A Basic Framework for Benchmarking of Performance Indicator for Urban Public Transport System

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ABSTRACT: The public transport system is the backbone of transport system in India and plays significant role in achieving sustainability, efficient mobility and high quality of urban life. Due to increasing urbanization, public transport users in Indian cities faces various problems such as overcrowding, unsafe and uncomfortable trips, higher travel cost, environmental degradation, poor connectivity etc. This has resulted in declining trend of public transport share in Indian cities and thus there is a challenge for public transport agencies to improve the performance of public transport system. However critical review of literature indicated that most of the studies could not provide significant strategies. Further could not provide meaningful information to identify simple benchmarks that can be easily used for performance improvement of public transport system. Thus, there is an urgent need to develop a basic framework for benchmarking of performance indicator of urban public transport system so that existing public transport can be improved easily. In this study, a framework has been developed for benchmarking of performance indicator of urban public transport system. Thus, the major contribution of this study is basic framework has development which consist of three stages for benchmarking of performance indicator. It is expected that this study will be useful to identify the rational strategies for performance improvement of public transport system and study will be implemented for the Indian cities.

Keywords: Framework, Benchmarking, Performance Indicator, Public Transport System.

I. INTRODUCTION

Public transport plays a social role in the urban environment, it improves access to work places and service infrastructure and at the same time, reduces travel expenses [1]. Public transportation is defined as transportation by a conveyance that provides continuing general or special transportation to the public [3]. Public transport system is one of the most important key factors to improve social and economic welfare of a city in growing countries including India. In past few years India has experienced a high growth in population. Increasing urbanisation in Indian cities, of all types, face problems related to urban transport.Presently, there are different public transport systems like Bus rapid transit (BRT) system, Light rail transit (LRT) system, Mass rapid transit (MRT) system and various others like non-motorized transport, many types of intermediate transport systems are being maintained and operated in the Indian cities [2, 6].

Despite huge investments in development of public transport system, all cities experience the ever-growing problems of congestion, accidents, air, and noise pollution and many hazards to our environment [10]. These days' people in large cities have started using their private vehicles (two wheelers and cars) and in small cities different forms of intermediate public transport are used. The intermediate public transport provided either by the private or by the informal economy fight to meet the demands of public like minimum cost of travelling for many kilometres on a daily basis [5]. The decrease in the public transport share in the cities are is decreasing over the past few years in Indian cities presented in the Fig. 1 in which the cities is categorized under 1 to 6 in which the city category 1 has lowest population and city category 6 has maximum population which clearly indicates that if the same situation will continue to do so for years it will affect the public transport share in the cities hardly. Thus it is necessary to promote the use of public transport system [2]. Fig. 1 presents the expected decline in public transport share in the Indian Cities.

User satisfaction plays a vital role in evaluating the performance of public transport systems on the basis of travel cost, travel time, safety, comfort, reliability, accessibility etc [13].

However, an inexpertly planned system causes trouble to the users, loses ridership and very importantly encourages use of private vehicles instead of public buses, metros etc and imposes burden on the operator for his daily earnings. An accessible, flexible, safe, comfortable, economical and dependable service encourages a user to shift from personal vehicle to public transport. Hence, it is required to identify the factors on which users lag to use the public transport systems and implement some strategies which can improve performance of existing system so that people will shift from private to public modes of transportation [2, 23].
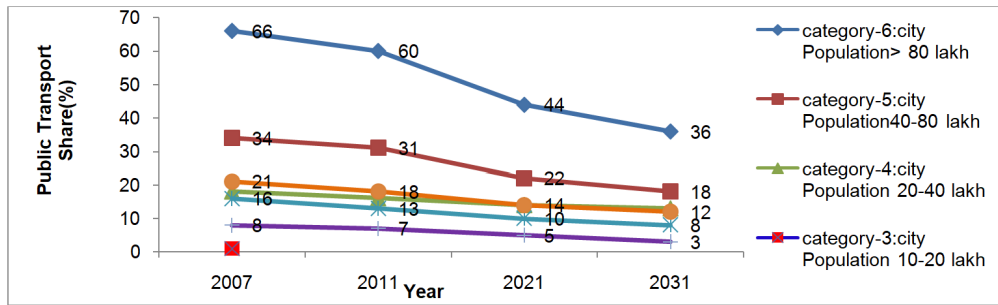
Fig. 1. Expected Decline in Public Transport Share in the Indian Cities.

