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PERFORMANCE EVALUATION OF PUBLIC TRANSPORT SYSTEM FROM USER POINT OF VIEW

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Abstract: ***User perspective play a vital role in determining whether a public transport system is used and which reflects travel time, travel cost, reliability, comfort as well as safety at the same time. Recently, various alternate public transport systems like Bus rapid transit (BRT) system, Light rail transit (LRT) system, Mass rapid transit (MRT) system and various others are operating or to design a new public transport system or to improve the performance of an existing one in various Indian cities. It is also observed that huge investment is required for implementation or alteration of this public transport system in Indian cities. Hence, the significant attention is required to planning, designing or performance evaluation of the alternate public transport system from the user aspect. Thus a simple, intelligent and scientific methodology is required for assessment of comparative performance of the alternate public transport system from user perspective so that to select the most appropriate alternate public transport system for a given city size. Hence, this study presents a simple and systematic methodology for comparative performance of the alternate public transport system in Indian cities considering user perspective. The proposed methodology also illustrated using Bhopal city bus services. It is expected that this study will be useful for evaluating the comparative performance of an existing public transport system as well as a new public transport system to any similar system or different public transport system from a user perspective in Indian context.***

Index Terms: User perspective, Alternate Public transport system, Fuzzy AHP, Comparative User performance index.

I. INTRODUCTION

Past few decades India has experienced high population growth in urban areas. It is expected that by 2050, about 60-70 per cent of the population will be living in urban areas in India. Mfinanga & Ochieng, 2006 [1] discussed that more than 80% of the riders of public transport in developing nations are captive, i.e. dependent on public transport. Hence, Public transport system in Indian cities must be more creative and attractive due to higher dependency of urban population. But at this time the public transport infrastructure in these cities is not appropriate for the current transport demand so that public transport systems are encounter distinctive challenges in planning, maintaining and operating their services in Indian cities results in an increase of travel cost, traffic congestion, pollution and land sprawl etc. Further, Recently, various alternate public transport systems like Bus rapid transit (BRT) system, Light rail transit (LRT) system, Mass rapid transit (MRT) system and various others like Mini bus service are operating or to design a new public transport system or to improve the performance of an existing one in various Indian cities. It is also observed that the enormous amount of money is required for implementation of this public transport system in Indian cities. Consequently, User perspective play a vital role in determining whether a public transport system is used and which reflects travel time, travel cost, reliability, comfort as well as safety at the same time. Now-a-days most of the providers have its own method to know the performance of public transport system. However, the performance evaluations by the providers do not necessarily reflect the user perspective and cannot be considered adequate. Hence, the significant explanation to determination of comparative performance of the alternate public transport system from the user aspect are to control operational & travel costs, and justify the adjustments in the system before its implementation. Thus a simple, intelligent and scientific methodology is required for assessment of comparative performance of the alternate public transport system from user perspective so that to select the most appropriate public transport system for a given city size. However, most of the methodologies available in literature from a user perspective may not be satisfactory for evaluating the performance of alternate public transport system due to absent of database. Hence, this study presents a simple and systematic methodology which can assess comparative performance of the alternate public transport system in Indian cities considering user perspective with minimal data which are available easily at minimum cost. The proposed methodology consists of four major stages. The first stage is to identify the most appropriate key user performance indicators for comparative performance evaluation of

alternate public transport system in Indian context. The second stage served to develop a methodology for evaluation of condition of identifying key user performance indicators. The third stage determines the relative weight of identified key user performance indicators using Fuzzy AHP method. In last stage developed comparative time performance index, comparative cost performance index and comparative quality performance index. These indices are developed in such a way that the comparative performance of the alternate public transport system can be evaluated separately from time, cost and quality aspect so as to identify the issues related to each separately from a user perspective. This study also developed a comparative user performance index (CUPI) which can be used to indicate the overall comparative performance of the alternate public transport system from a user perspective. The methodology proposed in this study is also illustrated using a BCLL bus service and Minibus service in Bhopal city. This paper consists of five sections among this is the one. The second section highlights the important deficiencies in the literature review. A methodology for comparative analysis of alternate public transport system from a user perspective is presented in section three. The analysis results using the proposed methodology for comparative performance of BCLL bus service and Minibus service are presented in section four. The last section presents the important conclusions drawn based on this study.

