



Identification of key performance indicators using hybrid COPRAS-TOPSIS for urban public transit systems by evaluating with AHP and FAHP

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Abstract

Development of urban transport facilities via analysing indicators has become one of the new domains explored worldwide, as cities are growing with no control. The present state of sustainability testing practices feels that technical analysis is rather very complex collaboratively and comprehensively met with local statements. As a result, developing indicators assessment techniques has become inevitable to deal with these challenges. In this study, a comprehensive transport assessment index such as trustworthiness, Amenity, Receptivity, Assurance and Affinity for the cities through passenger response can be useful for the researchers in the city. A set of 5 indicators has been formulated among 500 respondents that might influence and shape urban public transport performance. For finding the Key Performance Indicator (KPI) of the Urban transport system, the hybrid Complex Proportional Assessment (COPRAS)—Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is applied to measure the quantitative weight to analyze the complex process of perceived service quality. This model is validated by different Multi-Criteria Decision Making (MCDM) such as Analytic Hierarchy Process (AHP) and Fuzzy-AHP by comparing performance measures for randomly selected elements, which is new to mixed traffic flow conditions. The performance obtained such as computational complexity and agility in decision making by the hybrid COPRAS-TOPSIS are 132 and 1245. Hence, the proposed approach was more accurate than conventional ones, thus used to support decision-makers for long-term designing and planning of transport networks based on priority. Based on these factors, the present study successfully develops and applies KPI analysis prediction of the general transport approach in the background of India.

Keywords Key performance indicator (KPI) · Hybrid COPRAS-TOPSIS · Analytical Hierarchy Process (AHP) · Weight evaluators · Fuzzy logic

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1 Introduction

The public transportation model plays a major role in all areas, such as cities and metropolitans, as millions of people widely utilize them for daily travel. In addition, public services were developed in parallel due to the growth of these areas over a few years [1]. Hence, passenger response to satisfaction has been very important based on different parameters related to service parameters such as reliability, efficiency, comfort, and planners for transportation [2]. This was purely based on different time intervals linked to the quality of service and peak hours as soon as possible. It has been proved earlier that improving the indicator value towards the goal and its subjective and objective measures helps to improve the transportation model. Measures are analyzed to share the role of efficient, comfortable and effective operations for transit systems [3]. As passengers play an important role in a high level of transportation services, these operators express major concerns about the transit system [4]. It was noticed that people do not want just transportation but also time-saving during their travel [5].

Benchmarking is a vital process that helps to build the infrastructure of a public transport model. Benchmarking establishes a consistent and predictable neighbourhood and public knowledge base [6], setting the stage for distinguishing essential problems, outlining basic strategies, and creating a competitive climate between metropolitan areas [7]. Even though Public Transportation (PT) benchmarking is a well-established method on a passenger satisfaction scale. The establishment of modern PT programmes, as well as any reform steps, necessitate significant financial investments [8]. Prioritization is critical to solving certain problems in the current scenario of accelerated urbanization. LOS norms are developed based on users' observations of the facility achieved through the individual transportation system [9]. This system is found to be reliable in comparison with others who rely on OS. This OS is referred to as any other transportation mode.

Many common people will rely mutually on public and private transportation modes based on their requirements. The improved structuring and designing of one vehicle gradually decrease the operational functioning of the rest of the mode [10]. Many scholars from various domains have developed a technique for finding the quality of transportation facilities by observing the data. However, in India, limited researchers have focused on this area for research [11]. The criteria considered for the analysis are difficulty and compliance faced by the people and the quality of the road transport. The data were collected from multiple points of view and taken for analysis. Thus, the main goal of this article is to design an appropriate technique for revealing the influence of various attributes related to transportation in urban cities for predicting the satisfaction of road customers.