This paper consist of four sections, in this introduction section problem and need are briefly discussed, section two presents literature review to analyse the problem and to benchmark of performance indicator of urban the public transport system, section three presents the stages of framework for the study. Section four presents conclusions of the study.

II. LITERATURE REVIEW

The performance improvement of urban public transport system is an important measure in determining the level of success of the national transportation policies and to know the impact of a policy as well as the operation of transportation services effectively and efficiently. Hence, a systematic literature review is an important and useful approach to identify and analyses all relevant research on framework on performance improvement and benchmarks of performance indicator of public transport system in developing countries as well as developed countries. This section reviews the literature on different study on public transport systems.

This section presents a review on various performance indicators which are used for evaluation of public transport system. Chowdhury *et al.*, (2015) considered three performance indicators namely travel time, travel cost, and comfort at interchange for performance evaluation of public transport system in Auckland, New Zealand [8]. Singh *et al.*, (2014) examined a large no of literature about performance indicators which influencing the public transport system from user perspective. This study was identified 11 performance indicators from the literature to compare the customer satisfaction perceived by Mini bus system and Low Floor bus system in context of Bhopal city. These are journey time, frequency, fare, safety, seat availability, reliability, staff behavior, speed, internal aesthetic, entry & exit. According to this study the most influential parameters are fare, journey time, safety, and reliability [23]. Das and Pandit (2013) identified 25 performance indicators from available literature that affect the performance of public transport system in developing countries [9].

A critical literature review of various existing methodologies related to evaluation of user performance indicators for assessment of alternate public transport system is presented in this sub section. Singh *et al.*, (2014) carried out qualitative analysis to evaluation of performance indicators for assessment of alternate bus system of Bhopal city i.e. Low floor bus

system and Mini bus system. This research work was developed a framework based on fuzzy set theory to calculate user satisfaction using data obtained from a questionnaire based passenger opinions survey. Aidoo *et al.*, (2013) conducted a qualitative analysis to evaluate the condition of performance indicators for assessment of public transport system of Kumasi Ghana. This study developed binary logistic regression model to explain the effect of individual performance indicators associated with the passenger's rating for overall performance of public transport system [23]. Javid *et al.*, (2013) evaluated the condition of performance indicators using four point Likert scales (i.e. not satisfied, less satisfied, satisfied and totally satisfied) for assessment of commuters' perceptions of wagon service s in Lahore, Pakistan [15].

Critical reviews on benchmarking in transport system are done in this subsection. In this study a comprehensive mode-specific benchmarking framework for the urban bus system has developed under Indian conditions with a case study of Hyderabad city. The developed framework consists of 29 evaluators structured into eight indicator groups. The significance of these indicator groups and evaluators varies in the framework; the same has been determined by an expert opinion survey by applying multi-criteria decision-making techniques such as analytic hierarchy process and direct weighting. Hensher (2015) present a way of doing this using a construct called a Customer Service Quality Index (CSQI), in which a stated preference survey together with actual experience in using public transport is used to obtain preference weights for each significant attribute defining service quality, and which is used then to establish a CSQI for each sampled user, and by aggregation, the performance on service quality of each operator [12]. Savković (2015) presents the usage of benchmarking as a tool for improving the operation of companies. For analysis are observed three enterprises, dealing with the same activity, transport of goods, and one of them is taken as a standard. The parameters for evaluation are the financial and physical nature as well as non-financial nature [21]. The SLB guidelines released by MoUD (2010) were exercised on six Indian cities (MoUD and CEPT 2013) [17, 18]. Georgiadis (2012) paper examines the practice of benchmarking in public transportation and presents a preliminary study conducted for the public transport organizations of Thessaloniki, Greece [11]. The framework of benchmarking exercise should be defined by selecting

those performance topics that have the greatest importance for a well - functioning public transportation system. Ludema M., (2006) proposed benchmark contains five critical success factors: accessibility cost of transport, safety, environmental pollution and congestion. The benchmark result provides policy-makers with figures that describe the position of each aspect of an urban transport system of a city or region compared with that of other cities or regions. In a case study the proposed benchmarking approach is tested by analyzing the performances of the urban transport systems of the two cities Berlin and Rotterdam [16].

