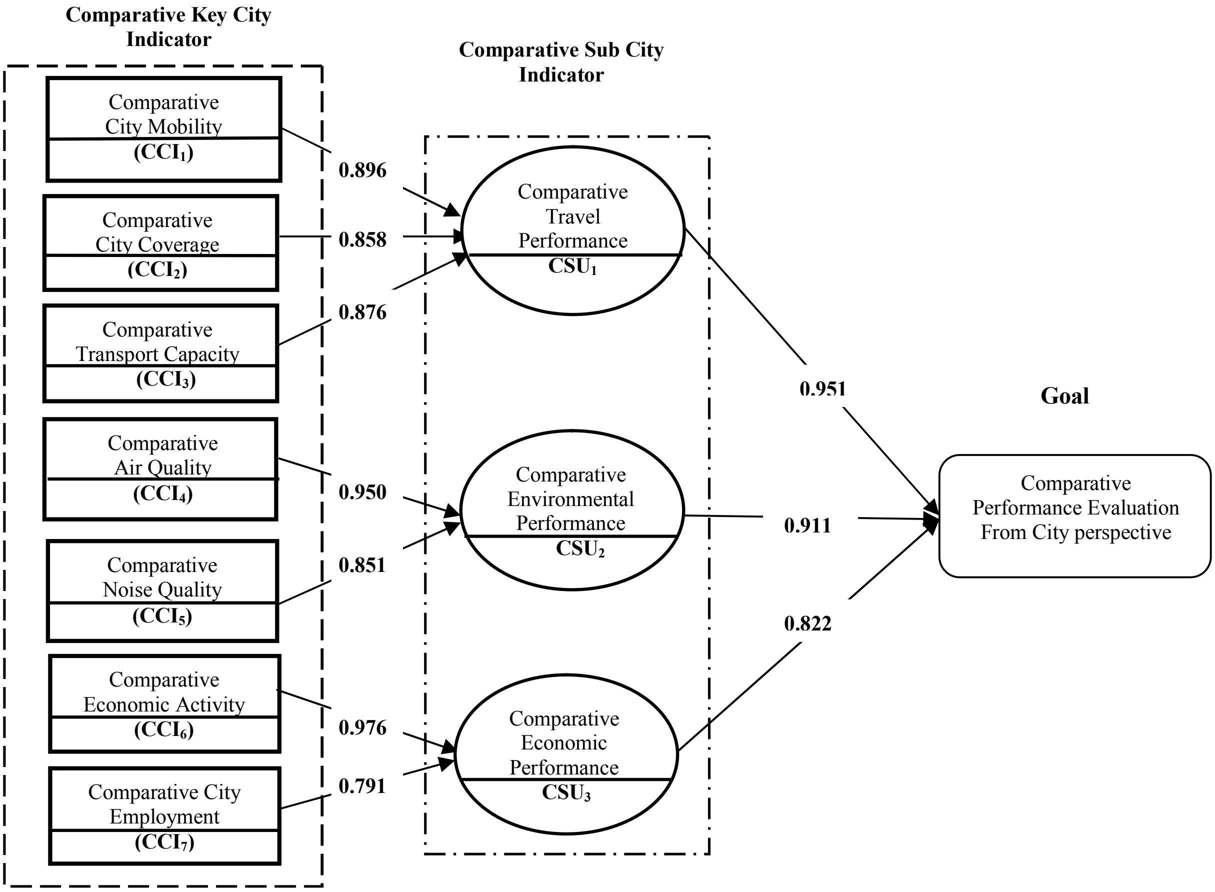

Figure 3: A Hierarchical Structure for Identification of Comparative City Performance Indicators

Based on the hierarchical structure the comparative key city performance indicators (CCI_1 to CCI_7) can be used to evaluate performance of public transport service 'I' with respect public transport service 'II' from separately city related issues. Out of 7 comparative key city performance indicators, three of them are from travel aspect (i.e. CCI_1, CCI_2 and CCI_3), two of them are from environment aspect (i.e. CCI_4 and CCI_5) and two of them are from economic aspects (i.e. CCI_6, and CCI_7). The sub performance indicators can be used to compare the performance of two public transport services from travel, environmental and economic aspect. The last level of the hierarchy put the main goal of the structure.

3.2 Stage-II: Evaluation of Condition of Comparative City Performance Indicators

The comparative city performance indices are developed in stage-II for evaluation of condition of identified comparative city performance indicators. These indices are developed in such a way that comparative performance of public transport service 'I' with respect to public transport service 'II' from city perspective can be evaluated individually considering various aspects such as city mobility, city coverage, passenger carrying capacity, air quality, noise quality, economic activity and city employment.

3.2.1 *Condition of Comparative Key City Performance Indicator 1, CCI_1 (Comparative City Mobility Index)*

It is proposed that the mobility of a vehicle in a city from origin to destination of public transport service 'I' with respect to public transport service 'II'can be evaluated using an index named as comparative city mobility index

($CCMI_{I/II}$). It is the ratio of city mobility index of public transport service 'I' and city mobility index of public transport service 'II'. The $CCMI_{I/II}$ is assessed by using Equation (1).

$$\mathbf{CCMI_{I/II} = \frac{CMBI_{I}}{CMBI_{II}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. Eq. (1)}$$

Where, $CMBI_I$ and $CMBI_{II}$ are city mobility index of public transport service 'I' and 'II' respectively. The value of $CCMI_{I/II}$ may be greater than one, equal to one and less than one. The detail guidelines are given in table 7.

Table 7: Criteria Considered in the Study for Comparison of two public transport services

S. No.	Index value	Description of Index Value
1	< 1.00	It means the performance of public transport service 'I' is superior with respect to public transport service 'II'.
2	=1.00	It means the performance of public transport service 'I' is equal to the public transport service 'II'.
3	>1.00	It means the performance of public transport service 'I' is inferior with respect to public transport service 'II'.

The city mobility index for public transport service 'I' and public transport service 'II' can be evaluated as follows.

- *Evaluation of City Mobility Index ($CMBI_S$)*

The city mobility means the ability to be mobile, or to travel freely in a city by vehicle of alternate public transport systems from origin to destination on a route. It is recommended that the city mobility index ($CMBI_s$) index is the ratio of average operational speed of a vehicle of alternate public transport system's' on a route and desirable operational speed of a vehicle of alternate public transport system's' on same route. It can be evaluated using equation (2).

$$\mathbf{CMBI_s = \frac{1}{NOR_s} \times \left\{ \sum_{i=1}^{i=n} \frac{AOS_{s,i}}{MOS_{s,i}} \right\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. Eq. (2)}$$

Where, $AOS_{s,i}$= Average operational speed of a vehicle of alternate public transport system's' on a route 'i' in kmph. $MOS_{s,i}$= Maximum operational speed of a vehicle of alternate public transport system's' on a route 'i' in kmph. NOR_s = Number of route on which ply vehicle of alternate public transport system's'.

The value of city mobility index of public transport service 's' may vary from 0 to 1.The value of city mobility index is divided into seven criteria as discussed in Table 8.

Table 8: City Satisfaction Criteria Considered in the Study for Performance of Public Transport Service

S. No.	Index Value	City Satisfaction Criteria
1	0.00-0.15	Performance are 'Not satisfactory'
2	0.15-0.30	Performance are 'Less satisfied
3	0.30-0.45	Performance are 'Preferably Satisfied'
4	0.45-0.55	Performance are 'Average satisfied'
5	0.55-0.70	Performance are 'Fairly satisfied'
6	0.70-0.85	Performance are 'Good satisfied'
7	0.85-1.00	Performance are 'Extremely Satisfied'

3.2.2 *Condition of Comparative Key City Performance Indicator 2, CCI_2 (Comparative City Coverage Index)*

It is proposed that comparative performance of public transport service 'I' with respect to public transport service 'II' from route coverage in a city can be evaluated using an index named as comparative city coverage index ($CCCI_{I/II}$). It is the ratio of city coverage index of public transport service 'I' and city coverage index for public transport service 'II'. The value of $CCCI_{I/II}$ may be greater than, equal to or less than one. The detail guideline of comparative city coverage index is similarly as discussed in Table 7. It is assessed using Equation (3).

$$\mathbf{CCCI_{I/II} = \frac{CCGI_{I}}{CCGI_{II}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. Eq. (3)}$$

$CCGI_I$ and $CCGI_{II}$ are city coverage index for public transport service I' and 'II' respectively. The city coverage index for public transport service 'I' and public transport service 'II' can be evaluated as follows:

- *Evaluation of City Coverage Index ($CCGI_S$)*

The city coverage measures the length of routes covered by alternate public transport systems in a city. It is recommended that the city coverage index ($CCGI_s$) is the ratio of total length of routes on which ply vehicles of alternate public transport service's' in a city in km and total length of routes on which ply vehicles of alternate public transport systems in a city in km. The value of $CCGI_s$ may vary from 0 to 1. It is divided into seven criteria (i.e. 'Not satisfactory' to 'Extremely Satisfactory') similarly as discussed in Table 8. It can be evaluated using equation (4).

$$\mathbf{CCGI_s = \frac{TLR_s}{TLR_a} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. Eq. (4)}$$

Where, TRL_s = Total length of routes on which ply vehicles of alternate public transport service's' in a city in km
TLR_a= Total length of routes on which ply vehicles of alternate public transport systems in a city in km.