II. REVIEW OF LITERATURE

Gandhi Et al [2] studied that user perspective play a prominent role in determining whether a system is used and thus deserve careful attention while planning, designing or evaluating a public transport system from a user perspective. Performance indicator can be used to control costs, maintain or improve the quality of the system, justify changes in a system like spacing between stops, peak speeds route & lane extensions, signal cycle lengths, types of vehicle etc., and report the status of the public transport system to decision makers. TRB [3] discussed that precise and relevant performance indicators will give a clear overview of the public transport systems and will help to monitor the benefits of implementing efficient public transport system in a city. The approach to assess the performance of the public transport system using performance indicators is relatively easy to implement.
However some indicators are operator specific indicators not user specific or some only qualitative nature and not quantitative indicators. Hence a critical literature review was carried out on performance evaluation of public transport system using performance indicators. Table 1 presents a critical literature review on performance evaluation of public transport system from a user perspective.

Table 1 Critical Review on Performance Evaluation of Public Transport System from User Aspect

S. No.	Author (Year)	Key Indicators	Study Area	Data Type
1	Gurjar J. Et al (2016) [4]	5	Bhopal, India	Quantitative & Qualitative
2	Agarwal P. K. Et al (2016) [5]	13	Bhopal, India	Quantitative & Qualitative
3	Chowdhury S. Et al (2015),[6]	3	Auckland, New-Zealand	Quantitative
4	Garrido C. Et al (2014), [7]	12	Granada, Spain	Qualitative
5	Singh A. P. Et al (2014),[8]	12	Bhopal India	Qualitative
6	Aidoo E. N., Et al (2013),[9]	13	Kumasi, Ghana	Qualitative
7	Gandhi Et al (2013), [2]	10	Ahmedabad, and Delhi, India	Qualitative
8	UDD, Govt. of Karnataka 2013[10,11]	4	Hassan, Tumkur, India	Quantitative
9	Putra A. A. (2013), [12]	14	Makassar, Indonesia	Qualitative
10	Choocharukul K. & Sriroongvikrai K. (2013),[13]	24	Bangkok	Qualitative
11	Ali J. M., Et al (2013), [14]	34	Kuala Lumpur and Selangor	Qualitative
12	Javid M.A. Et al (2013),[15]	13	Lahore, Pakistan	Qualitative
13	Roux Y. E. Et.al (2012), [16]	14	African Cities	Quantitative & Qualitative
14	Castillo J. M. D., & Benitez F. G. (2012), [17]	35	Bilbao (Spain).	Quantitative & Qualitative
16	Sezhian Et.al (2011), [18]	36	Tamil Nadu, India	Quantitative & Qualitative
17	Filipovic, S. Et al (2010), [19]	8	Belgrade city	Quantitative & Qualitative

Based on the critical review of the literature some of the important conclusion may be summarized as follows:

- It is observed that large no of performance indicators used worldwide previously{ Agarwal P. K. Et al (2016) [5], Garrido C. Et al (2014) [7],

Singh A. P. Et al (2014),[8], Aidoo E. N., Et al (2013),[9], Putra A. A. (2013), [12], Choocharukul K. & Sriroongvikrai K. (2013), [13], Ali J. M., Et al (2013), [14], Castillo J. M. D., & Benitez F. G. (2012), [17], Sezhian Et.al (2011), [18]} to evaluate the performance of public transport system from user aspect. Therefore, the criteria used for classification of performance indicator are acceptable from Indian context, consistent with goals and objectives, easy to understand, directly affect the user performance and availability of data. Stradling,(2002),[19], Choocharukul K. & Sriroongvikrai K., (2013),[13], Gurjar Et al, (2016),[4] Sharaby and Shiftan, (2012),[20], and Dell'Olio et al., (2011),[21]found that travel time is the most important indicator from user aspect as well as travel cost and comfort are also important indicators from user point of view. Filipovic, S. Et al (2010), [19], Gurjar Et al (2016) [4] and Peek & Van Hagen, (2002),[22] discussed that safety, reliability, and comfort are the foundation indicators from user perception. Table 2 presents most important performance indicators from user opinion and Indian expert opinion survey suggested by Das S. and Pandit D., (2013)[23].

