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Integrated Performance Assessment and Service Level Benchmarking of Urban Bus System using Fuzzy Logic

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Abstract

Ever increasing personalized modal share in Indian urban scenario has resulted in multiple issues like congestion, delays, deteriorating ambient air quality and increased accident rates. Existing Public transportation systems are either falling short of meeting the travel needs or deemed ineffective owing to multiple factors. Ever increasing personalized vehicular ownership due to improving per capita income of the household is resulting in gradual drop in occupancy of public transportation systems like buses. This scenario is almost similar in all progressive cities in India.

During the recent past, Urban Local Bodies (ULBs), State and Central Governments are exploring the option of introducing Mass Rapid Transit Systems (MRTS) to alleviate the above concerns. But, financial feasibility of such projects, demanding high capital investment, is a major bottleneck. However, societal benefits of these projects will pay off the investments during their life cycles. It is also important for the authorities to focus on developing sustainable cities which can maintain equilibrium in social, economic and environmental aspects. Opting for sustainable transportation planning would address the said objectives by adopting appropriate planning practices and policy analysis.

Sustainable transport planning needs a good assessment of the current scenario and due to non-availability of such assessment mechanisms, it was felt necessary to develop a suitable and comprehensive assessment scheme that appraise the current scenario of existing public transport system with pre-defined Performance Indicators (PI) having its special emphasis on environment, economic, financial and social sectors. Further, an appropriate benchmarking process to carry out a bespoke performance assessment of urban bus system with sustainability as key node is also been developed.

Augmenting the same, an Indicator based framework is developed with 30 evaluators nested under 8 Performance Indicators followed by a weight based ranking system. Till date, in the Indian benchmarking system of urban bus transport; no standardized mathematical approach is found to handle the imprecision and uncertainty that prevail in such assessment. In this context, an attempt is being made to normalize such uncertainties in benchmarking using Fuzzy Logic membership functions.

*Keywords:*Sustainable Benchmarking, Urban Bus System, Performance Evaluation, Public Transportation, Fuzzy Logic, Triangular membership function.

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1. Background and Study Objective

The state of wellbeing and the quality of urban life are highly determined by the condition of Intra-City mobility. It is an undeniable fact that better mobility results in enhanced economic productivity of any urban area. As a consequence of the unprecedented urbanization happening in India, transport systems and infrastructure in majority of the cities are taking a heavy beating. The prevailing transport infrastructure is failing to cater to the travel needs of city dwellers, thus forming a gap between demand and supply. Planning authorities and ULB's are investing huge funds in increasing the road infrastructure just to manage the prevalent travel demands in these ever-growingcities. Broader roads and other facilities thus provided along with enhanced purchasing power of public in general are resulting in increased vehicular ownerships. Thus, negative externalities like decreased ambient air quality, increased congestion and accidents have been observed to be on the rise always.

During the recent past, sustainable transport planning is slowly but surely is replacing conventional practice of continuous building of vehicular transport infrastructure. The basic objective of this sustainable growth usually is to encourage an integrated Mass Rapid Transit system (MRT) which is efficient and affordable in terms of space and resources with minimal impact on environment and mobility.

Before attempting the sustainable transportation planning, it is essential to comprehensively evaluate and benchmark the existing public transportation systems with the help of Performance Indicators (PIs) and evaluators. Performance indicator is a measure, typically quantitative in nature, which helps in revealing information about certain characteristics of a service. In a system, as complex as Urban Bus Transport, hundreds of such measures can be devised to assess performance. However, over the years, the problem of reducing those measures to a relatively smaller number, while not compromising with the quality of evaluation of the Mass Transportation Systems has been the target for many researchers working in this area.

The need to develop a public transport benchmarking system by integrating conventional service attributes, economic and financial attributes, and environmental andsocial attributes has been long due for Indian context. Also, the uncertainty and intangibility associated with the bench marking process also need to be addressed to develop more acceptable bench marking system. It was also felt essential to integrate the sustainability aspects with the conventional benchmarking process to make it more practical and viable. This paper attempts at summarizing the efforts being carried out in this direction. Current research also focuses to enable the ULBs perform such benchmarking institutionally, enabling them understanding timely performance of the system. This paper attempts at summarizing the efforts made in tackling the attributes, predominantly qualitative in nature, with well proven fuzzy approach, thus arriving at a more logical benchmarking process.