In comparison, most people generally use private and public transit when required. The design and maintenance of facilities for one mode's sustenance may have a detrimental effect on the operating implementation of alternate modes [12]. Researchers with scientific backgrounds have made important contributions to the advancement of methods for assessing the quality of service using perception evidence [13]. However, scholars in India have contributed very little to such studies. From a multimodal viewpoint, this study considered both qualitative metrics of road transportation, inconsistency, and complexities of human interpretation. As a result, the objective of this paper depends on both qualitative interventions. Inconsistencies and multimodal interpretation complications of road transport have been considered in this study. Therefore, this analysis aims to create an adequate method to evaluate road users' satisfaction levels from a Multimodal perspective in developed countries through the combined impact of several

features of a medium-range transport facility. The main contributions of this proposed approach are briefly explained in the following part.

The contribution of this study was given as

- Gathering survey responses from public people based on the city's public transport system.
- Analysis of the collected data to understand the public opinion on the city's public transport system.
- Designing an MCDM technique to analyze the performance indicators for transport systems in Indian urban areas.
- Numerous circumstances are taken into account from various aspects for evaluating the performance because a lot of information can be gathered in contrast to consideration of single circumstances.
- For attaining weight indicators, the hybrid COPRAS-TOPSIS technique is developed and synthesized using the defined circumstances.
- Key performance indicators are analysed for five parameters Trustworthiness, Amenity, Receptivity, Assurance and Affinity for different MCDM techniques such as Hybrid COPRAS-TOPSIS, AHP and FAHP.

1.1 Motivation of the work

Transportation difficulty causes an impact on many fields. Similarly, it can widely affect public transport. Hence the transportation facilities should be increased, including road-way expansion, concentration on pollution, etc. Transportation can become sustainable by incorporating all the essentials. Sustainable transportation will be more essential, time saving and comfortable for the public. Helping hands raised in the government and many other private sectors to investigate the excess treasury to expand the road organization to manage the increasing travel demands. Urban Local Bodies (ULB) and planning authorities have also started investing in good transport infrastructure for people. Increased accidents and congestion have, in turn, increased travel demands in conjunction with highly increased ownership of vehicles. This truly is a startling source of inspiration for long-haul maintainability. So in this proposed approach, an adequate method is developed to evaluate road users' satisfaction levels.

The organization of the manuscript is illustrated as follows; Section 2 provides the detailed background and related works so far proposed. Section 3 gives the research methodology in brief notes. Section 4 carries out the experimental results and discussions. The final section concludes the entire research work shortly.

2 Literature review

Demographic changes in peripheral areas are pressuring the regional transport systems to adopt innovative strategies. The existing approaches which analyse the performance of urban public transit systems are reviewed below.

2.1 Background study of key performance indicator

Suman et al. [14] developed a model and analyzed it by applying it to a real-time network of about thirty-four bus routes. The analysis was carried out in three ideal, practical and current circumstances. In practical circumstances, the extra and idle bus fleets can be used for the routes professionally by offering a physical distance. The experimental results showed that Business-as-Usual (BAU) circumstances on utilizing the current allocation system faced difficulty in offering a simple physical distance.

Liu et al. [15] reviewed the energy KPI in hospitals in urban countries like Australia. The health issues and sustainability attained through energy KPIs were suggested then a bag of rules was developed for illustrating energy KPIs in the case of the healthcare industry. This development of the renewable energy investment planning method achieved efficient and renewable energy measures. Additionally, the analysis was carried out at elderly care centres and hospitals.

Tokat S. et al. [16] have designed a key performance indicator approach with the assistance of the fuzzy c-means clustering method. This system was designed for warehouse loading operations. The clustering was performed with five parameters, and its performance was evaluated.

2.2 Implementation of KPI for performance evaluation

Bhadani et al. [17] computed critical KPIs for an aggregate production plant with the assistance of dynamic simulations. The KPIs were also implemented in a three-stage aggregate manufacturing facility using real-time plant data and dynamic process simulation. The developed KPIs aid operators and plant management in making decisions. The findings showed how various equipment and process KPIs are linked and interdependent. The dynamic simulation can be used as an exploration tool to uncover opportunities for improving aggregate processing using KPIs as a metric. The KPIs provided in this study were indeed based on the ISO 22400 standard and might be applied to similar processing processes like coarse and fine comminution in mineral processing. Besides diagnosis, the KPIs provided in the dynamic simulation platform can be used to study and optimize the design and operations of a crusher plant. J. Gao [18] provided a BP neural network and a rough set for performance measurement using KPI.