3.2.3 *Condition of Comparative Key City Performance Indicator 3, CCI_3 (Comparative Transport Capacity Index)*

It is proposed that comparative performance of public transport service 'I' with respect to public transport service 'II' from passenger carrying capacity in a city can be evaluated using an index named as comparative transport system capacity index ($CTCI_{I/II}$). It is the ratio of transport system capacity index for public transport service 'I' to transport system capacity index for public transport service 'II'. The value of $CTCI_{I/II}$ may be greater than, equal to or less than one. The detail guideline of value of $CTCI_{I/II}$ is similarly as discussed in table 7. It is assessed by using Equation (5).

$$\mathbf{CTCI_{I/II} = \frac{TSCI_I}{TSCI_{II}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. Eq. (5)}$$

$TSCI_I$ and $TSCI_{II}$ are transport capacity index for public transport service 'I' and 'II' respectively. The transport capacity index for public transport service 'I' and public transport service 'II' can be evaluated as follows.

- *Evaluation of Transport Capacity Index($TCTI_S$)*

The transport capacity measures the number of passengers carrying per day in vehicles of alternate public transport systems. It is recommended that the transport capacity index ($TCTI_s$) is the ratio of total number of passengers travelled per day in vehicles of alternate public transport service's' on a route 'i' and maximum capacity of passengers travelled per day in vehicles of alternate public transport service's' on a route 'i'. The value of $TCTI_s$ may vary from 0 to 1. It is divided into seven criteria (i.e. 'Not satisfactory' to 'Extremely Satisfactory') similarly as discussed in Table 8. It can be evaluated using equation (6).

$$\mathbf{TCTI_s = \frac{1}{NOR_s} \times \left\{ \sum_{i=1}^{i=n} \frac{TNP_{s,i}}{MPC_{s,i}} \right\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. Eq. (6)}$$

Where, $TNP_{s,i}$=Total number of passengers travelled per day in vehicles of alternate public transport service's' on a route 'i' in nos. $MPC_{s,i}$= Maximum passengers carrying capacity per day of alternate public transport service's' on a route 'i' in nos.

$$\mathbf{MPC_{s,i} = 2 \times ANT_{s,i} \times TNV_{s,i} \times PCV_{s,i} \ldots\ldots\ldots\ldots\ldots\ldots. Eq. (7)}$$

$ANT_{s,i}$=Average number of trips per day per vehicle of alternate public transport service's' on a route 'i' in nos.
$TNV_{s,i}$ = Total number of vehicles of alternate public transport service's' ply on a route 'i' in nos.
$PCV_{s,i}$= Passenger Carrying capacity of a vehicle of alternate public transport service's' on a route 'i' in nos.

3.2.4 *Condition of Comparative Key City Performance Indicator 4, CCI_4 (Comparative Air Quality Index)*

It is proposed that comparative performance of public transport service 'I' with respect to public transport service 'II' from vehicle emission aspects can be evaluated using an index named as comparative air quality index ($CAQI_{I/II}$). It is the ratio of air quality condition index for public transport service 'I' to air quality condition index for public transport service 'II'. The value of $CAQI_{I/II}$ may be greater than, equal to or less than one.The detail guideline of the value of $CAQI_{I/II}$ is similarly as discussed in table 7. It is assessed using Equation (8).

$$\mathbf{CAQI_{I/II}} = \frac{\mathbf{AQCI_I}}{\mathbf{AQCI_{II}}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \mathbf{Eq.(8)}$$

$AQCI_I$ and $AQCI_{II}$ are air quality condition index for public transport service I and 'II' respectively. The air quality condition index for public transport service 'I' and public transport service 'II' can be evaluated as follows.

- *Evaluation of Air Quality Condition Index ($AQCI_S$)*

The air quality measures are used to predict emission levels from vehicle of alternate public transport system. It is suggested that the air quality condition index ($AQCI_s$) is the ratio of total air emission from a vehicle of alternate public transport system's' on a route 'i' in a city in kg per day per seat per vehicle and maximum air emission from a vehicles of alternate public transport system's' on any route in a city in kg per day per seat per vehicle. The value of $AQCI_s$ may vary from 0 to 1. The value of $AQCI_s$ is divided into seven criteria (i.e. 'Not satisfactory' to 'Extremely Satisfactory') similarly as discussed in Table 8. It can be evaluated using equation (9).

$$\mathbf{AQCI_s} = \mathbf{1} - \left[\frac{\mathbf{1}}{\mathbf{NOR_s}} \times \left\{\sum \frac{\mathbf{TAN_{s,i}}}{\mathbf{MAN_s}}\right\}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \mathbf{Eq.(9)}$$

Where, $TAN_{s,i}$= Total air emission from alternate public transport service's' on a route 'i' in a city in gm per day per seat per vehicle, MAN_s = Maximum air emission from alternate public transport service's' on any route in a city in gm per day per seat per vehicle

$$\mathbf{TAN_{s,i}} = \frac{\mathbf{TVK_{s,i}} \times \mathbf{AAE_{s,i}}}{\mathbf{MPC_{s,i}}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \mathbf{Eq.(10)}$$

Where, $TVK_{s,i}$= Total vehicle kilometre travelled by vehicles of alternate public transport service's' on a route 'i' in km. $AAE_{s,i}$= Average air emission from vehicles of alternate public transport service's' in gm/km on a route 'i'. $MPC_{s,i}$= Maximum passenger carrying capacity in a day of alternate public transport service's' on a route 'i' in nos.

$$\mathbf{TVK_{s,i}} = \mathbf{2} \times \left\{\mathbf{TNV_{s,i}} \times \left(\mathbf{LOR_{s,i}} \times \mathbf{ANT_{s,i}} + \mathbf{ADO_{s,i}}\right)\right\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \mathbf{Eq.(11)}$$

$LOR_{s,i}$= Length of route for alternate public transport service's' in km. $ANT_{s,i}$=Average number of trips per day of a vehicle of alternate public transport service's' in a day. $ADO_{s,i}$ = Average distance travelled by a vehicle from origin to vehicle stop of alternate public transport service's' on route 'i'

$$\mathbf{MPC_{s,i}} = \mathbf{2} \times \mathbf{ANT_{s,i}} \times \mathbf{TNV_{s,i}} \times \mathbf{PCV_{s,i}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \mathbf{Eq.(12)}$$

$PCV_{s,I}$=Passenger carrying capacity of a vehicle of alternate public transport service's' on a route 'i'

$$\mathbf{AAE_{s,i}} = \sum \left\{\mathbf{AER_{p,s}} \times \mathbf{SCF_{p,s,}}\right\}$$

Where, $AER_{p,s}$=Air emission rate of pollutant 'p' from a vehicle of alternate public transport service's' in gm/km $SCF_{p,s,i}$= Speed correction factor of pollutant 'p' for a vehicle of alternate public transport service's' on a route 'i'

$$\mathbf{SCF_{p,s,i}} = \mathbf{e}^{\left[\mathbf{A_{p,s}} \times \left\{\mathbf{AMS_{s,i,}} - \mathbf{27.6}\right\} + \mathbf{B_{p,s}} \times \left\{\mathbf{AMS_{s,i}} - \mathbf{27.6}\right\}^{\mathbf{2}}\right]} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \mathbf{Eq.(13)}$$

Where, $AMS_{s,i}$ = Average operational mile speed of alternate public transport system's' on route 'i' in miles per hour (ranging from 2.5 to 65 mile/hour). $A_{p,s}$, $B_{p,s}$ = Cycle correction factor for pollutant 'p' of alternate public transport service's' p= Types of pollutantsuch as CO, CO_2, HC, and NO_x

3.2.5 *Condition of Comparative Key City Performance Indicator 5, CCI_5 (Comparative Noise Quality Index)*

It is proposed that comparative performance of public transport service 'I' with respect to alternate public transport service 'II'from noise emissions can be evaluated using an index named as comparative noise quality index ($CNQI_{I/II}$). The $CNQI_{I/II}$ is the ratio of noise quality condition index of public transport service 'I' to noise quality condition index of public transport service 'II'. The value of $CNQI_{I/II}$ may be greater than, equal to or less than one. The detail guideline of value of $CNQI_{I/II}$ is similarly as discussed in table 7. It is assessed using Equation (14)

$$\mathbf{CNQI_{I/II} = \frac{NQCI_I}{NQCI_{II}}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \mathbf{Eq.\,(14)}$$

$NQCI_I$ and $NQCI_{II}$ are noise quality condition index for public transport service 'I' and 'II' respectively. The noise quality condition index for public transport service 'I' and public transport service 'II' can be evaluated as follows.