A few terms used in the paper, which are not very common, are explained in Table 1 for ready reference

Table 1:Nomenclature and its detailing

Nomenclature	*Detailing*
Performance Indicator (PI)	Specific factors that are measured to indicate progress towards goals. It consists of various specific evaluators under each performance indicator.
Evaluator	An element which needs to be evaluated with specific formulation/criteria.
Quality of Service (QOS)	Performance rating of an evaluator based on the result achieved from a formulation/criteria on a scale of 1 to 4, with 1 being inferior and 4 being superior in performance.
Indicator Quality of Service (IQOS)	Performance rating of a PI, calculated by taking the weighted average of QOSs' attained under respective PI. Weights are assigned to each evaluator for benchmarking purpose.
Overall Quality of Service (OQOS)	Performance rating of city's urban bus system, calculated by weighted average of IQOSs' of the entire PIs'. Weights to PI's are assigned prior to benchmarking.

2. Literature Review

The concept of public transport benchmarking is in inceptive phase in India and the notion of integrated service level benchmarking of public transport still being proposed with this research. This section throws a light on various global attempts in evaluation and benchmarking of public transport systems and summarizes the same.

Todd Litman (2006) identified the scope of issues examined under sustainability, its perspectives, criticism, issues in implementation of sustainable transportation etc. and proposed visions of sustainable transportation. According to the author, a comprehensive assessment of economic, environment and social aspects of sustainability yields better results on a broader perspective.

Karel Martens (2015) has demonstrated a framework to assess the accessibility and mobility of a transport network simultaneously. The author introduced a new framework, Potential Mobility and Accessibility (POMA) in which accessibility and potential mobility are juxtaposed on horizontal and vertical axis respectively.

Sabyasachee et.al (2012) proposed an approach to measure connectivity in multimodal transport systems with minimal data. Formulations for assessment of connectivity at various levels varying from nodal to regional centres are established. Application of the proposed approach has also been demonstrated on Washington-Baltimore transit network.

Vaidya et.al (2014) evaluated relative performance of 26 urban public transport service providers (TSP) with 19 criteria. Author have adopted Data Envelopment Analysis (DEA) and Analytic Hierarchy Process (AHP) as performance analysis tools and developed a Transportation Efficiency Number (TEN) as a crisp out output for all 26 TSP. As this is a relative benchmarking attempt, the highest scoring by TSP in each criterion is opted as benchmark for the rest.

Rohit (2016) has attempted to develop a human perception model using triangular membership functions of Fuzzy Logic approach. Travel time, waiting time, travel cost, journey speed, and discomfort level are taken as the attributes and fuzzy sets are created. Accordingly rule base was developed for finding the human perception towards opting public transportation and the same was validated.

Initiatives/schemes being undertaken by the Indian Govt. for improving urban public transport and encourage modal shift to public transport are as below (pib.nic.in) :-

i. Priority for developing sustainable public transport networks in "National Urban Transport Policy-2014" by MoUD

ii. 50% cost for preparation of Detailed Project Report (DPR) for MRTS is funded under Urban Transport planning and Capacity Building Scheme.

iii. Financial assistance up to 20% for Metro Rail Projects initiated by State Govt.

iv. More than 22,500 buses sanctioned to 157 cities/cluster of cities under erstwhile JnNURM Scheme.

v. 80% financial assistance for Comprehensive Mobility Plans (CMPs) and other Urban Transport related studies by cities.

vi. Facilitated financial assistance for Bus Rapid Transit System (BRTS) in 12 cities.

vii. Components of Urban Transport such as Buses, BRTS, Footpaths, and Cycles etc are given significant importance in AMRUT (Atal Mission for Rejuvenation and Urban Transformation) scheme of the Ministry.

In the said policies/schemes and initiatives by the Govt., significance of comprehensive evaluation and benchmarking of existing public transport or guidelines/frameworks to achieve so, are is still unrealized.