2.3 Operations performed by KPI

Scheepmaker et al. [19] defined a group of key performance indicator approaches for train operations. The designed model was time-relevant, accurate, suitable, quantifiable and ideal. These criteria were greatly influenced by the driving approach of the train driver. Among the important performance metrics are safety, brand image, on-time delivery, driver workload, the environment, maintenance expenses, and energy consumption. Our findings enable train and freight companies to make an informed choice when picking a preferred driving strategy for their drivers and a Driver Advisory Framework to help that strategy.

Feiz et al. [20] developed a set of key performance indicators (KPI) for comparing different biogas production systems in terms of climate impact, primary energy consumption, nutrient recycling, and cost. We present an example to demonstrate how

our method might be applied in the field, in which we investigate several heat supply alternatives for a biogas facility. For uncertainty management and further analysis, we explain how the suggested taxonomy and KPIs can be combined with global and local sensitivity evaluations. The KPIs provide valuable data for future decision-making in developing biogas systems from food waste.

2.4 Analyzing the performance of KPI in various applications

Ali et al. [21] presented the Key Performance Indicators (KPIs) for Sustainable Freight Transport Systems based on existing literature research and standards of sustainability measurement in freight transport (SFTS). Then, using KPIs, various scenario-based impediments to freight transportation performance in Pakistan to achieve sustainable development goals are highlighted. The key bottlenecks are Strategic Determinants (SD), Information Systems (IS), Infrastructure Management Systems (IMS), and City Logistics (CL). Turcanu et al. [22] investigate the importance of KPIs in port management.

From the perspective of users, Gurjar et al. [23] provided a simple and systematic methodology for comparing the performance of alternative public transportation systems in Indian towns. The methodological approach is also demonstrated using Bhopal city bus services. This research is thought to be useful in comparing the performance of an existing public transportation system and a new public transportation system in India to any comparable or different public transportation system.

Putra et al. [24] investigated the service quality of metropolitan public transportation systems. At the same time, the study's goal was to establish how well public transportation services are performing now in terms of the satisfaction, expectations, and interests of individuals who utilize them. Important Performance Analysis (IPA) and customer satisfaction index (CSI) were utilized as data analysis methodologies for public transportation performance. At the same time, the Structural Equation Model was employed to examine whether there was an influence on public transportation user satisfaction (SEM) performance.

Mladenovic et al. [25] developed a two-step evaluation process for PPP projects. The first stage was based on an assessment of the project and its eventual aims from the standpoint of each stakeholder, including commercial profitability, public sector efficacy and value for money, and user service level. The attainment of multiple stakeholder objectives was adjusted and weighted in an overall method (second layer) for describing a PPP's success or failure.

2.5 Analysing the performance of KPIs for Urban Public Transit Systems

The urban transit system has many impacts in developing countries due to the population in the cities. Urban transportation has many complexities due to population and traffic. In the mid-range of cities, the availability of transport facilities is also inadequate. It is essential to find the KPIs of the urban transit system to provide quality transportation in mid-cities. Some of the research on KPI identification in urban transit systems is listed below.

Gadepalli R. et al. [26] have undertaken a comprehensive analysis of the metro rail service supply and travel demand patterns and the existing urban bus services for the city of Bengaluru, India. Grote M. et al. [27] have analysed the delivery of UTC systems' urban transport policies, thereby identifying Key Performance Indicators (KPIs) to provide user-led guidance for future system development. Burke J. et al. [28] have proposed a framework to create a series of urban form typologies, generally describing a city's shape and size as a

unifying concept to describe a city's design underlying pattern. Identifying and characterizing their internal tapestry of city form typologies is possible, as evaluating their respective urban performance KPIs. Caballini C. et al. [29] have proposed a methodology to select, calculate and analyse a set of KPIs to define reference model cities and then measure the level of preparedness of city respect with respect to electric mobility with a main focus on the charging infrastructure. Elsayed E.N.S., [30] have recommended key performance indicators (KPIs) of smart, sustainable urban spaces which affect the quality of life and can be easily applied by users as self-assessing criteria for evaluating urban spaces. Mohammadi, A. and El-Diraby, T. [31] have improved the classical asset-based approach and proposed a user-oriented platform to maintain urban railway systems. Their results indicated that the proactive approach significantly could save money and bring higher value and performance to the agency. Based on this review, we found some of the parameters have importance in the public transport system, which is given in Table 1.