- *Evaluation of Noise Quality Condition Index ($NQCI_S$)*

It is proposed that the noise quality condition index ($NQCI_s$) for alternate public transport system's' is the ratio of total noise rating given by passengers during whole journey from origin to destination on a route and maximum possible noise rating given by passengers during whole journey from origin to destination on same route. The value of $NQCI_s$ may vary from 0 to 1. The value of $NQCI_s$ is divided into seven criteria (i.e. 'Not satisfactory' to 'Extremely Satisfactory') similarly as discussed in Table 8. It can be evaluated using equation (15).

$$\mathbf{NQCI_s = \frac{1}{NOR_s} \times \sum_{i=1}^{i=n} \frac{TNR_{s,i}}{MNR_{s,i}}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \mathbf{Eq.\,(15)}$$

Where, $TNR_{s,i}$= Total noise rating given by passengers for alternate public transport system's' on a route 'i'.

$$\mathbf{TNR_{s,i} = 5 \times NNR_{5s,i} + 4 \times NNR_{4s,i} + 3 \times NNR_{3s,i} + 2 \times NNR_{2s,i} + 1 \times NNR_{1s,i}} \dots \mathbf{Eq.\,(16)}$$

$MNR_{s,i}$= Maximum possible noise rating given by passengers for alternate public transport system's' on a route 'i'.

$$\mathbf{MNR_{s,i} = 5 \times TNN_{s,i}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \mathbf{Eq.\,(17)}$$

$NNR_{5s,i}$= number of respondent given 5 rating to noise quality of alternate public transport service's' on a route 'i'
$NNR_{4s,i}$= number of respondent given 4 rating to noise quality of alternate public transport service's' on a route 'i'
$NNR_{3s,i}$= number of respondent given 3 rating to noise quality of alternate public transport service's' on a route 'i'
$NNR_{2s,i}$ = number of respondent given 2 rating to noise quality of alternate public transport service's' on a route 'i'
$NNR_{1s,i}$ = number of respondent given 1 rating to noise quality of alternate public transport service's' on a route 'i'
$TNN_{s,i}$ =Total number of respondent given noise rating for alternate public transport service's' on a route 'i'

3.2.6 *Condition of Comparative Key City Performance Indicator 6, CCI_6 (Comparative Economic Activity Index)*

It is proposed that comparative performance of public transport service 'I' with respect to public transport service 'II' from land value improvement aspect can be evaluated using an index named as comparative economic activity index ($CEAI_{I/II}$). It is the ratio of economic activity index of public transport service 'I' to economic activity index of public transport service 'II'. The value of $CEAI_{I/II}$ may be greater than, equal to or less than one. The detail guideline of value of $CEAI_{I/II}$ is similarly as discussed in table 7. It is assessed by using Equation (18).

$$\mathbf{CEAI_{I/II} = \frac{EATI_I}{EATI_{II}}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \mathbf{Eq.\,(18)}$$

$EATI_I$ and $EATI_{II}$ are economic activity index for alternate public transport service 'I' and 'II' respectively. The economic activity index for public transport service 'I' and public transport service 'II' can be evaluated as follows

- ***Evaluation of Economic Activity Index ($EATI_S$)***

It is recommended that the economic activity index ($EATI_s$) for alternate public transport system's' is the ratio of average land value of an area near the route and maximum land value of a area near any transport route of a city.The value of $EATI_s$ may vary from 0 to 1. The value of $EATI_s$ is divided into seven criteria (i.e. 'Not satisfactory' to 'Extremely Satisfactory') similarly as discussed in Table 8. It can be evaluated using equation (19).

$$\mathbf{EATI_s} = \left[\sum_{i=1}^{i=n} \frac{\mathbf{ALV_{s,i}}}{\mathbf{MLV}}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{Eq.\,(19)}$$

Where, $ALV_{s,i}$= Average land value near the route 'i' on which ply vehicles of alternate public transport service's' in Rs/ft^2. MLV= Maximum land value of an area near any transport route of a city in Rs/ft^2

3.2.7 *Condition of Comparative Key City Performance Indicator 7, CCI_7 (Comparative City Employment Index)*

It is proposed that comparative performance of public transport service 'I' with respect to public transport service 'II' from employment generation in city can be evaluated using an index named as comparative city employment index ($CCEI_{I/II}$). It is the ratio of city employment index of public transport service 'I' and city employment index of public transport service 'II'. The value of $CCEI_{I/II}$ may be greater than, equal to or less than one. The detail guideline of value of $CCEI_{I/II}$ is similarly as discussed in table 7. It is assessed by using Equation (20).

$$\mathbf{CCEI_{I/II}} = \frac{\mathbf{CEMI_I}}{\mathbf{CEMI_{II}}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{Eq.\,(20)}$$

$CEMI_I$ and $CEMI_{II}$ are City employment index for public transport service 'I' and 'II' respectively. The city employment index for public transport service 'I' and public transport service 'II' can be evaluated as follows.

- *Evaluation of City Employment Index ($CEMI_S$)*

It is recommended that the economic activity index ($CEMI_s$) for alternate public transport system's' is the ratio of average land value of an area near the route and maximum land value of a area near any transport route of a city. The value of $CEMI_s$ may vary from 0 to 1.The value of city coverageindex is divided into seven criteria (i.e. 'Not satisfactory' to 'Extremely Satisfactory') similarly as discussed in Table 8. It can be evaluated using equation (21).

$$\mathbf{CEMI_S} = \frac{\mathbf{NJG_s}}{\mathbf{TJG_t}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{Eq.\,(21)}$$

Where, NJC_s = Number of jobs generated by alternate public transport system's' in a city in Nos. TJC_t= Total no. of job generated by all alternate public transport service in a city in Nos.

3.3 Stage-III: Determination of Relative Weight of Comparative City Performance Indicators using FAHP Technique

The relative weight of identified comparative key city performance indicators are determined using Fuzzy AHP technique in Stage-III. First of all to develop a hierarchical structure with comparative city performance indicators including key criteria and sub criteria is presented in Figure 2 as discussed earlier. An expert opinion survey is conducted by the researcher to collect the preferences for comparative key city performance indicators at same level by transport experts and academicians. The integrated fuzzy comparison matrix is developed for comparative key city performance indicators by analyzing the opinions of 33 transport experts and presented in Table 7. The fuzzy judgment matrices from all decision makers can be aggregated by using the fuzzy geometric mean method. Further, the value of fuzzy synthetic extent Si with respect to the i^{th} criterion can be computed. Based on the fuzzy synthetic extent values and the non-fuzzy values the relative preferences are compared and to find the degree of possibility. The analysis results of estimation of weight of comparative key city performance indicators using FAHP Technique is presented in Table 8. The de-fuzzy comparison matrix and normal comparison matrix are developed to check the consistency property of the matrix for ensuring the consistency of judgments in the pair-wise comparison of comparative key city performance indicators. The De-fuzzy comparison matrix and normalized matrix are presented in Table 9 and Table 10.