The conventional urban transport benchmarking framework proposed by MoUD (2010) has a broader approach towards assessment of several components of urban transport with its own set of drawbacks on spatial transferability. At the outset, it has got only 9 dedicated PIs for public transport, whereas, to have a more realistic picture, the assessment should be extensive. India is currently in a transition phase switching towards modern public transport system such as MRTS (Monorail, Metro), BRTS and Light Rail Transit System (LRTS). Such transition attracts huge investments from various bi-lateral and multi-lateral funding agencies, hence timely repayment of these loans shall also symbolize the nation's pride. Hence a comprehensive evaluation and benchmarking of the existing public transport system in integration with sustainability aspects is mandatory to ensure the right investment in right time.

Also a question of spatial transferability evolves, when exercising PIs of MoUD's framework, like "Usage of Intelligent Transportation System facilities", "Non-Motorized Transport facilities", "Integrated Land Use Transport System" etc. as benchmarking of such PIs shall only be limited to Tier I cities. Whereas, assessment of Tier II and Tier III cities shall concentrate on different aspects altogether, such as

Intermediate Public Transport (IPT), development of Sustainable Public Transport, assessment of road quality index etc.

The current study focuses on addressing the same by integrating sustainability aspect with evaluation and benchmarking in regards with Urban Bus System. General benchmarking practices followed in Western and European nations has also been carried out and summarized as below. Understanding the same, the proposed framework of assessment is developed.

Table 2:Global Literature on Sustainable Benchmarking of Urban Transport

Indian Literature	*Western Literature*	*European Literature*
Attention limited to Conventional Benchmarking – Ministry of Urban Development	A broader attempt on Sustainable Assessment by: Victoria Transport Int.	Guidelines stipulated by European Commission (EC) evaluation of urban bus system in operators' perspective.
No such comprehensive framework exists for sustainable evaluation	Sustainability is substantiated in regards with Demand Response Transportation.	A comparative study has been conducted by EC on 42 cities with a common set of 7 Indicators nested with 25 Evaluators.
No absolute Benchmarking prescribed for Urban Public Transportation System	Sustainability is perceived as contribution of Environment, Social and economic sectors.	An attempt of sustainable evaluation has been made on 15 European Countries.
Sustainability is assessed on a broader perspective at urban level and no lookout at nuclear level	No specific significance found for Financial Sustainability	Contemplated as the modern research so far
No productive attempts on integrating conventional and sustainable assessment in the context of Public Transport	No attempts noticed on integrating conventional and sustainable assessment	No discussion on integration

3. Study Area Description

Hyderabad, a tier I and 6th largest metropolitan city, has been chosen as the study area for the current research activity as it has the distinction of having highest bus modal share amongst all other Indian tier 1 cities. Further, the study area is limited to the Municipal Corporation of Hyderabad (MCH), the core of urban cluster of Hyderabad Metropolitan Authority (HMA), as this core is observed to be representing the significant engine of growth for the whole region. Through figure 1, the core MCH has been shown as subset of HMA cluster for reference.

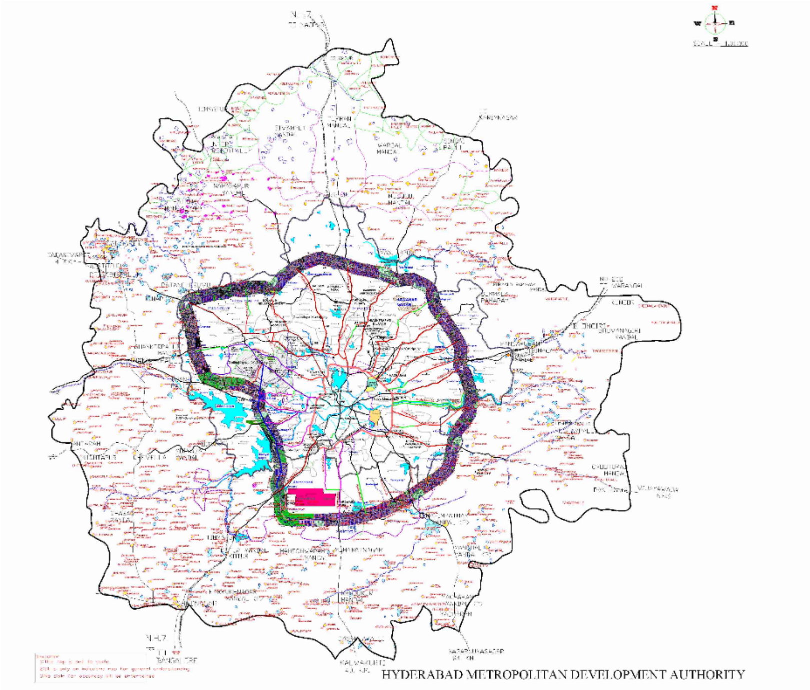

Figure 1: Map showing MCH & HMA Jurisdictions
Source: https://www.hmda.gov.in/images/map.jpg