Table 2 Important Performance Indicators from User Opinion and Indian Expert Opinion Survey

S. No.	Important Performance Indicators From Users Opinion	Important Performance Indicators From Indian Transport Expert opinion
1	Journey time	Number of transfers
2	Bus stop accessibility	Waiting time at transit stop
3	Service coverage	Safety and security
4	Reliability / On time performance	Travel time
5	Safety and security from accidents and thefts	Ease of access to bus stop
6	Crowding level	Vehicle design & Comfort

- A literature review indicated that most of the performance indices developed in previous studies will not have any comparisons of services to identify necessary changes needed to provide more effective and efficient service. For example, most of the studies considered travel time index which can evaluate by total time taken by transit from origin to destination although these index cannot used to directly compare two public transport systems which is operate on different routes. Further, Very few methodologies {Gurjar et al., (2016)[4] Gandhi Et. al., (2013)[2]; Agarwal Et al., (2016)[5], Roux Y. E. et.al, (2011)[16]; Sezhian Et. al., (2011),[18]} is available for comparative performance evaluation of the public transport system. Therefore, there is need to select performance indices in such a way so that it can compare two alternate public transport system directly.

- Most of the researchers {MOUD, (2009)[24], UDD, Govt. of Karnataka, (2013)[10,11], Javid, M. A. Et al., (2013)[15], Shukla A. (2012)[25], Fu, L. & Xin, Y., (2007)[26]} simply aggregate the performance indicators to estimate the overall performance of public transport system from a user perspective. However, the significant differences exist between several categories of performance indicators that have a greater or lesser impact on comparative performance evaluation of alternate public transport system. Hence, need to determine the relative weight of performance indicators for significantly performance analysis of public transport system in Indian context individually as well as combined.

- It is notified that in most of research studies developed performance indices which are often relatively straight forward but Gurjar et al., (2016)[4], Agarwal P.K. Et al., (2016)[5], Khasnabis S. Et al., (2003)[27] and Pticina I., (2011)[28] discussed that in practice it may be much more complicated to obtain the necessary comparative information about public transport system due required data for some of the indicators are promptly available and others are sophisticated to obtain from field such as % population in walking distance, number of accidents from public transport system.

Thus, there is need to develop a simple, easy and systematic methodology which can evaluate the comparative performance of the alternate public transport system from user point of view with minimal data which is easily available at minimum cost.

III. RESEARCH METHODOLOGY

This study presents a simple and systematic methodology for comparative performance evaluation of alternate public transport system from a user perspective. The proposed methodology consists of four major stages. The major stages of proposed methodology and their purpose are presented in table 3.

Table 3 Major Stages of Proposed Methodology

S. No	Stages	Purpose of the Stage
1	**Stage – I:** Identification of key Indicators for comparative performance evaluation from user perspective	The first stage is to identify the most appropriate key user performance indicators for comparative performance evaluation of alternate public transport system in Indian context.
2	**Stage-II:** Evaluation of Condition of Key User Performance Indicators	The second stage served to develop a methodology for evaluation of condition of identified key user performance indicators.
3	**Stage-III:** Determination of Relative Weight of Key User Performance Indicators Using Fuzzy AHP	The third stage determines the relative weight of identified key user performance indicators using Fuzzy AHP method.
4	**Stage-IV:** Development of Comparative User Performance Index	The comparative user performance index (CUPI) is developed in last stage.

The details of major stages are presented in subsection of this section are as follows:

A. Stage I: Identification of Key Indicators for Comparative Performance Evaluation from User Perspective

The purpose of the first stage is to identify the most appropriate key user performance indicators which are affecting the comparative performance of the alternate public transport system in India. The classification of key performance indicators from a user perspective is a complicated task because many indicators are available in the literature and there is no comprehensive classification. The criteria used for classification of performance indicator in this study are acceptable from Indian context, consistent with goals and objectives, easy to understand, measure, minimum cost of data collection, availability of data, and lesser time needed for collection of data. Therefore, this study developed a hierarchical structure logically to the selection of the most significant indicators on the basis of literature review. A hierarchical structure for identification of key user performance indicators is presented in Figure 1.