The KPI approach proposed in various articles in this literature review is listed. Based on this review, it is observed that there is adequate research on KPI identification. However, there is no proper and effective parameter for mid-populated cities with average transportation facilities in India. Hence this study is motivated to survey to identify KPI for an urban transport system in mid-populated cities in India.

3 Methodology

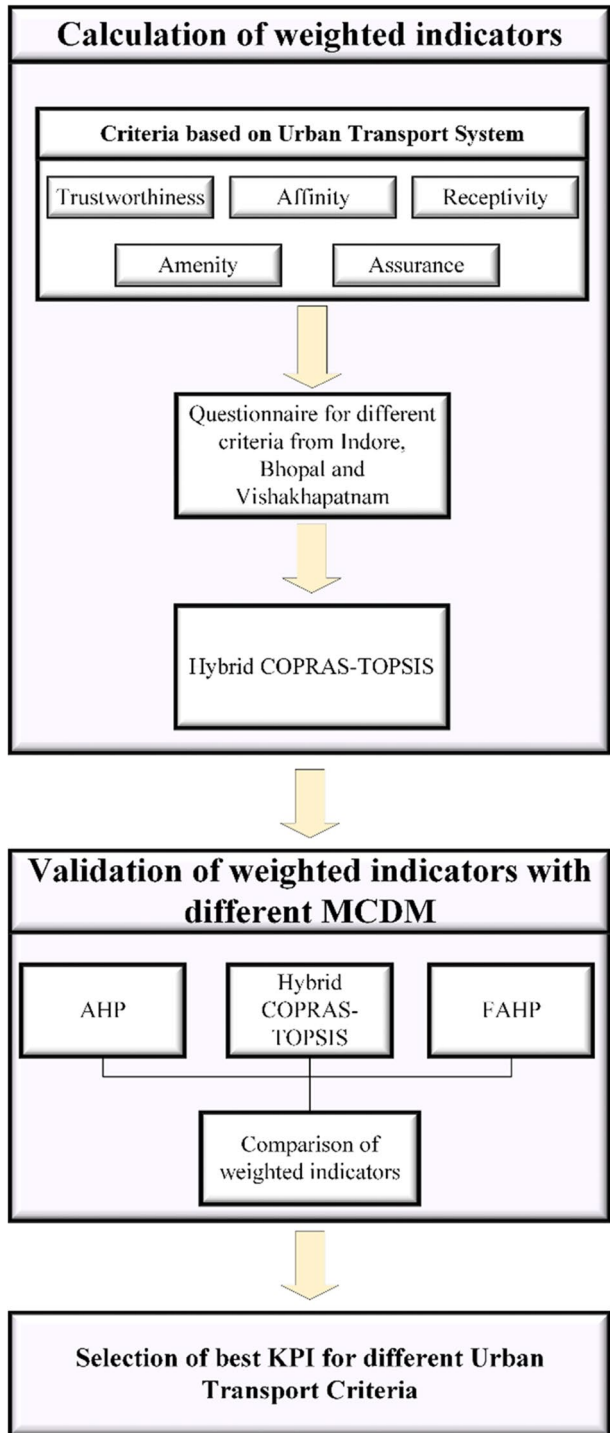
Developing a transport model for three cities such as Bhopal, Indore and Vishakhapatnam, concerning KPI parameters as they were amended in five dimensions by gathering passenger responses for a questionnaire prepared from 500 respondents with different aspects. These responses are then computed for weight using the hybrid COPRAS-TOPSIS and compared with the help of the AHP [32] and FAHP [33] techniques.