4. Study Details

The current study is targeted to develop a framework for benchmarking the urban mass transportation system, with special reference to bus transportation system and develop a methodology to achieve 100% spatial/geographical transferability with all other Indian Tier I cities. From the practices adopted for traditional Service Level Benchmarking of urban transport in India, it can be clearly observed that aspects of Environmental and Social sustainability aren't considered as priority items unlike in international practices. In this context, modern service level benchmarking system is being developed in integration with sustainability aspects as presented in the following stages.

4.1. Stage 1: Development of Regular and Sustainable Framework with Performance Indicators:

Service Level Benchmarking guidelines were first released by MoUD during the year 2009 and later revised in 2010. In 2013, benchmarking of 6 Indian cities has been carried out by applying the guidelines setforth during that time. Similarly, benchmarking of urban transport system for many cities has been carried out with these guidelines. It can be observed that the conventional benchmarking proposed by MoUD, adopted uniform weights system for all the performance indicators which resulted in a not so accurate replica of the performance.

Several evaluators categorized under a broad spectrum of performance indicators have been identified based on expert opinions and logic. Many of these evaluators are found wanting in the conventional benchmarking mechanisms while they are covered under sustainable benchmarking mechanism. These details are summarized and presented in Table 3 for ready reference.

Table 3:A Comparison of Conventional and Proposed Sustainable Benchmarking

Performance Indicator	*Evaluators*	*Presence in Conventional Benchmarking*	*Presence in Sustainable Benchmarking*
Service Availability	Public Transport Intensity (% Network Covered)	☑	☑
	Frequency	☒	☑
	Ease of Availability (Bus Stops/10Kms along Major Corridors Only)	☒	☑
	Bus Transfers	☒	☑
	Intensity of Buses	☑	☑
Service Reliability	Presence of Organized Public Transportation	☑	☑
	Average Waiting for Bus	☑	☑
	Travel Time Ratio	☒	☑
	Headway Regularity in Peak Hour as per Schedule	☒	☑
Comfort	Passenger Comfort Load Factor (Passenger/Seat)	☑	☑
	Smoothness of Bus Ride	☒	☑
	Accessibility	☒	☑
Fare	Ratio of PT Expense to Personal Transport Expense	☒	☑
	% commuters Benefiting from Discounted Fares	☒	☑
	Fare Affordability	☒	☑
Passenger Information System (PIS)	% Bus Stops/Terminals with PIS	☑	☑
	% of Buses Equipped with Global Positioning System (GPS) for Real-Time PIS	☒	☑
	Existence of Customer Care for Intracity Travel	☒	☑
Environment Sustainability	Pollution Levels & Green House Gas (GHG) Emissions	☒	☑
	Noise Limits	☒	☑
	% CNG Buses	☒	☑
Financial/ Economic Sustainability	Extent of Non-Fare Revenue	☑	☑
	Staff/Bus Ratio	☑	☑
	Operating Ratio	☑	☑
	Ridership & Occupancy Ratio	☒	☑
	Modal Share	☒	☑
Social Sustainability	% of Accidents involving Buses in last 5 Years	☒	☑
	Accessibility of Physically Disabled	☒	☑
	Social Priority	☒	☑
	Signal Priority	☒	☑

4.2. Stage 2: System Evaluation & Benchmarking:

The sustainable benchmarking based on a comprehensive evaluation with weight based ranking system demands extensive data, to name a few, Vehicle Operating Costs (VOCs), GHG emissions, passenger opinions, Air & Noise quality levels, Traffic volumes, speed & delay data etc.. Collection of raw data and its requisite analysis to draw proper conclusion, plays a key role in successful assessment of the system. Also, one should be vigilant in maintaining the uniform timelines of the entire data.