Some of the major findings of literature review are summarized as follows:

— From earlier literature indicated that limited studies are available on performance evaluation of multimodal public transport system. In earlier studies, authors focus on only single mode of transportation so it is necessary to evaluate the performance of multimodal transportation systems.

— The critical review of literature indicated that most of the studies could not compare the performance of multimodal public transport system. Also these studies do not provide meaningful and information to identify the exact performance indicators values to judge or compare the public transport system that why benchmarking is necessarily for finding exact values for performance indicators that can be easily used for performance improvement of multimodal public

transport system so there is need for identification of some rational and simple benchmarks for performance improvement of multimodal public transport system.

— The critical review of literature indicated that limited studies are available on strategies for performance improvement of multimodal public transport system.

III. A BASIC FRAMEWORK FOR BENCHMARKING OF PERFORMANCE INDICATOR OF PUBLIC TRANSPORT SYSTEM

This section presents a framework of proposed methodology for Benchmarking of Performance Indicator of Urban Public Transport System. Most of the developing countries the public transport service services are adequately provided in some areas while there are inadequate or no services provided in other areas. Further, there is variation in socio-economic characteristics of the dwellers from place to place [13]. Hence, this study presents a comprehensive approach for performance evaluation of public transport system.

Fig. 2 presents the basic approach for performance evaluation of multimodal public transport system in a City.

The developed methodology can be used to identify the strategies for performance improvement for public transport system Fig. 3 presents a framework of proposed methodology.
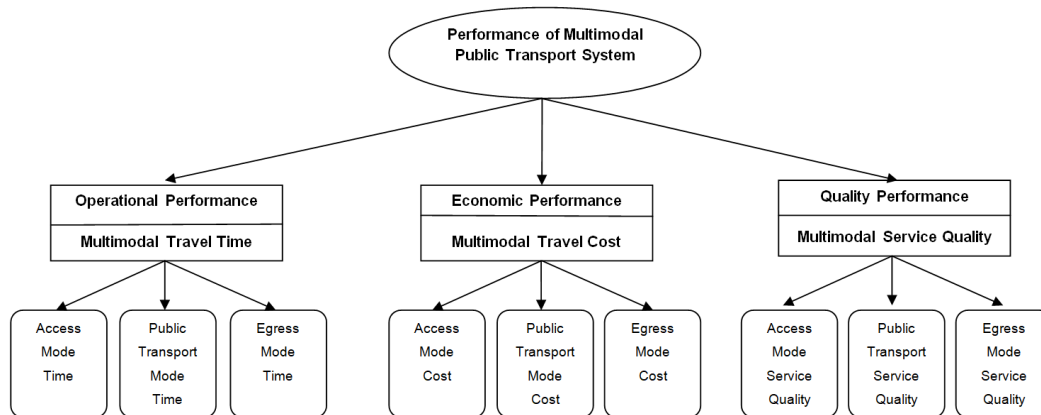

Fig. 2. Basic approach for Performance Evaluation of Multimodal Public Transport System in a City.
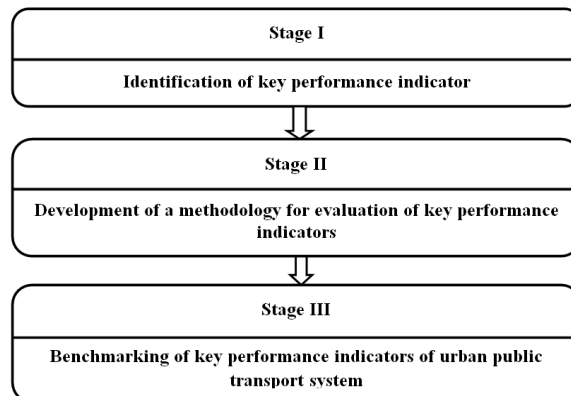

Fig. 3. A Framework for Benchmarking of Performance Indicator of Urban Public Transport System.