Table 9: Development of Integrated Fuzzy Comparison Matrix for Comparative Key City Performance Indicators Using FAHP Technique

Performance indicators	Comparative city mobility			Comparative city coverage			Comparative transport capacity			Comparative air quality			Comparative noise quality			Comparative economic activity			Comparative city employment		
Comparative city mobility	1.000	1.000	1.000	0.614	0.848	1.154	0.892	1.181	1.546	0.616	0.804	1.081	1.026	1.388	1.872	0.983	1.307	1.733	0.736	0.993	1.322
Comparative city coverage	0.867	1.179	1.628	1.000	1.000	1.000	0.854	1.189	1.633	0.705	0.949	1.291	0.711	0.949	1.276	1.018	1.414	1.950	0.851	1.216	1.699
Comparative transport capacity	0.647	0.847	1.122	0.613	0.841	1.171	1.000	1.000	1.000	0.878	1.216	1.651	0.831	1.126	1.527	1.063	1.448	1.988	0.707	0.930	1.257
Comparative air quality	0.925	1.244	1.624	0.775	1.053	1.419	0.606	0.822	1.139	1.000	1.000	1.000	1.335	1.769	2.303	1.032	1.372	1.809	0.791	1.083	1.475
Comparative noise quality	0.534	0.720	0.975	0.784	1.053	1.407	0.655	0.888	1.204	0.434	0.565	0.749	1.000	1.000	1.000	0.657	0.891	1.220	0.856	1.159	1.561
Comparative economic activity	0.577	0.765	1.017	0.513	0.707	0.982	0.503	0.691	0.941	0.553	0.729	0.969	0.820	1.123	1.522	1.000	1.000	1.000	0.588	0.785	1.064
Comparative city employment	0.757	1.007	1.358	0.589	0.823	1.175	0.796	1.076	1.415	0.678	0.923	1.264	0.641	0.863	1.169	0.940	1.274	1.701	1.000	1.000	1.000

Table 10: Analysis Results of Estimation of Weight of Comparative Key City Performance Indicators Using FAHP Technique

Performance indicators	**Fuzzy Sum of Each Row** $\tilde{u}_{ij} = \left(\prod_{i=1}^{n} \tilde{a}_{ijk}\right)^{1/n}$			**Fuzzy Synthetic Extent value** $S_i = \sum_{j=1}^{j=m} M_{g,i}^{j} \times \left[\sum_{i=1}^{i=n}\left\{\sum_{j=1}^{j=m} M_{g,i}^{j}\right\}\right]^{-1}$			**Fuzzy Priorities value** $uS_j(d) = \begin{cases} 1 & \text{if } m_j \geq m_i \\ 0 & \text{if } l_i \geq u_j \\ \frac{l_i - u_j}{(m_j - u_j) - (m_i - l_{aj})} & \text{otherwise} \end{cases}$						**Degree Preferred** $[D(A_i) = \text{Min.Val}(S_i \geq S_k)]$	**Relative Weight**
Comparative City Mobility	0.821	1.055	1.352	0.090	0.150	0.249	0.946	1.000	0.909	1.000	1.000	1.000	0.909	**0.152**
Comparative City Coverage	0.850	1.117	1.465	0.093	0.159	0.269	1.000	1.000	0.965	1.000	1.000	1.000	0.965	**0.161**
Comparative Transport capacity	0.804	1.040	1.352	0.088	0.148	0.249	0.987	0.934	0.898	1.000	1.000	1.000	0.898	**0.149**
Comparative Air Quality	0.899	1.160	1.488	0.098	0.165	0.273	1.000	1.000	1.000	1.000	1.000	1.000	1.000	**0.166**
Comparative Noise Quality	0.680	0.875	1.130	0.074	0.124	0.208	0.822	0.769	0.837	0.730	1.000	0.888	0.730	**0.121**
Comparative Economic Activity	0.631	0.816	1.057	0.069	0.116	0.194	0.755	0.703	0.770	0.662	0.934	0.822	0.662	**0.110**
Comparative City Employment	0.759	0.986	1.282	0.083	0.140	0.235	0.937	0.884	0.951	0.847	1.000	1.000	0.847	**0.141**
Sum	5.442	7.048	9.127									**Sum**	**6.011**	**1.000**
Inverse of Sum	0.184	0.142	0.110											

Table 11: Development of De-Fuzzy Comparison Matrix of Comparative Key City Performance Indicators using FAHP Technique

Comparative Key City Performance indicators	Comparative City Mobility	Comparative City Coverage	Comparative Transport capacity	Comparative Air Quality	Comparative Noise Quality	Comparative Economic Activity	Comparative City Employment
Comparative City Mobility	1.000	0.866	1.200	0.826	1.419	1.333	1.011
Comparative City Coverage	1.213	1.000	1.216	0.974	0.971	1.449	1.245
Comparative Transport Capacity	0.866	0.866	1.000	1.240	1.152	1.487	0.956
Comparative Air Quality	1.259	1.075	0.847	1.000	1.794	1.396	1.108
Comparative Noise Quality	0.737	1.074	0.909	0.579	1.000	0.915	1.183
Comparative Economic Activity	0.781	0.727	0.706	0.745	1.147	1.000	0.805
Comparative City Employment	1.032	0.852	1.091	0.947	0.884	1.297	1.000

Table 12: Development of Normalized Matrix of Comparative Key City Performance Indicators using FAHP Technique

Comparative Key City Performance indicators	Comparative City Mobility	Comparative City Coverage	Comparative Transport capacity	Comparative Air Quality	Comparative Noise Quality	Comparative Economic Activity	Comparative City Employment	**Mean Value of Each row**
Comparative City Mobility	0.145	0.134	0.172	0.131	0.170	0.150	0.138	**0.1486**
Comparative City Coverage	0.176	0.155	0.175	0.154	0.116	0.163	0.170	**0.1585**
Comparative Transport Capacity	0.126	0.134	0.143	0.197	0.138	0.167	0.131	**0.1480**
Comparative Air Quality	0.183	0.166	0.122	0.158	0.214	0.157	0.152	**0.1646**
Comparative Noise Quality	0.107	0.166	0.130	0.092	0.120	0.103	0.162	**0.1257**
Comparative Economic Activity	0.113	0.113	0.101	0.118	0.137	0.113	0.110	**0.1150**
Comparative City Employment	0.150	0.132	0.156	0.150	0.106	0.146	0.137	**0.1396**

The consistency rate (CR) is computed using the Equation 2.13, Equation 2.14, and Equation 2.15 and data given in Table 9 and Table 10. The consistency ratio is obtained 0.0274 which is acceptable.

Table 13 Detailed Summary of Relative Weight of comparative key City Performance Indicators

S. No.	**Comparative Key City Performance Indicators**	**Notation**	**Relative Weight**	**Comparative Sub-City Performance Indicators**	**Notation**	**Relative Weight**
1	Comparative City Mobility	W_{MBT}	0.152	Comparative Travel Performance	W_{TLP}	0.462
2	Comparative Transport Capacity	W_{TSC}	0.161			
3	Comparative City Coverage	W_{RCG}	0.149			
4	Comparative Air Quality	W_{AQT}	0.166	Comparative Environmental Performance	W_{ELP}	0.287
5	Comparative Noise Quality	W_{NQT}	0.121			
6	Comparative Economic Activity	W_{EAT}	0.110	Comparative Economic Performance	W_{ECP}	0.251
7	Comparative City Employment	W_{CEM}	0.141			
		Sum	**1.000**		**Sum**	**1.000**

3.4 Stage-IV: Development of a Methodology for Evaluation of City Comparative Performance

The main objective of the Stage-IV is to develop an evaluation methodology for comparison and quantification of performance of public transport service 'I' with respect to public transport service 'II' from travel, environmental and economic as well as combined aspects from city perspective. Hence, this study developed comparative travel performance index ($CTLI_{I/II}$) from travel aspect, comparative environmental performance index ($CEPI_{I/II}$) from environmental aspect, comparative economic performance index ($CECI_{I/II}$) from economy development aspect and city comparative performance index ($CCPI_{I/II}$) from combined aspect. The details of these indices are presented in sub section of this section.