A systematic mechanism of data collection has been adopted in order to avoid any repetitive data collection exercises. In this mechanism, a detailed framework of PIs and evaluators are developed first along with its formulations. Expert opinion is sought after developing such frameworks and necessary modifications are induced into the framework. Post freezing the formulations, requirement of data feed to these formulations are identified, so as it source. Most of the formulations attract customized analysis which was carried out post collecting the raw data. An outline of data collection and its source are shown in Table 4 below: -

Table 4:Outline of Data Collection and its source

Description of Data	*Category*	*Analysis/Processing*
Accident	Secondary	Accident Analysis
Air & Noise Quality	Secondary	Emission calculations
Bus commuting/scheduling	Secondary	Reliability Assessment
Commuter Survey data	Primary/Secondary	Travel Scenario Evaluation
Facility/Infrastructure	Secondary	Infrastructure Ranking
Fare slabs of services	Secondary	Travel Cost Analysis
Operation &Maintenance Data	Secondary	Economic & Financial Return Analysis
Opinion Surveys	Primary/Secondary	Bus Quality Index
Socio-economic benefits	Primary/Secondary	Travel Cost Analysis
Speed & Delay Studies	Primary/Secondary	Travel Time savings Analysis
Staffing/Manning schedule	Secondary	Financial Sustainability Analysis
Traffic Intersections Traffic Studies	Primary/Secondary	Peak Hour Factor analysis Speed & Delay Analysis Air & Noise Quality Analysis
VOC figures	Primary/Secondary	Travel Cost Analysis Economic & Financial Analysis

Analysis has been carried out for all the evaluators using the collected data. A summary of the analysis, in the form of formulations of Quality of Service (QOS) is presented in Table 5. Here, quality of service 1 indicates the least level of performance while the quality of service 4 indicates the best level of performance.

Table 5:Evaluation Framework of Performance Indicator: Service Availability

<table>
<tr><th>S.No.</th><th colspan="2">Evaluators</th><th>Quantity</th><th>Remarks</th></tr>
<tr><td rowspan="7">1</td><td colspan="2">PT Availability in Km's</td><td>2,400</td><td rowspan="7">PT Network within the GHMC Area was considered.

Total Road Network within GHMC Area.</td></tr>
<tr><td colspan="2">Total Road Network in Km's</td><td>3,428</td></tr>
<tr><td>QOS</td><td>Public Transport Intensity (% Network Covered)</td><td>70.01%</td></tr>
<tr><td>1</td><td>4 >75</td><td rowspan="4">QOS Achieved 3</td></tr>
<tr><td>2</td><td>3 50-75</td></tr>
<tr><td>3</td><td>2 26-49</td></tr>
<tr><td>4</td><td>1 ≤25</td></tr>
<tr><td rowspan="3">2</td><td>QOS</td><td>Frequency of a Service in Min's</td><td>10.14</td><td rowspan="3">The Frequency of the Services (To-and-fro) along the Identified 29 Major Routes within GHMC is</td></tr>
<tr><td>1</td><td>4 <5</td><td rowspan="2">QOS Achieved 3</td></tr>
<tr><td>2</td><td>3 06-15</td></tr>
</table>

S.No.	*Evaluators*		*Quantity*	*Remarks*
	3	2 15-30		calculated using the Secondary data.
	4	1 >30		
3	Total No. of Bus stops		445	Network Length of 29 Major Corridors. Bus Stops along the 29 Major Corridors.
	Total Route Length in 10 Km's		77.6	
	QOS	Ease of Availability	5.73	
	1	4 >7	QOS Achieved 3	
	2	3 5-7		
	3	2 3-5		
	4	1 <3		
4	QOS	Bus Transfer to reach the Destination in No's	0.60	From the Commuter Survey carried out at 47 Locations along the Identified Major Corridors with a Total Sample of 5,116 (CTS Report)
	1	4 < 1	QOS Achieved 4	
	2	3 2-3		
	3	2 3-4		
	4	1 > 5		
5	Total No. of Bus stops		3,752	This is to concentrate on the intensity of the bus accessible locations to the public.
	Population in 1000's		6,809.97	
	QOS	Intensity of Buses in No's	0.55	
	1	4 > 0.6	QOS Achieved 3	
	2	3 0.4-0.6		
	3	2 0.2-0.4		
	4	1 < 0.2		
Indicator Quality of Service (IQOS) = (2*3+2.25*3+2.25*3+1.75*4+1.75*3)/10 = 3.175 = 3.2 (On a Maximum of 4.0)				