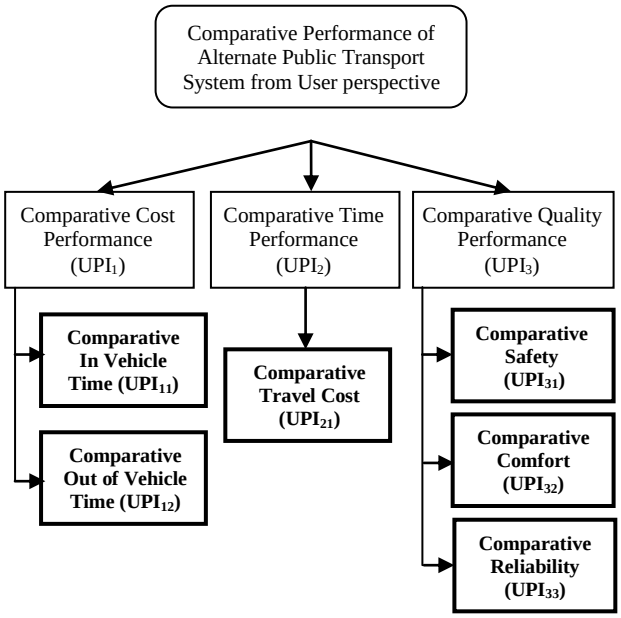

Figure 1: A Hierarchical Structure for Decomposition of User Performance Indicators

The highest level of the hierarchy is the overall goal of the methodology. The second level represents the three major criteria, i.e. comparative time performance, comparative cost performance and comparative quality performance. Further at third level these major criteria decomposed in 6 key user performance indicators, four (UPI_{11}, UPI_{12}, UPI_{21}, and UPI_{33}) of them are measured by quantitative indices and the remaining two (UPI_{31}, and UPI_{32}) are measured by qualitative indices (user rating survey). These key performance indicators used to evaluate comparative performance of the alternate public transport system each separately from a user perspective.

B. Stage II: Evaluation of Condition of identifying Key User Performance Indicator

The third stage developed various important indices for evaluation of condition of identified key user performance indicators. These indices are developed in such a way that the comparative performance of the alternate public transport system can be evaluated in Indian cities from a user perspective with minimal data**.** The value of indices greater than one, equal to one and less than one indicates the comparative performance of alternate public transport system 1 is superior, equal and inferior quality with respect to alternate public transport system 2.

1. Comparative in Vehicle Time Index (CITI)

It is the ratio of Average travel time per km in vehicle in minute for alternate public transport System1 (ATT_1) to Average travel time per km in vehicle in minute for alternate public transport System 2 (ATT_2). It can be evaluated using equation (1).

$$\mathrm{CITI} = \frac{\mathrm{ATT}_2}{\mathrm{ATT}_1} \ldots\ldots\ldots \text{Equation (1)}$$

Average travel time (ATT) is the average time spent by users in a vehicle during journey. It is calculated using equation (2).

$$\mathrm{ATT}_{1/2} = \frac{60 * \mathrm{CRL}_{1/2}}{\mathrm{AOS}_{1/2}} \ldots\ldots\ldots \text{Equation (2)}$$

Where,

CTL = Compared Route length in km
AOS = Average operational speed in kmph

2. Comparative out of vehicle Time Index (COTI)

It is the ratio of average out of vehicle time in minute for alternate public transport System1 (AOT_1) to average out of vehicle time in minute for alternate public transport System 2 (AOT_2). It can be assessed using equation (3).

$$\mathrm{COTI} = \frac{\mathrm{AOT}_2}{\mathrm{AOT}_1} \ldots\ldots\ldots \text{Equation (3)}$$

Average out of vehicle time is the average time spent by users from out of vehicle during journey. It includes average waiting time at stop (WTT) and average transfer time (TFT) from origin to stop and stop to destination during journey. Average waiting time at stop (WTT) is calculated using equation (4).

$$\mathrm{WTT}_{1/2} = \frac{60}{\mathrm{NVS}_{1/2}} \ldots\ldots\ldots \text{Equation (4)}$$

Where,

NVS=No of vehicles of particular public transport system reached at stop per hour.

3. Comparative travel Cost Index (CTCI):

It is the ratio of average travel cost per km for alternate public transport System 1 (ATC_1) to average travel cost per km for alternate public transport System 2 (ATC_2). It can be evaluated using equation (5)

$$\mathrm{CTCI} = \frac{\mathrm{ATC}_2}{\mathrm{ATC}_1} \ldots\ldots\ldots \text{Equation (5)}$$

4. Comparative Safety Index (CSFI)

It is the ratio of Safety rating given by users during travel in vehicle and waiting at stop for alternate public transport System 1(SRT_1) to Safety rating given by users during travel in vehicle and waiting at stop for alternate public transport System 2 (SRT_2). It can be evaluated using equation (6)

$$\mathrm{CSFI} = \frac{\mathrm{SRT}_1}{\mathrm{SRT}_2} \ldots\ldots\ldots \text{Equation (6)}$$

$$\mathrm{SRT}_{1/2} = \frac{(5 * \mathrm{R}_5)_{1/2} + (4 * \mathrm{R}_4)_{1/2} + (3 * \mathrm{R}_3)_{1/2} + (2 * \mathrm{R}_2)_{1/2} + (1 * \mathrm{R}_1)_{1/2}}{\mathrm{TNR}_{1/2}}$$