The methodological framework comprises four major stages for Benchmarking of Public Transport System in India is as follows:

Stage I: Identification of key performance indicators
Stage II: Development of a methodology for evaluation of key performance indicators
Stage III: Benchmarking of key performance indicators of urban public transport system

Stage I: Identification of key performance indicators

The purpose of the stage is to identify the most appropriate key performance indicators which are affecting the performance of public transport systems. The classification of performance indicators 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 service in a city. Therefore, the performance indicators are identified in such a manner that it includes all critical criteria that affect performance of public transport system. The criteria used for identification of performance indicator in this study are logically acceptable from Indian context, consistent with goals and objectives, easy to understand, measurable, minimum cost and time for data collection or availability of data. A questionnaire based survey was conducted by the researcher to identification of importance level of performance indicators.

The SPSS tool is used to detect most important performance indicators and inter-relationship between various key indicators and also to detect underlining structure of performance indicators. A principal component analysis with orthogonal (varimax) rotation is performed. The determinant value of correlation matrix, Kaiser-Meyer-Olkin Measure (KMO) value, and Bartlett's test of sphericity more than 0.01, more than 0.50 and less than 0.05 respectively is acceptable. The details of identified multimodal key performance indicators are presented in Table 1.

Stage II: Development of a methodology for evaluation of key performance indicators

The main objective is to develop strategies for methodology for evaluation of key performance indicators. The value of individual indices may vary from 0 to 1. The value '0' indicates worst. Performance of public transport system and '1' indicates better performance of public transport system. The value of indices may be greater than one, equal to one and less than one. The value of indices are greater than one, equal to one and less than one, indicates the performance of public transport system is superior, equal and inferior quality. The performance index of public transport system is determined by multiplication of relative weight and indices. The details of multimodal key performance index are presented by Table 2.

The performance index of public transport system is determined by multiplication of relative weight and indices of key performance indicators and then developed the performance index of public transport system. Further, the details of multimodal key sub performance index are presented by Table 3.

Stage III: Benchmarking of key performance indicators of urban public transport system

In this stage, first determine the relative weight of identified multimodal key performance indicators using Fuzzy analytical hierarchical process (FAHP) technique. The identified multimodal key performance indicators may not be equally affecting the performance of urban public transport system. It is observed that the significant differences exist among different categories of performance indicators that have a greater or lesser impact on overall performance of urban public transport system. Therefore, a system of weights needs to be introduced to reflect the contribution to overall performance of urban public transport system. The relative weight of multimodal key performance indicators will be determined using Fuzzy analytical hierarchical process (FAHP) technique by opinion survey of transport experts from relevant fields and academic. The Fuzzy AHP (FAHP) technique can be viewed as an advanced analytical method developed from the traditional AHP. The Fuzzy AHP technique is used to generate the weighting of multimodal key performance indicators because it is proposed to relieve the uncertainness of AHP method, where the fuzzy comparisons ratios are used. From benchmarking, exact values for performance indicators can be easily used for performance evaluation of existing multimodal public transport system. It is expected that this study will be useful to identify more rational strategies for performance improvement of existing multimodal public transport system which can be implemented for the Indian cities.

Table 1: Details of Multimodal Key Performance Indicators (MKP$_i$ Identified)

S.No.	MKP$_i$	Name of Multimodal Key Performance Indicators	Notation	Remark
1.	MKP$_1$	Multimodal travel time of public transport system for city C	MTT$_c$	Average overall multimodal travel time per km of a public transport mode p in a city C It directly affects the travel performance.
2.	MKP$_2$	Multimodal travel cost of public transport system for city C	MTC$_c$	Average overall multimodal travel cost per km of a public transport trips in a city C. It directly affects the economic considerations.
3.	MKP$_3$	Multimodal Service quality of public transport system for city C	MSQ$_c$	Average overall multimodal service quality of a public transport trips in a city C It directly affects the quality performance.