Figure 1 promotes a KPI-related transport model for three urban populations, such as Bhopal, Indore, and Vishakhapatnam, as altered by collecting travellers' responses from 500 respondents. These responses are then assessed for weight indicators using the hybrid COPRAS-TOPSIS MCDM technique. Initially, data are collected from the study areas and processed by using the hybrid technique. This processing results in weight values, thus organizing them in a hierarchical form. The hierarchical structure is then ranked and sorted

Table 1 Analysis of KPI from review evaluation

KPI	Evaluation criteria
Safety	Distance remaining and time remaining
Timeliness	Deviation from time of arrival
Energy consumption	Total amount of energy
Environment	Average Pass by noise
Cost of Maintenance	Wear of braking blocks
Effective transport facility	Excluding transport performance
Climate impact	Creating impact of bad weather and pandemic
Recycling	Eco-friendly vehicles
Enhancement of transport	After measuring field response
Resource cost	Cost that happened for transport at all time period

Fig. 1 Flow chart of the proposed methodology



to make predictions finalize. For validating the designed model, the Hybrid COPRAS-TOPSIS, AHP and FAHP models are used.

3.1 Data collection using questionnaire

Data collected through a questionnaire is collected from 1500 respondents who are passengers from three different cities in India. Initially, a questionnaire with around 102 questions is circulated in Google Form ([https://docs.google.com/forms/d/1vq1UHmH0njxh6FaVES1bWq4nibmxXg7r_ZtRKpTikcs/](https://docs.google.com/forms/d/1vq1UHmH0njxh6FaVES1bWq4nibmxXg7r_ZtRKpTikcs/viewform?edit_requested=true) viewform?edit_requested=true). The form includes nine sections; Section 1 describes the introduction to the project and the need for data. Section 2 has questions related to personal information. Section 3 to Section 7 contains questions related to five key parameters: Trustworthiness, Amenity, Receptivity, Assurance and Affinity. Section 8 contains questions to understand the changes that occurred due to COVID-19, and the final Section 9 contains a question for a recommendation for the public transport system.

3.2 Hybrid COPRAS-TOPSIS

Combining the COPRAS and TOPSIS approaches to discover the weight indicators for each characteristic based on the five different criteria such as trustworthiness, affinity, amenity, assurance, and receptivity is used to design a proposed hybrid model. The selection of KPI from five parameters is illustrated in Fig. 2.

In this model, the TOPSIS method is an efficient and advanced MCDM methodology used in this model, which was first presented by Hwang and Yoon in order to achieve the best decision based on the compromise solution principle [34]. Similarly, the COPRAS method analyzes alternative progress in terms of numerous criteria and related weights by employing a step-by-step ordering and selecting the method of selection for variations relevant and degree of usage [35]. Thus, the hybrid COPRAS-TOPSIS algorithm is used in the following operations to select the best alternatives.

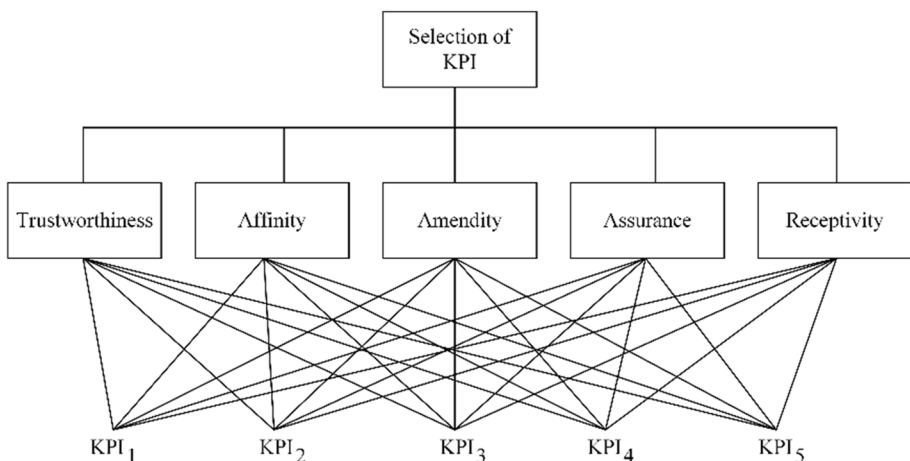


Fig. 2 Schematic diagram of KPI

Step 1: Primary identification of essential features (dependent and independent factors) is required. In general, the dependent parameters' desire maximisation is seen as the most ideal, whereas the dependent parameters' calculation is regarded as least desirable. In this analysis, all variables are evaluated for least desirable (for minimization), whereas none of these are considered most preferable (for maximisation). Because of the decreasing responses result in an improvement in component output and quality.