Where,

TNR = Total no of respondent
R5= No of respondent feel extremely safe during travel in vehicle and waiting at stop (5), R4= No. of respondent feel good safe during travel in vehicle and waiting at stop (4), R3= No. of respondent feel average safe during travel in vehicle and waiting at stop (3), R2 = No. of respondent feel safe to some extent during travel in vehicle and waiting at stop (2), R1 = No. of respondent feel not at all safe during travel in vehicle and waiting at stop (1).

5. Comparative Comfort Index (CCFI):

It is the ratio of comfort rating given by users during travel in vehicle and waiting at stop for alternate public transport system 1(CRT_1) to comfort rating given by users during travel in vehicle and waiting at stop for alternate public transport system 2 (CRT_2). It can be evaluated using equation (7).

$$\mathrm{CCFI} = \frac{\mathrm{CRT}_1}{\mathrm{CRT}_2} \ldots\ldots\ldots \text{Equation (7)}$$

$$\mathrm{CRT}_{1/2} = \frac{(5 * \mathrm{R}_5)_{1/2} + (4 * \mathrm{R}_4)_{1/2} + (3 * \mathrm{R}_3)_{1/2} + (2 * \mathrm{R}_2)_{1/2} + (1 * \mathrm{R}_1)_{1/2}}{\mathrm{TNR}_{1/2}}$$

Where,

TNR=Total no of respondent
R5= No of respondent feel extremely comfort during travel in vehicle and waiting at stop (5), R4= No. of respondent feel good comfort during travel in vehicle and waiting at stop (4), R3= No. of respondent feel average comfort during travel in vehicle and waiting at stop (3), R2 = No. of respondent feel comfort to some extent during

travel in vehicle and waiting at stop (2), R1 = No. of respondent feel not at all comfort travel in vehicle and waiting at stop (1).

6. Comparative Reliability Index (CRBI)

It is the ratio of average reliability of vehicle at stop for alternate public transport System 1 (ARB_1) to average reliability of vehicle at stop for alternate public transport System 2 (ARB_2). It can be evaluated using equation (8).

$$\mathrm{CRBI} = \frac{\mathrm{ARB}_1}{\mathrm{ARB}_2} \ldots\ldots\ldots \text{Equation (8)}$$

$$\mathrm{ARB}_{1/2} = \frac{\mathrm{NOT}_{1/2}}{\mathrm{TNT}_{1/2}} \ldots\ldots\ldots \text{Equation (8)}$$

Where,

NOT= No. of trips on time on the stop in a route
TNT= Total no. of trips in same route.

C. Stage III: Determination of Relative Weight of Key User Performance Indicators Using Fuzzy AHP Method

The third stage determines the relative weight of identified key user performance indicators using Fuzzy AHP. The identified indicators may not be equally affecting because significant differences exist among several categories of performance indicators that have a greater or lesser impact on comparative performance evaluation of alternate public transport system. Therefore, a system of weights needs to be introduced to reflect the contribution to comparative performance of public transport system. The relative weight of key user performance indicators are determined by Fuzzy AHP method using passengers and transport expert opinion survey. The fuzzy AHP (FAHP) technique can be viewed as an advanced analytical method developed from the traditional AHP. FAHP is used to generate the weighting of the major criteria and key user performance indicators. FAHP is proposed to relieve the uncertainness of AHP method, where the fuzzy comparisons ratios are used { Lee Et al [29] }. Lee Et al [29] explained there are six essential steps for determination of relative weight using Fuzzy AHP:

1. Construct a hierarchical structure with performance indicators, including main criterion and sub criterion. Each decision maker is asked to express the relative importance of two decision elements in the same level by a nine point linguistic scale. Collect the scores of pairwise comparison, and form pairwise comparison matrices for each of the K decision makers.
2. The consistency property of the matrix is then checked to ensure the consistency of judgments in the pairwise comparison.
3. Construct fuzzy positive matrices. The scores of pairwise comparison are transformed into linguistic variables.
4. Calculate the fuzzy weights of decision elements.
5. Arithmetic average is applied to combine the fuzzy weights of decision makers.
6. Determine the normal weight of performance indicator.