Framework of "Service Availability" with evaluation criteria of QOS for all evaluators is as shown above. An illustrative calculation of weight based IQOS is shown below.

$$IQOS = (WE\ 1*QOS\ of\ 1+\ldots+ WE\ n*QOS\ of\ n)/ \quad (1)$$

WE 1= Weight of Evaluator 1
WE n= Weight of Evaluator n

In Equation No.1 shown above, the achieved QOSs' of Evaluators (second term) are multiplied with their respective weights (first term).

These weights are assigned based on the significance of evaluators in the process of assessment within respective PI. Weight based assessment is always preferred over the conventional assessment, as it magnetizes the overall evaluation system leaving a room for priority components. Summation of all evaluator weights are kept equivalent to 10 under every Performance Indicator.

Accordingly, the evaluation & benchmarking is carried out for all the 8 Performance Indicators and IQOS is calculated as detailed above. Performance Summary of all the 8 PI's is tabulated in the subsequent sections in Table No.6.

5. Development of Weight Based Ranking System

After completion of Urban Bus System evaluation, a weight based Ranking system need to be developed keeping in view the significance of sustainability in Indian context. Formulation for "OQOS Achieved" is as shown in equation No.2 below:

$$\text{OQOS Score} = (\text{WPI } 1 * \text{QOS of PI } 1 \ldots + \text{WPI } n * \text{QOS of PI } n)/100 \qquad (2)$$

WPI 1= Weight of Performance Indicator 1
WPI n= Weight of Performance Indicator n

Weight based ranking system for achieving an Overall Quality of Service (OQOS) for a Tier I city is as shown below along with the lacunae identified and the measures suggested for the current study area. The rating is performed on a scale of 1 – 5 with OQOS 5 being the best and OQOS 1 being the least measure of performance.

Table 6: OQOS of Hyderabad Intracity Bus System

Performance Indicator (1)	*Weightage (2)*	*Weighted IQOS (3)*	*Total IQOS (4) =Col2 * 4*	*Rate of Performance (%) (5)*
Service Availability	12.5	40.00	50	80.00
Service Reliability	12.5	40.62	50	81.24
Comfort	10	34.00	40	85.00
Fare	12.5	37.50	50	75.00
Passenger Information System (PIS)	10	14.00	40	35.00
Environment Sustainability	14.5	49.30	58	85.00
Financial / Economic Sustainability	14	39.20	56	70.00
Social Sustainability	14	25.90	56	46.25
Overall Quality of Service (OQOS) achieved = 280.52/400 = 0.70 (On a Maximum of 1.0)				
Scale of OQOS: OQOS 1 = < 0.30; OQOS 2 = 0.31 - 0.55; OQOS 3 =0.56 - 0.70; OQOS 4 = 0.71 - 0.85; OQOS 5 = >0.85;				

6. Linguistic Ratings

Based on the obtained rate of performance, the linguistic ratings are categorized as shown in the table 7. Since these ratings are perceptive and qualitative in nature, the same are normalized to avoid such uncertainty and vagueness in benchmarking using Fuzzy Logic membership functions.

Table 7:OQOS Linguistic Ratings of the Benchmarking

Rate of Performance (%)	*Linguistic Ratings*
0-30	Poor (P)
31-60	Fair (F)
61-89	Good (G)

> 90	Very Good (VG)

7. Application of Fuzzy Logic

In 1965 LotfiZadeh, founder of fuzzy mathematics has introduced the concept of Fuzzy Logic. Fuzzy logic approach is based on the “Degree of Truth”, rather than habitual approach of “True or False”. In conventional mathematics, numerical values are generally taken as variables whereas in fuzzy logic, non-numerical values are generally considered for expression of facts and rules. Such non-numerical values are otherwise called as linguistic variables. Fuzzy logic operates on membership functions for processing data and facilitates an effective way in arriving at a precise conclusion based on imprecise, vague or uncertain information (Alexander Paz et.al). In present study, several evaluators were assessed and ranked under the nest of multiple Performance Indicators.