Step 2: A matrix often known as a decision matrix is a type of data representation that includes I rows (m—possibilities) and j columns (n—criteria).

$$[D_{1500 \times 102}] = \begin{pmatrix} x_{m1} & x_{m2} & \dots & x_{m102} \\ \cdot & \cdot & \dots & \cdot \\ x_{n1500} & x_{n1500} & \dots & x_{n1500} \end{pmatrix} \tag{1}$$

The decision matrix $[D_{1500 \times 102}]$ is given in Eq. (1).

Step 3: The following formula Eq. (2) is used to determine the elements in the normalized matrix N_{ij} .

$$N_{ib} = \frac{x_{mn}}{\sqrt{\sum_{i=1}^b x_{mn}^2}} \quad j = 1, 2, \dots, n \tag{2}$$

Step 4: Individual weights are multiplied by the appropriate column of the normalised decision matrix to produce a weighted normalised decision matrix.

$$W_{ib} = N_{ib} \times W_b \tag{3}$$

where N_{ij} is the normalized matrix and W_j is the weight criteria. The weighted normalized value $W_{1500 \times 102}$ is calculated using Eq. (2) and Weight values for each criterion.

$$[W_{1500 \times 102}] = \begin{pmatrix} W_{m1} & W_{m2} & \dots & W_{m102} \\ \cdot & \cdot & \dots & \cdot \\ W_{n1500} & W_{n1500} & \dots & W_{n1500} \end{pmatrix} \tag{4}$$

The perceived weighted normalized matrix $[W_{1500 \times 102}]$ is given in Eq. (4).

Step 5: Calculation of P_i , which is identified by the summation of attributes that need to be maximized. That is the summation of the beneficial criteria.

$$P_i = \sum_{b=1}^L x_{mn} \tag{5}$$

In the above formula Eq. (5), (m – k) is the number of responses which required to be lessened. Conceiving the current study, all of the attributes have to be minimized, due to their adverse features.

Step 6: Perceiving the diminutive value of R_i Eq. (6).

$$R_{min} = \min_i R_i, \text{ where } i = 1, 2, 3, \dots, m \tag{6}$$

Step 7: Determination of the relative weight of each response Q_i is given in Eq. (7). The proportional significant value of a response indicates the level of content attained by that response. The greater the priority of the alternative, the higher the value of Q_i . The best choice among the alternatives is one of the highest relative value Q_{max} .

$$Q_i = P_i + \frac{R_{min} \sum_{i=1}^m R_i}{R_i \sum_{i=1}^m \frac{R_{min}}{R_i}} \quad (7)$$

Based on these steps, the weight indicators are evaluated for different Urban transport criteria using the hybrid COPRAS-TOPSIS MCDM method.

3.3 AHP method

The ideal strategy for multi-criteria decision making is AHP, which has the greatest benefit of considering several criteria. The main steps are as follows:

- i) *Putting together the hierarchical model*: The dilemma is first organized as conceptual data, with multiple degrees of alternate evaluation. At the highest level, the overall objective is further defined by key criteria and low-level sub-criteria. The evaluation of performance variables for every aspect needs to be mutually distinct.
- ii) *Pairwise evaluation of conditions and possibilities for the development of evaluation matrices*: The next step is to do a pairwise analysis to establish the relative weights of the qualities of the decision element. This approach yields the rated priority for each decision alternative under each criterion. To get the consistency rate, multiply the Consistency Index by the following equation:

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (8)$$

The satisfactory value for CI is below 0.1. The CI and R1 ($CR = CI/R1$) were then used for the constant ratio. CR versus 0.1 can be considered consistent enough. Decision-makers are also uncertain about prioritizing the AHP process with one criterion above the other. To solve this ambiguity, a fluid logic is combined with AHP.