The final relative weight of key indicators obtained from Fuzzy AHP method is presented in Table 3.

Table 3: Relative Weight of Identified Key User Performance Indicators

	Fuzzy Sum of Each Row			Heating Expansion Phase			Preferred Si to Sk					Degree Preferred	Normal Weight	
Comparative in vehicle time	6.294	8.196	10.515	0.119	0.202	0.341	1.000	0.712	1.000	1.000	1.000	0.712	0.238	0.402
Comparative Out of vehicle time	5.152	6.522	8.238	0.097	0.161	0.267	0.782	0.491	1.000	1.000	1.000	0.491	0.164	
Comparative Travel Cost	8.175	11.250	14.577	0.155	0.278	0.473	1.000	1.000	1.000	1.000	1.000	1.000	0.334	0.334
Comparative Safety	3.734	4.820	6.459	0.071	0.119	0.209	0.521	0.727	0.257	0.930	1.000	0.257	0.086	0.265
Comparative Comfort	3.989	5.231	7.022	0.075	0.129	0.228	0.598	0.804	0.330	1.000	1.000	0.330	0.110	
Comparative Reliability	3.493	4.482	6.097	0.066	0.111	0.198	0.462	0.666	0.206	0.939	0.869	0.206	0.069	
Sum	**30.837**	**40.501**	**52.908**									**2.996**	**1.000**	
Inverse of Sum	**0.032**	**0.025**	**0.019**											

D. Stage IV: Development of Comparative User Performance Index (CUPI)

A user perspective is the primary determinant which reflects quality of service, affordability and accessibility of public transport system as well as the user's comfort-discomfort, safety and reliability at the same time during travelling as well as waiting at the

stop. It is proposed that the comparative performance of the alternate public transport system from a user perspective can be evaluated using an index named as a comparative user performance index (CUPI). The value of the comparative user performance index (CUPI) indicates the comparative performance of alternate public transport system 1 with respect to alternate public transport system 2. The comparative user performance index (CUPI) is evaluated using equation (9).

$CUPI=W_{CTP}*CTPI+W_{CCP}*CCTI+W_{CQP}*CQPI$…….. Equation (9)

Where,

W_{CTP}, W_{CCP}, and W_{CQP} are relative weights of respective comparative time performance comparative cost performance and comparative quality performance of public transport system as discussed earlier. Now putting the value of weight in Equation (9) it can be written as Equation (10)

CUPI=0.402*CTPI+0.334*CCTI+0.265*CQPI…… … Equation (10)

1. Comparative Time Performance Index (CTPI)

It is proposed that time performance of the alternate public transport system can be evaluated using an index named as a comparative time performance index (CTPI). The value of CTPI index indicates the comparative time performance of alternate public transport system 1 with respect to alternate public transport system 2. Comparative time performance index, which are depends upon comparative time in a vehicle and comparative time out of vehicle. It can be assessed utilizing Equation (11).

$CTPI=W_{CIT}*CITI+W_{COT}*COTI$..... Equation (11)

Where,

W_{CIT} and W_{COT} are relative weight of comparative in vehicle time and comparative out of vehicle time respectively as discussed earlier. Presently putting the estimation of weight in Equation (11) it can be composed as Equation (12)

CTPI=0.238*CITI+0.164*COTI..... Equation (10)

2. Comparative Cost Performance Index (CCPI)

It is recommended that cost performance of the alternate public transport system can be assessed utilizing comparative cost performance index (CCPI). The value of CCPI index indicates the comparative cost performance of alternate public transport system 1 with respect to alternate public transport system 2. The comparative cost performance index, which are depends upon the comparative cost during travel in a vehicle. It can be assessed utilizing Equation (13)

$CCPI=W_{CTC}*CTCI$..... Equation (13)

Where, W_{CTC} is the relative weight of the comparative travel cost as discussed earlier. Presently putting the estimation of weight in Equation (13) it can be composed as Equation (14).

CCPI=0. 334*CTCI..... Equation (14)

3. Comparative Quality Performance Index (CQPI)

It is recommended that quality performance of alternate public transport system can be assessed utilizing comparative quality performance index (CQPI). The value of CQPI index indicates the comparative quality performance of alternate public transport system 1 with respect to alternate public transport system 2. Comparative quality performance index which are depends upon comparative comfort, comparative safety and comparative reliability during travel in a vehicle and waiting at stop. It can be assessed utilizing Equation (15).