Defining ranking intervals for evaluators and PI’s requires knowledge about the interdependencies between the system performance measures and the corresponding PI’s. Examining complexity of such qualitative subject, the data required for assessment is sometimes vague and ambiguous. In such situations, Fuzzy logic facilitates a mathematical approach to blend the best of available knowledge and counterpoise the intangibility and vagueness within the ranking system.

Triangular membership function (TMF) is adopted in this research because, it is easy to define; computational simplicity, only three parameters required: lower and upper width (a and c) as “feet” and a modal point (b) which locates peak. For many of the practical applications, triangular fuzzy numbers are widely used.

The triangular curve in TMF depends on three scalar parameters a, b, c and is a function of vector, X as shown in equation no. 3 below

$$f(x; a, b, c) = max\left\{\min\left(\frac{x-a}{b-a}, \frac{c-x}{c-b}\right), 0\right\} \quad (3)$$

Based on the realistic scenario of urban transport in India, the scalar parameters of for all 4 linguistic variables are perceived as shown in table 8

Table 8:Scalar parameters of linguistic variables

Linguistic Variable	*Scalar Parameters*		
	a	*b*	*c*
Very Good (VG)	0.95	1	1
Good (G)	0.75	0.85	0.9
Fair (F)	0.55	0.7	0.8
Poor (P)	0.35	0.45	0.5

The above scalar parameters are applied using triangular membership function to the Performance Indicators, based on the respective linguistic ratings achieved. After application of triangular membership function and defuzzification, the corresponding rating for PI's is as shown in Table 9 below.

Table 9:Performance Ratings post Defuzzification

Performance Indicator	*Linguistic Rating*	*Scalar Parameters*			Defuzzification
		a	*b*	*c*	$\frac{(a+b+c)}{3}$
Service Availability	G	0.75	0.85	0.9	0.83
Service Reliability	G	0.75	0.85	0.9	0.83
Comfort	G	0.75	0.85	0.9	0.83
Fare	G	0.75	0.85	0.9	0.83
Passenger Information System (PIS)	P	0.35	0.45	0.5	0.43
Environment Sustainability	G	0.75	0.85	0.9	0.83
Social Sustainability	G	0.75	0.85	0.9	0.83
Financial / Economic Sustainability	F	0.55	0.7	0.8	0.68
Overall Rate of Performance of Hyderabad's Urban Bus System					0.76

Post applying triangular membership function and defuzzification, the overall Rate of Performance of Hyderabad's urban bus system is obtained as 76%.

8. Conclusions & Discussions

Globally adopted techniques for assessment and benchmarking of public transport system has been discussed in view of integrating the same with sustainability. For nations like India, the concept of sustainability is so far localized to Environmental aspects, this paper extends it further to financial and social aspects of sustainability. Being one of the fastest growing nation, substantial funding for developing urban public transportation system in the country is being funded by multi-lateral and bi-lateral funding agencies such as Japan International Cooperation Agency (JICA), World Bank, KfW Development Bank, Asian Development Bank (ADB) etc. Timely repaying such huge loans is not only a responsibility, but also plays a key role in maintaining an esteemed position in global market. In this regard, it is vital to choose and prioritize the funding distribution for public transport projects within India which requires a perfect assessment and understating of existing performance of public transportation system. Hence, the said framework and methodology is developed in a perspective to enable the geographical transferability to other Indian cities (Tier I & Tier II) with no or minimal changes. The integration of conventional and sustainable benchmarking resulted in a framework consisting of 8 Performance Indicators with 30 evaluators. Current research demonstrates the rate of performance (RoP) of Hyderabad City's urban bus system as 70% i.e at OQOS 3 revealing the performance as average and alarming the need for improvement in the sectors of PIS, and social sustainability. A decent performance in the sectors of fare, environmental sustainability and economic/financial sustainability is also found. Similarly, it can be applied to other Tier I & II cities in the Country to have a clear vision of sustainable urban public transport planning for ULB's.

Post applying fuzzy logic and neutralizing the vagueness and intangibility within the ranking system, the Overall Rate of Performance of Hyderabad's Urban Bus System is found to be 76%. The proposed membership function of fuzzy logic is recommended as an evaluation tool involving vagueness of data.

Future direction of this research would be to assess the MRT system in urban context and verify the adaptability of alternate membership functions in addressing vagueness and intangibility.

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