Table 2: Details of Multimodal Key Performance Index.

S.No.	Name of Index	Notation	Formula*
1.	Multimodal travel time index	MTIc	MTIc= (ATIc+PTIc+ETIc)
2.	Multimodal travel cost index	MCIc	MTIc=(ACIc+PCIc+ECIc)
3.	Multimodal Service quality index	MQIc	MSQi=(AQIc+PQIc+EQIc)

*Notation used in Table 2 is explained in Table 3.

Table 3: Details of Multimodal Sub Index.

S.No.	Name of Index	Name of Sub index	Notation	Description
1.	Multimodal travel time index (MTI$_c$)	(i) Access mode travel time index	ATI$_c$	Average overall multimodal access mode travel time per km of a public transport trips in a city C
		(ii) Public transport mode travel time index	PTI$_c$	Average overall multimodal public transport mode travel time per km of a public transport trips in a city C
		(iii) Egress mode travel time index	ETI$_c$	Average overall multimodal egress mode travel time per km of a public transport trips in a city C
2.	Multimodal travel cost index (MCI$_c$)	(i) Access travel cost index	ACI$_c$	Average overall multimodal access mode travel cost per km of a public transport trips in a city C
		(ii) Public transport mode travel cost index	PCI$_c$	Average overall multimodal public transport mode travel cost per km of a public transport trips in a city C
		(iii) Egress travel cost index	ECI$_c$	Average overall multimodal egress mode travel cost per km of a public transport trips in a city C
3.	Multimodal service quality index (MQI$_c$)	(i) Access service quality index	AQI$_c$	Average overall multimodal service quality of a public transport trips in a city C
		(ii) Public transport mode service quality index	PQI$_c$	Average overall multimodal public transport mode service quality of a public transport trips in a city C
		(iii) Egress service quality index	EQI$_c$	Average overall multimodal service quality of a public transport trips in a city C

IV. CONCLUSIONS

Some of the important conclusions drawn from this study are summarised as follows:

— From earlier literature indicated that limited studies are available on performance evaluation of multimodal public. Further authors focus on only single mode of transportation so it is necessary to evaluate the performance of multimodal transportation systems. Also these studies do not provide meaningful and information to identify the exact performance indicators values to judge or compare the public transport system that why benchmarking is necessarily for finding exact values for performance indicators that can be easily used for performance improvement of multimodal public transport system so there is need for identification of some rational and simple benchmarks for performance improvement of multimodal public transport system.

— In this study, a basic framework has developed for performance indicator for public transport system which consists of three stages.

— In first stage, a hierarchical structure is developed for identification multimodal key performance indicators. The identified multimodal key performance indicators are multimodal travel time, multimodal travel cost and multimodal service quality.

— In second stage, a methodology for evaluation of key performance indicators has developed. Further multimodal key performance index have determined which are multimodal travel time index, multimodal travel cost index and multimodal service quality index.

— In third stage, the threshold value for identified multimodal key performance indicators have been found out. Further some rational strategies are identified for improving performance of public transport system.

It is expected that strategies developed in this study will be useful to improve the performance of public transport system in Indian cities. Thus, this study will be useful in improving satisfaction level of public transport users and hence will be useful in enhancing ridership of public transport system.

V. FUTURE SCOPE

In this study is basic framework has development which consist of three stages for benchmarking of performance indicator. Now based on the outcomes of this study, we have the following future plan and suggestions:

— Key performance indicators for multimodal public transport system have evaluated.

— The benchmarking of key performance indicators for multimodal public transport system in Indian cities has determined.

— With benchmarking, further the rational strategies will be identified for performance improvement of public transport system.

Conflict of Interest. The authors declare no conflict of interest.

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