$CQPI=W_{CSF}*CSFI+W_{CCF}*CCFI+W_{CRB}*CRBI$ ..... Equation (15)

Where,

W_{CSF}, W_{CCF} and W_{CRB} are relative weight of comparative safety, comparative comfort and comparative reliability respectively as discussed earlier. Presently putting the estimation of weight in Equation (15) it can be composed as Equation (16).

CQPI=0.086*CSFI+0.110*CCFI+0.069*CRBI ..... Equation (16)

Thus, it is expected that this indices will be useful to evaluating the comparative performance of an existing public transport system as well as a new public transport system to any similar system or different public transport system from user perspective in Indian context.

IV. ANALYSIS AND RESULTS

The total route length is considered 9 km from Chetak Bridge (Kasturwa Nagar) to Misrod to delineate the proposed methodology utilizing alternate public transport system I i.e. BCLL bus service and alternate public transport system II i.e. Mini bus service of Bhopal city. The information has been gathered in this route for comparative analysis of BCLL bus service and mini bus service from field overview, previous studies and various authorities of BCLL bus service and Mini bus service. Also some of the data has been gathered

from opinion of users of BCLL bus service and mini bus service. The details of final input data for comparative analysis of BCLL bus service and mini bus service in Bhopal city are presented in Table 3.

Table 3 Details of Final Input Data for Analysis using Proposed Methodology

S. No.	Parameters	Alternate Public Transport System 1 (BCLL Bus Service)	Alternate Public Transport System 2 (Mini Bus Service)
1.	Total Route length	24km*	105km***
2	Compared route length	9km	9km
3	Total no of buses on compared route**	12	24
4	Average operational speed **	27.6 km/h	18.4km/h
5	No of vehicles reached at stop per hour**	4	6
6	Transfer time (Assumed)	10 min	10 min
7	Average travel cost per km (Rs /km)***	1.56 (for 9km-Fare Rs 14)	1.33 (for 9 km-Fare Rs 12)
8	Safety rating given by users****	3.87	2.76
9	Comfort rating given by user****	3.91	2.34
10	Total no of trips**	36	51
11	No of trips on time**	29	96
12	No of intersection**	12	12
13	No of stoppage**	9	17
14	Average signal cycle length **	45 sec	60 sec

(Source: *www.mybusbhopal.in, **Field Survey, ***Jain U. and Nanda K. K. [30], ****User opinion survey)

Using the input data analysis results of comparative performance of alternate public transport system I i.e. BCLL bus service with respect to alternate public transport system II i.e. Mini bus service are presented in Table 4. The analysis results are also presented graphically in Figure 4.

Table 4: Comparative Performance of BCLL Bus Service w. r. t. Mini bus service

S. No.	Key User Performance Indicator	Index value	Remark
1.	Comparative in vehicle Time Index **(CITI)**	1.56	Better performance of BCLL bus service
2.	Comparative out of vehicle Time Index **(COTI)**	0.80	Inferior performance of BCLL bus service
3.	Comparative travel Cost Index **(CTCI)**	0.85	Inferior performance of BCLL bus service
4	Comparative safety Index **(CSFI)**	1.40	Better performance of BCLL bus service
5	Comparative comfort Index **(CCFI)**	1.67	Better Performance of BCLL bus service
6	Comparative reliability Index **(CRBI)**	1.53	Better performance of BCLL bus service