3.4.1 Comparative Travel Performance Index ($CTLI_{I/II}$)

It is proposed that comparative performance of public transport service 'I' with respect to public transport service 'II' from travel aspect can be evaluated using an index named as comparative travel performance index ($CTLI_{I/II}$). It is recommended that the comparative travel performance index ($CTLI_{I/II}$) is developed by multiplication of condition of comparative city mobility, comparative city coverage, and comparative transport capacity and their relative weight. The value of $CTLI_{I/II}$ may be greater than, equal to or less than one. The value of index greater than one, equal to one and less than one indicates the performance of public transport service 'I' is superior, equal and inferior quality with respect to public transport service 'II'. It can be evaluated using equation (22).

$$\mathrm{TLPI_{I/II}} = \frac{\mathrm{W_{CMB}} \times \mathrm{CCMI_{I/II}} + \mathrm{W_{TSC}} \times \mathrm{CTCI_{I/II}} + \mathrm{W_{CCG}} \times \mathrm{CCCI_{I/II}}}{\mathrm{W_{CMB}} + \mathrm{W_{TSC}} + \mathrm{W_{CCG}}} \dots\dots\dots\dots\dots\dots \mathrm{Eq.}\,(22)$$

Where,
$CCMI_{I/II}$=Comparative city mobility index of public transport service 'I' with respect to public transport service 'II'., $CTCI_{I/II}$= Comparative transport capacity index of public transport service 'I' with respect to public transport service 'II'., $CCCI_{I/II}$=Comparative city coverage index of public transport service 'I' with respect to public transport service 'II'., W_{CMB} = Relative weight of comparative city mobility., W_{TSC} = Relative weight of comparative transport capacity., W_{CCG} = Relative weight of comparative city coverage

3.4.2 Comparative Environmental Performance Index ($CELI_{I/II}$)

The comparative performance of alternate public transport service from environmental aspect is affected by air quality and noise quality in city aspects. It is proposed that comparative performance of public transport service 'I' with respect to public transport service 'II' from environment aspect can be evaluated using an index named as comparative environmental performance index ($CELI_{I/II}$). It is recommended that the comparative environmental performance index ($CELI_{I/II}$) is developed by multiplication of condition of comparative air quality index, and comparative noise quality index and their relative weight. The value of comparative environmental performance index ($CELI_{I/II}$) may be greater than one, equal to one and less than one. The value of index greater than one, equal to one and less than one indicates the performance of public transport service 'I' is superior, equal and inferior quality with respect to public transport service 'II'. It can be evaluated using equation (23).

$$\mathrm{CELI_{I/II}} = \frac{\mathrm{W_{AQT}} \times \mathrm{CAQI_{I/II}} + \mathrm{W_{NQT}} \times \mathrm{CNQI_{I/II}}}{\mathrm{W_{AQT}} + \mathrm{W_{NQT}}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \mathrm{Eq.}\,(23)$$

Where, $CAQI_{I/II}$=Comparative air quality index of public transport service 'I' with respect to public transport service 'II'., $CNQI_{I/II}$= Comparative noise quality index of public transport service 'I' with respect to public transport service 'II'., W_{AQT} = Relative weight of comparative air quality condition., W_{NQT} = Relative weight of comparative noise quality condition.

3.4.3 Comparative Economic Performance Index ($CECI_{I/II}$)

The comparative performance of alternate public transport service from economic aspect is affected by land value and employment generation in a city. It is proposed that comparative performance of public transport service 'I' with respect to public transport service 'II' from economic aspect can be evaluated using an index named as comparative economic performance index ($CECI_{I/II}$). It is recommended that the comparative economic performance index ($CECI_{I/II}$) is developed by multiplication of condition of comparative economic activity and comparative city employment and their relative weight. The value of comparative economic performance index ($CECI_{I/II}$) may be greater than one, equal to one and less than one. The value of index greater than one, equal to one and less than one indicates the performance of public transport service 'I' is superior, equal and inferior quality with respect to public transport service 'II'. It can be evaluated using equation (24).

$$\mathrm{CECI_{I/II}} = \frac{\mathrm{W_{EAT}} \times \mathrm{CEAI_{I/II}} + \mathrm{W_{CEM}} \times \mathrm{CCEI_{I/II}}}{\mathrm{W_{CEM}} + \mathrm{W_{EAT}}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \mathrm{Eq.}\,(24)$$

Where, $CEAI_{I/II}$= Comparative economic activity Index of public transport service 'I' with respect to public transport service 'II'., $CCEI_{I/II}$= Comparative city employment Index of public transport service 'I' with respect to public transport service 'II'., W_{EAT}= Relative weight of comparative economic activity., W_{CEM}= Relative weight of comparative city employment

3.4.4 City Comparative Performance Index ($CCPI_{I/II}$)

The overall comparative performance of alternate public transport service from city perspective is affected by travel performance, environmental performance and economic performance. It is proposed that comparative performance of public transport service 'I' with respect to public transport service ‘II’ from city perspective can be evaluated using an index named as city comparative performance index ($CCPI_{I/II}$). It is recommended that the city comparative performance index ($CCPI_{I/II}$) is developed by multiplication of condition of comparative travel performance, comparative environmental performance and comparative economic performance and their relative weight. The value of city comparative performance index ($CCPI_{I/II}$) may be greater than one, equal to one and less than one. The value of index greater than one, equal to one and less than one indicates the performance of public transport service ‘I’ is superior, equal and inferior quality with respect to public transport service ‘II’. The city comparative performance index ($CCPI_{I/II}$) is evaluated using equation (25).

$$\mathbf{CCPI_{I/II} = W_{TLP} \times CTLI_{I/II} + W_{ELP} \times CELI_{I/II} + W_{ECP} \times CECI_{I/II} \ldots\ldots\ldots\ldots\ldots\ldots. Eq. (25)}$$

Where, $CTLI_{I/II}$=Comparative travel performance index of public transport service ‘I’ with respect to public transport service ‘II’., $CELI_{I/II}$=Comparative environmental performance index of public transport service ‘I’ with respect to public transport service ‘II’., $CECI_{I/II}$=Comparative economy performance index of public transport service ‘I’ with respect to public transport service ‘II’., W_{TCP} = Relative weight of comparative travel performance., W_{ELP} = Relative weight of comparative environmental performance., W_{ECP}= Relative weight of comparative economic performance

4. Analysis and results of comparative performance evaluation of Bhopal transport service

Currently Bhopal’s public transport consists of mini buses system and BCLL bus system. The five important routes are considered for each system for comparative performance evaluation of BCLL bus system with respect to Mini bus system. The details of input data considered in this study are presented in sub section 4.1.

4.1 Details of Input Data for Application of proposed methodology

This section is presented input data of public transport service ‘I’ (BCLL bus system) and public transport service ‘II’(Mini bus system) for application of proposed methodology in Bhopal city. The input data are presented in this section is collected from literature review, various authorities and operators of BCLL bus system and mini bus system as well as field survey and questionnaire survey in Bhopal city. The input data such maximum operational speed, average land value, air emission rate, maximum land value etc are collected from literature review. Further, the average operational speed of BCLL buses and Mini buses are measured using radar speed gun. The basic input data for BCLL bus system and Mini bus system are presented in Table 14, Table 15, Table 16 and Table 17.

Table 14: Basic details of existing routes of public transport service ‘s’ considered in study area

S. No	Public transport system ‘s’	Details of Route ‘i’	Length of route ‘i’	Number of Bus stop on a route ‘i’	Average number of trips in a day per vehicle	Total number of vehicles ply on a route ‘i’ in a day	Average distance travelled from depot to origin of route to by a vehicle ***	Passenger Carrying capacity of a vehicle ***
		Unit	km	Nos.	Nos.	Nos.	km	Nos.
		Notation	$LOR_{I,i}$	$NBS_{I,i}$	$ANT_{I,i}$	$TNV_{I,i}$	$ADO_{I,i}$	$PCV_{I,i}$
1	*Public Transport System ‘I’ **(BCLL bus system)**	**SR_1** (Sehore Naka to Bairagarh Chichili)	19.30	29	4	17	10	80
		SR_2 (Nehru Nagar to Katara Hills)	20.50	44	4	19	10	80
		SR_4 (People's College to Bairagarh Chichili)	22.80	36	4	26	10	80
		SR_5 (Chirayu Hospital to Awadhpuri)	27.90	45	4	24	10	80
		SR_8 (Coach Factory to Bairagarh Chichili)	23.40	49	4	28	10	80
2	**Public Transport System ‘II’ **(Mini bus system)**	**RA_1** (Nayapura Kolar to Nadra Bus Station)	21.5	30	5.5	21	10	44
		RT_1 (Indus Garden to Lambakheda)	17.4	18	6.0	35	10	44
		RT_2 (Indus Garden to Gandhi Nagar)	27.4	23	5.0	46	10	44
		RT_7 (Bairagarh to Bagmugalia)	28.2	28	4.0	18	10	44
		RT_{11} (Bairagarh To Aura Mall Trilanga)	25.3	29	4.5	32	10	44

[Source: www.mybrts.com,** www.myblogspot.com,* **Field Survey*

Table 15: Details of input data for public transport system 'I' (BCLL bus service)