- iii) *Calculating local priorities*: The local priorities are calculated from the decision matrices after the pairwise comparison is made using the Eigenvalue method (EVM). The deviation degree for the evaluation matrix from the point of entire consistency is greater if the weight index value is greater. To check the estimated weight, the values obtained for weight must be less than 0.10. This value is determined to be the maximum threshold value. At last, the choice is made with the assistance of the normalized values.
- iv) *Substitutions Ranking*: The ultimate move is to reach the final or global ranking, with the basic weighted figure taking into account all the local preferences obtained from the previous step. The final classification of the alternatives is then determined. The accuracy review must be carried out until the weight has been assigned for each criterion and registered.

3.4 Fuzzy AHP method

The involvement increases the consistency by using the scale of 1–9 of the decision-making process. The unsafeness inherent in using crisp judgemental values underlines the necessity of weighing the potential values of membership. To reach a crisp conclusion, fuzzy logic is used to handle incertitude or imprecise judgment due to insufficient or imperfect information. Each criterion is crossed with the matrix to calculate the ultimate weight for

every criterion. This matrix is reached by estimating each substituent related to every criterion. The hierarchical architecture of the Fuzzy-AHP is illustrated in Fig. 3.

Qualitative and perceptible analysis is a stream of ratings that must be generalized to remove uncertainty for benchmarking via fuzzy logic membership functions (x). TMF has also been embraced because of its straightforward calculation methods, which require three parameters: upper and lower widths (a and c) representing feet and a nodal point (b) at the peak. The fuzzy triangular numbers are frequently utilized to address that maximum practical application. The function of vector x is written in the equation with the help of three scalar parameters (3).

$$f(x;a,b,c) = \max\left\{\min\left(\frac{x-a}{b-a}, \frac{c-x}{c-b}\right), 0\right\} \quad (9)$$

Based on real-time circumstances related to public transport in India, some of the scalar parameters for every linguistic variable were observed. They also applied KPIs to TMF based on the language ratings obtained. An ONRoP of the Bhopal and Visakhapatnam bus model was created utilizing fuzzy logic techniques such as TMF and the Defuzzification function.

3.4.1 Determining the weights of evaluation dimensions

For evaluating the weight indicators for different criteria, some of the target evaluators are framed as a questionnaire to get responses from the public people. The performance indexes used in this study were Hybrid COPRAS-TOPSIS, AHP and FAHP. The evaluators with descriptions for the five parameters are illustrated in Table 2.

As this is a subjective judgement, people's perceptions of the importance and weight of KPIs and evaluators differ. As a result, an expert opinion is sought by employing the AHP approach for calculating KPI weights, which allows for pairwise comparison of the eight KPIs. Then, using the 'direct weighting' technique, expert opinion was used to calculate the weights of evaluators under the KPIs. Weights are evaluated using the equations stated above, and these weight values are then sorted and ranked for prediction purposes.