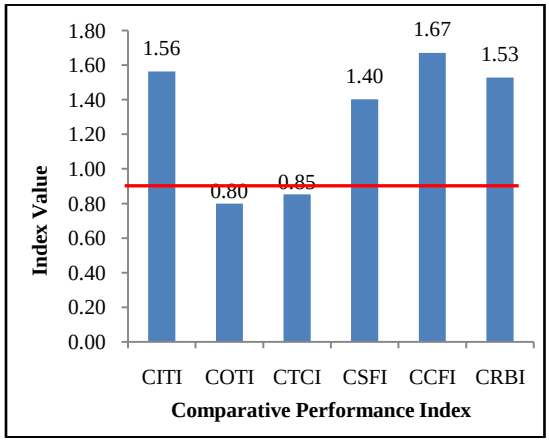

Figure 4: Comparative Performance of BCLL Service from User Perspective

The value of comparative in vehicle time index, comparative safety index, comparative comfort index and comparative reliability index of alternate public transport system 1 are greater than one which indicates open BCLL bus service gives better performance than Mini bus service except comparative out of vehicle time index and comparative travel cost index which are less than 1. The outcomes obtained are coherent as BCLL bus transport service is viewed as superior to Mini bus transport service from travel time in vehicle, safety and comfort perspective in light of the fact that BCLL bus transport service having more speed, lesser stops, more capacity of vehicle, better seat, legitimate location of stops and so forth. Further, investigation results demonstrated that BCLL transport service is viewed as inferior to Mini bus transport service from out of vehicle travel time and cost view point in light of the fact that BCLL bus transport service having less number of vehicles and more fare for same route length. The analysis results of overall comparative performance of BCLL bus service from time, cost, and quality aspects are presented in Table 5. The comparative performance of BCLL bus service from time, cost, and quality aspects are also presented graphically in Figure 5.

Table 5: Comparative Performance of BCLL Bus Service

S. No.	Performance Index	Index value
1.	Comparative time performance	0.503

	index **(CCTI)**	
2.	Comparative cost performance Index **(CCSI)**	0.288
3.	Comparative quality performance index **(CCEI)**	0.405
	Comparative user performance index (CUPI)	**0.405**

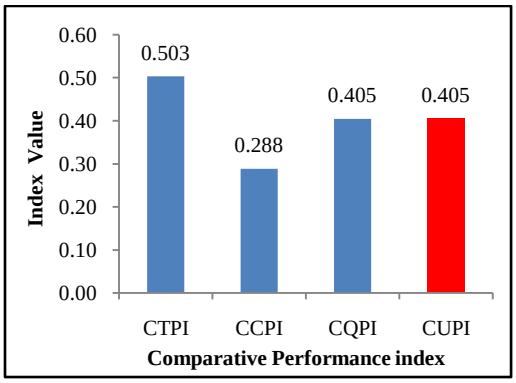

Figure 5: Comparative Overall User Performance of BCLL Bus Service

Thus it may be concluded that this study can be used to compare the two different route, two different services on same route as well as two different public transport system or two similar public transport system from user perspective in Indian context and useful to take significant decisions before implementation of new alternate system.

CONCLUSIONS

The main objective of this study is to present a basic methodology for comparative performance of alternate public transport system in Indian cities. The vital conclusions drawn from this study are as per the following.

- A critical literature review indicated that in practice most studies may be much more complicated to obtain the necessary information about public transport system due to absence of data base. Henceforth, there is have to develop a simple, intelligent and easy methodology which can assess the comparative performance of alternate public transport system from user point of view and works palatable with quantifiable negligible information.
- This study proposes a simple methodology for comparative performance of alternate public transport system which consists four major stages are as follows:
  - A hierarchical structure is developed logically in Indian context on the basis of literature review in Stage I of this study by considering inter relationship between major user performance indicators and key user performance indicators. This study distinguished three major criteria i.e. comparative time performance, comparative cost performance and comparative quality performance. Further these major criteria disintegrated in 6 key user performance indicators, four (comparative in vehicle time, comparative out of vehicle time, comparative travel cost and comparative reliability) of them are measured by quantitative indices and the remaining two (comparative safety, and comparative comfort) are measured by qualitative indices.
  - Various important indices for evaluation of condition of identified key user performance indicators are developed in stage II. These indices are developed in such a way so that the performance of two different route or public transport system and same route or public transport system can be compared from user perspective with minimal data.
  - The relative contribution of comparative in vehicle time, comparative out of vehicle time, comparative travel cost, comparative safety, comparative comfort and comparative reliability in comparative performance evaluation of alternate public transport system are 0.238, 0.164, 0.334, 0.086, 0.110 and 0.069 respectively which are determine in stage III using Fuzzy AHP method.
  - The last stage of this study are developed comparative time performance index, comparative cost performance index and comparative quality performance index in such a way that performance of public transport system can be assessed separately from time, cost and quality aspect. Comparative user performance index (CUPI) is also developed in this stage which can be used to determine the overall comparative performance of alternate public transport system from user perspective.
- The proposed methodology is delineated utilizing BCLL bus transport service and Mini transport service in Bhopal city. The results showed that the proposed technique is straightforward, simple and works satisfactory with minimal information which can without much of a stretch accessible at least cost.

It is expected that the application of this methodology provides significant comparative information to the authorities and operating companies to take appropriate decisions before implementation of new public transport system or alteration of existing system.

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