S. No	Parameters	Notation	Unit	Value					Source of Input Data
				SR_1	SR_2	SR_4	SR_5	SR_8	
1	Average Operational speed in a trip	$AOS_{I,i}$	kmph	42.62	37.95	39.93	37.20	31.65	Field Survey (Radar Speed Gun)
2	Maximum Operational speed in a trip	$MOS_{I,i}$	kmph	60	60	60	60	60	Bhopal RTO Guidelines
3	Total number of passengers to travel per day	$TNP_{I,i}$	Nos.	3820	6500	11890	10792	10908	Field survey
4	passenger carrying capacity of a vehicle	TCV_I	Nos.	80	80	80	80	50	Field survey
5	Total route length of roads on which ply vehicles in a city	TRL_I	km	291.17					Singh, et al. (2012)
6	Total Network Length of roads in a city	TNL	km	1500					Jaiswal (2012)
7	Average operational mile speed in miles per hour	AMS_I,i	Mile/h	26.50	23.59	24.82	23.13	19.68	Survey by Speed Radar method
8	Cycle correction factor for pollutant 'p' (CARB technology)	A, B	Unit less	Details of Cycle correction factor for pollutant 'p' are presented in previous Table 16					ARAI, (2007)
9	Air emission rate of pollutant 'p', from a vehicle	$AER_{p,I}$	gm/km	Details of air emission rate of pollutant 'p' are presented in Table 17					ARAI, (2007)
10	Noise quality Rating given by users	$NNR_{Rs,i}$	Rating	Details of respondent of Noise rating is presented in Table 18					Questionnaire Survey
11	Average land value near the transport route on which ply	$APV_{I,i}$	Rs/ft^2	3567	4266	3678	3216	3782	Bhopal Collector Guidelines (2016)
12	Maximum land value of area near any transport route	MLV	Rs/ft^2	8357	8357	8357	8357	8357	
13	No of jobs created by in a city	$NJC_{I,i}$	Nos.	980					Bhopal city link limited
14	Total No. of Job created by transport system in a city	TJC_t	Nos.	4730					Bus Operator Survey

Table 16: Details of cycle correction factor for pollutant 'p' of public transport system 'I' (BCLL bus Service)

S. No.	Parameters	Notation	Value
1	Cycle correction factor for pollutant 'CO' of public transport system 'I'	$A_{CO,I}$	-0.0287910
		$B_{CO,I}$	0.0019220
2	Cycle correction factor for pollutant 'CO2' of public transport system 'I'	$A_{CO2,I}$	-0.0259500
		$B_{CO2,I}$	-0.0003090
3	Cycle correction factor for pollutant 'HC' of public transport system 'I'	$A_{HC,I}$	-0.0317600
		B_{HC},I	0.0009080
4	Cycle correction factor for pollutant 'NOX' of public transport system 'I'	$A_{NOX,I}$	0.0089670
		$B_{NOX,I}$	-0.0000270

[Source: ARAI, (2007)]

Table 17: Details of Air Emission Rate of Pollutant 'p' from Public transport service 'I' (BCLL Bus System)

S. No.	Parameters	Notation	Air Emission Rate (gm/km)
1	Air emission rate of pollutant 'CO', from a vehicle of public transport service 'I'	$AER_{CO,I}$	3.92
2	Air emission rate of pollutant 'CO2', from a vehicle of public transport service 'I'	$AER_{CO2,I}$	602.1
3	Air emission rate of pollutant 'HC', from a vehicle of public transport service 'I'	$AER_{HC,I}$	0.16
4	Air emission rate of pollutant 'NOX', from a vehicle of public transport service 'I'	$AER_{NOx,I}$	6.53

[Source: ARAI, (2007)]

Table 18: Noise Quality Rating Given by Users for Public transport service 'I' (BCLL Bus service) on Route 'i'

S. No.	Description	Notation	Noise Rating given by users on a Route 'i'				
			SR_1	SR_2	SR_4	SR_5	SR_8
1	Number of users given noise rating 5 for public transport service 'II'	$NNR_{5I,i}$	13	12	14	11	12
2	Number of users given noise rating 4 for public transport service 'II'	$NNR_{4I,i}$	9	10	12	13	12
3	Number of users given noise rating 3 for public transport service 'II'	$NNR_{3I,i}$	16	13	11	12	13
4	Number of users given noise rating 2 for public transport service 'II'	$NNR_{2I,i}$	9	10	9	11	9
5	Number of users given noise rating 1 for public transport service 'II'	$NNR_{1I,i}$	6	8	7	6	7
6	Total number of users given noise rating for public transport service 'II'	$TNN_{I,i}$	53	53	53	53	53

[Source: Field Survey]

Table 19: Details of input data for public transport system 'II' (Mini bus service)

S. No.	Parameters	Notation	Unit	Value					Source of Input Data
				$RT_1(A_1)$	RT_1	RT_2	RT_7	RT_{11}	
1	Average Operational speed in a trip	$AOS_{II,i}$	kmph	30.21	31.89	29.75	28.25	34.26	Field survey
2	Maximum Operational speed in a trip in a city	$MOS_{II,i}$	kmph	60.00	60.00	60.00	60.00	60.00	Bhopal RTO Office
3	Total number of passengers to travel per day	$TNP_{II,i}$	Nos.	6783	11795	15686	5922	10528	Field survey
4	Passenger carrying capacity of a vehicle in a day	$PCV_{II,i}$	Nos.	44	44	44	44	44	Field survey
5	Total route length of roads on which ply vehicles	TRL_I	km	276.67					Jaiswal A. (2014)
6	Total Network Length of roads in a city	TNL	km	1500					Bhopal Smart city Authority
7	Average operational mile speed in miles per hour	$AMS_{II,i}$	Mile/h	18.78	19.83	18.50	17.56	21.30	Field survey
8	Cycle correction factor for pollutant 'p' (CARB Technology)	A, B	Unit less	Details of Cycle correction factor for pollutant 'p' are presented in previous Table 16					ARAI,2007
9	Air emission rate of pollutant 'p', from a vehicle	$AER_{p,I}$	gm/km	Details of air emission rate of pollutant 'p' are presented in previous Table 20					ARAI,2007
10	Noise quality Rating given by users	$NNR_{RII,i}$	Rating	Noise rating given by users are presented in Table 21					Questionnaire Survey
11	Average land value near the transport route on which ply	$APV_{II,i}$	Rs/ft^2	3126	3028	3286	2968	3925	Bhopal Collector Guidelines (2016)
12	Maximum land value of area near any transport route	MLV	Rs/ft^2	8357	8357	8357	8357	8357	
13	No of jobs created in a city	$NJC_{I,i}$	Nos.	1350					Bhopal city link limited
14	Total No. of Job created by transport system in a city	TJC_t	Nos.	4730					Survey

Table 20: Details of air emission rate of pollutant 'p' from public transport service 'II' (Mini bus service)

S. No.	Parameters	Notation	Air Emission Rate (gm/km)
1	Air emission rate of pollutant 'CO', from a vehicle of public transport service 'II'	$AER_{CO,II}$	3.66
2	Air emission rate of pollutant 'CO2', from a vehicle of public transport service 'II'	$AER_{CO2,II}$	401.25
3	Air emission rate of pollutant 'HC', from a vehicle of public transport service 'II'	$AER_{HC,II}$	1.35
4	Air emission rate of pollutant 'NOX', from a vehicle of public transport service 'II'	$AER_{NOx,II}$	2.12

[Source: ARAI, (2007)]

Table 21: Noise Quality Rating Given by Users for Public transport service 'II' (Mini bus service) on Route 'i'

S. No.	Description	Notation	Noise Rating given by users on a Route 'i'				
			$RT_1(A_1)$	RT_1	RT_2	RT_7	RT_{11}
1	Number of users given noise rating 5 for public transport service 'II'	$NNR_{5II,i}$	9	8	8	5	6
2	Number of users given noise rating 4 for public transport service 'II'	$NNR_{4II,i}$	8	7	10	11	9
3	Number of users given noise rating 3 for public transport service 'II'	$NNR_{3II,i}$	13	16	15	12	15
4	Number of users given noise rating 2 for public transport service 'II'	$NNR_{2II,i}$	11	12	11	13	14
5	Number of users given noise rating 1 for public transport service 'II'	$NNR_{1II,i}$	12	10	9	12	9
6	Total number of users given noise rating for public transport service 'II'	$TNN_{II,i}$	53	53	53	53	53

[Source: Field Survey]

4.2 Analysis and Results of Comparative Performance Evaluation of public transport services

This section presented the analysis results of comparative performance of public transport service 'I' (i.e. BCLL bus system) with respect to public transport service 'II' (i.e. Mini bus system of Bhopal city from city perspective. The input data of Table 10 to Table 21 are analyzed using Equation 1 to Equation 21 to determination of the comparative performance of BCLL bus service w.r.t Mini bus service. The results obtained from the analysis of input data are presented in Table 22.

Table 22: Analysis Results of Performance of public transport service's'

S. No.	Performance Index	Notation	Index Value	
			Public transport service 'I' (BCLL bus service)	Public transport service 'II' (Mini Bus service)
1	City Mobility index	CMBIs	0.631	0.515
2	City Coverage index	CCGIs	0.194	0.178
3	Transport Capacity index	TCTIs	0.581	0.769
4	Air Quality Condition index	AQCIs	0.653	0.524
5	Noise Quality Condition index	NQCIs	0.648	0.564
6	Economic Activity index	EATIs	0.443	0.391
7	City Employment index	CEMIs	0.207	0.285

It is clearly indicated that analysis results from Table 22 The performance of BCLL bus system are poorly satisfactory from route coverage and local employment aspects, preferably satisfactory from land value aspect and fairly satisfactory from mobility, passenger carrying capacity, air quality and noise quality aspects from city perspective. Further, the analysis results also indicated that The performance of Mini bus system are poorly satisfactory from route coverage and local employment aspects, preferably satisfactory from mobility, air quality and land value aspect and fairly satisfactory from passenger carrying capacity and noise quality aspects from city perspective. The analysis and results of BCLL bus system and Mini bus system are also represented graphically in Figure 4.

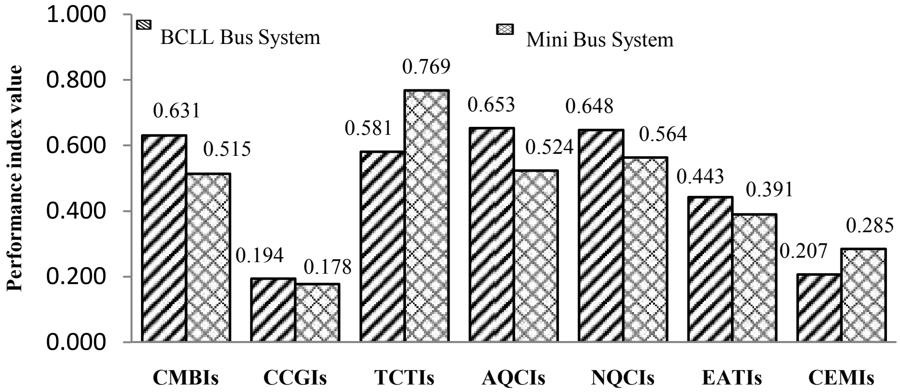

Figure 4: Graphical results of performance of alternate bus systems from various aspects of city perspective

Further, the analysis and results of comparative performance of BCLL bus service w.r.t Mini bus service from city mobility, city coverage, passenger carrying capacity, air quality, noise quality, land development and local employment aspects are presented in Table 23.

Table 23: Analysis Results of Comparative Performance of BCLL Bus System W.r.t Mini Bus System

S. No.	Comparative City Performance Index	Notation	Index Value	Remark
1	Comparative city mobility index	$CCMI_{I/II}$	1.227	Superior performance of BCLL bus system from city mobility aspect
2	Comparative city coverage index	$CCCI_{I/II}$	1.088	Superior performance of BCLL bus system from city coverage aspect
3	Comparative transport capacity index	$CTCI_{I/II}$	0.756	Inferior Performance of BCLL bus system from transport capacity aspect
4	Comparative air quality index	$CAQI_{I/II}$	1.247	Superior performance of BCLL bus system from air quality aspect
5	Comparative noise quality index	$CNQI_{I/II}$	1.150	Superior performance of BCLL bus system from noise quality aspect
6	Comparative economic activity index	$CEAI_{I/II}$	1.133	Superior Performance of BCLL bus system from economic activity aspect
7	Comparative city employment index	$CCEI_{I/II}$	0.726	Inferior Performance of BCLL bus system from city employment aspect

The analysis results from Table 23 clearly indicated the performance of BCLL bus system is superior with respect to Mini bus system under city mobility, city coverage, air quality, noise quality, and land value aspects from in context of Bhopal city perspective. It is logically true because BCLL bus system having more operating speed, excellent route information facilities, less no of buses operating, high seating capacity and major route connectivity. While the Mini bus system is flexible and having poor route information facilities, low seating capacity and more no of mini buses operating. Further, the performance of BCLL bus system is inferior with respect to Mini bus system under transport capacity and city employment aspects from Bhopal city perspective. It is also logically true because BCLL bus system having more passengers travelled in a day and more no of buses create more jobs. The analysis and results of comparative performance of BCLL bus system are also represented graphically in Figure 5.

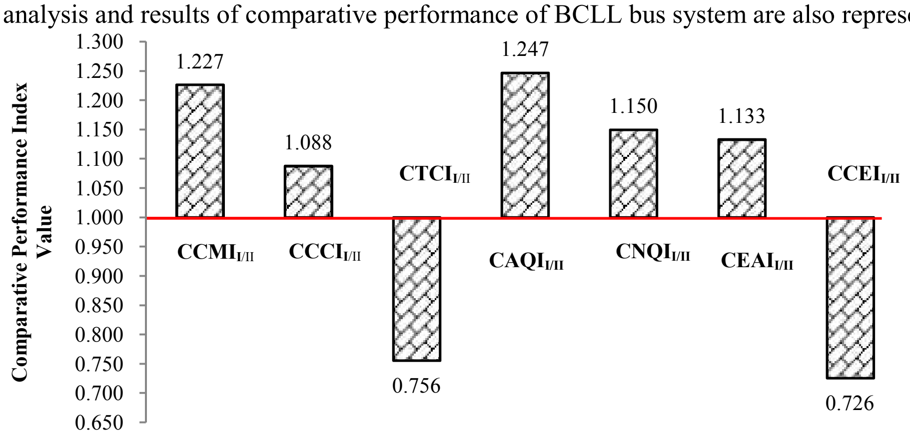

Figure 5: Graphical analysis results of comparative performance of BCLL bus system w.r.t Mini bus system from various city aspects

Further, the analysis and results of performance of BCLL bus system with respect to Mini bus system from travel, environmental and economic aspects as well as combined from city perspective are presented in Table 23.

Table 23: Analysis results of performance of BCLL bus system w.r.t Mini bus system from travel, environmental, and economic aspects

S. No.	Comparative City Performance Index	Notation	Index Value	Remark
1	Comparative Travel Performance Index	$CTLI_{I/II}$	1.018	Superior performance of BCLL bus system from travel aspect
2	Comparative Environmental Performance Index	$CELI_{I/II}$	1.206	Superior Performance of BCLL bus system from environmental aspect
3	Comparative Economical Performance Index	$CECI_{I/II}$	0.904	Inferior Performance of BCLL bus system from economical aspect
4	**City Comparative Performance index**	$CCPI_{I/II}$	**1.043**	**Superior performance of BCLL bus system from overall aspects from city perspective**

The analysis results from Table 9.12 clearly indicated the performance of BCLL bus system with respect to Mini bus system is superior under time aspect and quality aspect and inferior from cost aspects. However the overall comparative performance of BCLL bus system with respect to Mini bus system is superior. The analysis and results of comparative performance of BCLL bus system are also represented graphically in Figure 9.6.

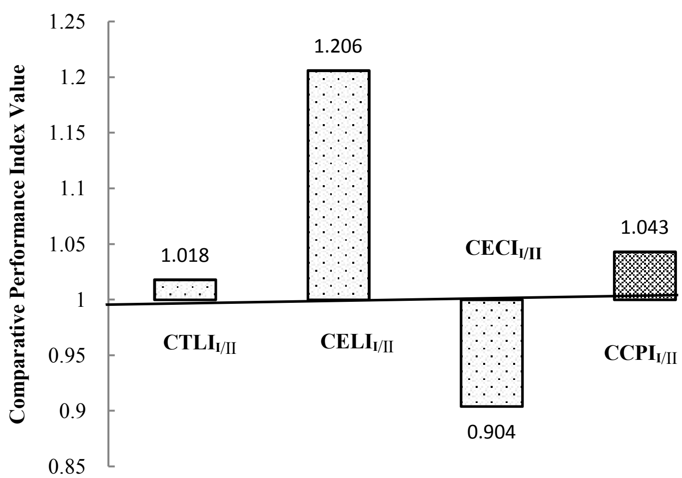

Figure 6 : Graphical results of comparative performance of BCLL bus service w.r.t Mini bus service from travel, environmental, and economic aspects

5 Conclusions

The important conclusions drawn from this study are as follows:

- The research studies conducted for evaluating the comparative performance of public transport services in context to the developed countries might be irrelevant for the developing countries due to difference in socio economic structure and therefore, it is necessary to develop a methodology for comparative performance evaluation of alternate public transport system in context to developing countries.
- The selection of appropriate performance indicators for a particular perspective is a complicated task. In the present work, a methodology is proposed to select most relevant and appropriate, simple but effective, performance indicators for all the three perspectives in Indian context.
- The performance indices developed in the present study are simple and can evaluate the comparative performance of alternate public transport system easily.
- Different categories of performance indicators have a greater or lesser impact in evaluating the performance of alternate public transport system. Hence, relative contribution of these performance indicators in analyzing the overall performance of public transport system in Indian context has been proposed. A hierarchical structural model is developed in sub stage-IIA for identification of the most important comparative key city performance indicators. This structure is developed on the basis of results of factor analysis. A hierarchical structure is presented seven most significant comparative key city performance indicators as CCI_1 to CCI_7. The most important to least important indicators are comparative air quality (CCI_4), comparative city coverage (CCI_2), comparative city mobility (CCI_1), comparative transport capacity (CCI_3), comparative city employment (CCI_7) comparative noise quality (CCI_5) and comparative economic activity (CCI_6). The comparative key city performance indicators are aggregated under three sub criteria i.e. comparative sub performance indicators asCSC_1 to CSC_3.These are comparative travel performance (CSC_1), comparative environmental performance (CSC_2) and comparative economic performance (CSC_3).

- The comparative city mobility index ($CCMI_{I/II}$), comparative city coverage index ($CCCI_{I/II}$), comparative transport capacity index ($CTCI_{I/II}$), comparative air quality index ($CAQI_{I/II}$), comparative noise quality index ($CNQI_{I/II}$), comparative economic activity index ($CEAI_{I/II}$) and comparative city employment index ($CCEI_{I/II}$). These indices are developed in such a manner so that it is used to compare and quantify the comparative performance of public transport system 'I' with respect to public transport system 'II' from various aspects. The value of indices may be greater than, equal to or less than one. Greater than one means the performance of public transport system 'I' is superior to the public transport system 'II'.
- The relative weight of comparative key city performance indicators is determined using FAHP in sub stage-IIC. The relative weight of city mobility, city coverage, transport capacity, air quality, noise quality, economic activity, and city employment are assigned 0.152, 0.161, 0.149, 0.166, 0.121, 0.110, and 0.141 respectively from analysing of opinions of transport experts and academicians using FAHP technique. Further the relative weights of comparative travel performance, comparative environmental performance and comparative economic performance are assigned 0.462, 0.287 and 0.251respectively in this sub stage.
- The city comparative performance index ($CCPI_{I/II}$) is developed in sub stage-IID. This index is used to evaluate the overall comparative performance of public transport system 'I' w.r.t. public transport system 'II' from city perspective. Further, The comparative travel performance index (CTLII/II), comparative environmental performance index (CELII/II), and comparative economic performance index (CECII/II) is also developed for comparison of public transport system 'I' w.r.t. public transport system 'II' from travel, environmental and economic aspects respectively. In this study, the application of proposed methodology is illustrated using BCLL bus system and Mini bus system of Bhopal city in the state of Madhya Pradesh.

References

[1] Abreha, D. A., (2007), "Analyzing Public Transport Performance using Efficiency Measures and Spatial Analysis; the case of Addis Ababa", International Institute for Geo- Information Science and Earth Observation, University of Twente, Ethiopia.

[2] Agarwal P.K., Gurjar J., Gupta V (2017), "Evaluation of Socio-economic Impact of City Bus Services in Developing Countries."Transportation Research Procedia 25 (2017), 4589–4605.

[3] Agarwal P. K., Gurjar J., Gautam A., Jain P. K. (2015), "A Rational Methodology for Evaluation of the Impact of Public Transit Service in a City" International Journal of Frontier technology (IJFT), 2 (2), 18-25.

[4] Alonso A., Monzón A., and Cascajo R., (2015) "Comparative analysis of passenger transport sustainability in European cities", Ecological Indicators, 48,578–592.

[5] Bhat C.R., GuoJ. Y., Sen S., and Weston L., (2005) "Measuring Access to Public Transportation Services: Review of Customer-Oriented Transit Performance Measures and Methods of Transit Submarket Identification", Technical Report, Center for Transportation Research, University of Texas, Austin.

[6] Cascajo, R., (2014) "Socio-Environmental Benefits of Rail Urban Projects: An European Benchmarking", Proceedings of the European Transport Conference.

[7] Castillo, H., and Pitfield D., (2010) "A Methodological Framework for Identifying and Selecting Sustainable Transport Indicators", Transportation Research Part D, 15 (4), 179–188.

[8] Das S., and Pandit D., (2013) "Importance of User Perception in Evaluating Level of Service for Bus Transit for a Developing Country like India: A Review" Transport Reviews: A Transnational Tran disciplinary Journal, 33(4), 402–420.

[9] DULT, (2013), "Tumkur City Bus Service Evaluation Report" Directorate of Urban Land Transport (DULT), Government of Karnataka.

[10] Feng C., and Hsieh C., (2009) "Resource Allocation for Sustainable Urban Transit from a Transport Diversity Perspective", Sustainability, 1, 960–977.

[11] Gandhi S., Tiwari G., and Joseph F., (2013) "Comparative Evaluation of Alternate Bus Rapid Transit System (BRTS) Planning, Operation and Design Options", Proceedings of the Eastern Asia Society for Transportation Studies, 9.

[12] Gurjar J. Agarwal P. K. and Ahirwar P. P. (2015) "Development of a Smart Public Transport System in Indian Cities: Basic Concepts" "TJPRC: International Journal of Traffic and Transportation Engineering & Research (TJPRC: IJTTER) 1, 1-9.

[13] Kanuganti S., Subramanian U., Arkatkar S.S., Singh A.P., and Sarkar A.K.,(2013) "Quantification of Level-of-Service Index for Bus Routes in Developing Countries: A Case Study in India", Proceedings of the Eastern Asia Society for Transportation Studies, 9.

[14] Litman T., (2007) "Developing Indicators for Comprehensive and Sustainable Transport Planning", Transportation Research Record, TRB, 10-15.

[15] Ministry of Urban Development (2009) "Service Level Benchmarks for Urban Transport", Ministry of Urban Development (MOUD) New Delhi, Government of India.

[16] Ministry of Urban Development (2014) "Draft Concept Note on Smart Cities, National Conclave of Ministers and Principal Secretaries/Secretaries of States and Union Territories" MoUD, Government of India, New Delhi.

[17] Jain U. and Nanda K. K., (2014) "Innovative Strategy towards Organized Public Transport. Case Study: Bhopal" Research Symposium Urban Mobility India.

[18] Pticina, I., (2011), "The Methodology of Data Collection about Public Transport Service Quality," Proceedings of the 11th International Conference on Reliability and Statistics in Transportation and Communication, Riga, Latvia, pp, 155-164

[19] Ramani T., Zietsman J., Eisele W., Rosa D., Spillane D.,andBochner B., (2009), "Developing Sustainable Transportation Performance Measures for TXDOT's Strategic Plan", Technical Report, Texas Transportation Institute, Texas.

[20] Sheth, C. H., (2003). The Measurement and Evaluation of Performance of Urban Transit Systems□: The Case of Bus Routes" MS A Dissertation, Virginia Polytechnic Institute, Virginia.

[21] The Automotive Research Association of India (ARAI) 2007. "Draft report on "Emission Factor development for Indian Vehicles,". Pune, 2007.

[22] TRB-Transportation Research Board, (2010) "A Methodology for Performance Measurement and Peer Comparison in the Public Transportation Industry", TCRP Report 141. Washington D.C.

[23] TRB-Transportation Research Board (2003), "A Guidebook for Developing a Transit Performance- Measurement System" TCRP Report 88. Washington D.C

[24] Wilbur Smith Associates, (2008), "Study on Traffic and Transportation Policies and Strategies in Urban Areas in India" Technical Report, Ministry of Urban Development, India.