Fig. 3 Fuzzy- AHP hierarchical architecture

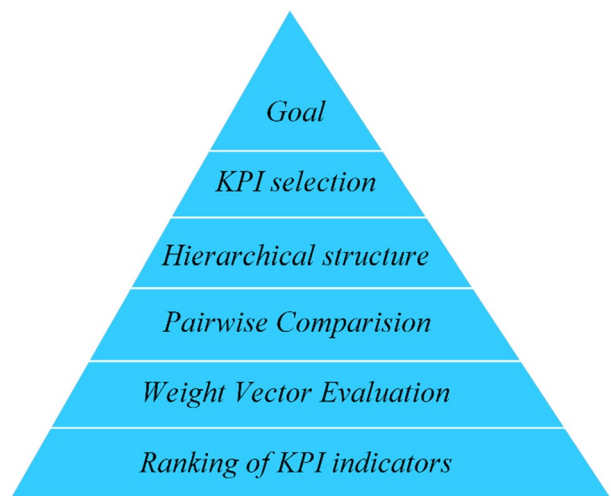


Table 2 Proposed model evaluation dimensions

Indicator Group (IG)	Evaluators	Target Evaluation and Description
Trustworthiness	<ul style="list-style-type: none"> ■ Bus information and schedule is available at every stop ■ Buses are strictly maintaining schedule ■ Bus information with route maps is available at every stop ■ Bus information with route maps is available in every bust station ■ Bus service is reliable even in bad weather condition ■ All buses are functioning on the weekend and holidays 	<p>To test the framework's SA qualities and arrange Improvement zones, essential components, like reasonableness, recurrence and strength, were estimated. Importance is upon fascinated to consider the number of exchanges it unveils Network Robustness</p>
Amenity	<ul style="list-style-type: none"> ■ Buses are found to be hygienic and are maintained in a better way ■ Buses are considered as a model for a safe journey ■ Buses are determined to be an excellent system for the purpose of campaigning and advertising ■ Many eco-friendly buses are used by the government to reduce global warming ■ Controversy lot of eco-friendly buses are used by private also ■ The bus stops are maintained in a better way ■ Travel by train is safer and cleaner than the busway 	<p>While it makes minimal effort travel simpler, a few classes of travellers pick accommodation over costs. This IG thusly assesses factors, for example, traveller load factor, travel proficiency and ease of use</p>
Receptivity	<ul style="list-style-type: none"> ■ Large ticket price variation among each category of buses ■ Have a well-structured route plan for buses to reduce lengthy journeys ■ Average Bus tickets are affordable ■ Bus stops are conveniently located in every region ■ The number of stopping on government buses is less than the private bus service ■ In Government service, a separate officer is available at every station to receive complaints and take action 	<p>The point is to evaluate the benefits given by the PT administration to end-clients and get the client's appraisal of reasonableness</p>
Assurance	<ul style="list-style-type: none"> ■ Drivers & Conductors in private buses are courteous ■ Drivers & Conductors in government buses are courteous ■ There is a lot of safety measures against crime on public transport ■ Safety measure in private buses is better in intercity transit ■ Safety measure in government buses is better in intercity transit 	<p>This IG assumes a fundamental part in guaranteeing that each PT plot is long haul feasible. Assessments are directed in the decent method of representatives in the bus plot, including the network, to the different versatile modes, sign and social need and modular sharing</p>

Table 2 (continued)

Indicator Group (IG)	Evaluators	Target Evaluation and Description
Affinity	<ul style="list-style-type: none"> ■ Government buses have a separate seat for senior citizen ■ Government buses have separate seats for physically challenged ■ The private bus has a separate seat for senior citizen ■ The private bus has a separate seat for physically challenged ■ The seats of special persons will never be occupied by other people 	<p>This IG ensures the safety and comfortless level of passengers. Thus certain features like accessibility, ride quality and passenger load factors are evaluated in this case of IG</p>

3.5 Study area and data collection methodology

In this research for analyzing the public transport system, we have considered three cities in India such as Indore, Vishakhapatnam, and Bhopal. These cities are moderately populated and in the developing stage. So, these cities may expect valuable suggestions for improving their public transportation. Thus, our Questionnaire was circulated among these three cities to gather opinions.

- i) *Indore*: The population of Indore is over 1.6 million, with a mean growth rate of 40% per year. Indore metropolitan area is spread over 504.87 square kilometres and consists of 4 towns and 90 villages of Indore Municipal Corporation. Indore, a large city in Western Madhya Pradesh, is a major educational, medical, and industrial trading centre. Road vehicle traffic has increased due to rapid urbanization and population growth. Congestion, delay, pollution, and accidents are among the challenges that have arisen as a result of increased traffic. Indore's public transportation system comprises structured, standard bus service operations with metro taxis provided by Indore City Transport Service Limited (ICTSL) and disorganized systems. The road network is almost 1710 kms long, with main routes covering 234 kms with intermediate nodes and city roads covering 211 kms and 936 kms, respectively. On most roadways, essential road features such as medians and walkways are absent. The transport details of this Indore city are taken from [36].
- ii) *Vishakhapatnam*: The Municipality of Vishakhapatnam was founded in 1858 and became a Municipal Corporation in 1979. With 4,534 officials and workers, Vishakhapatnam Municipal Corporation served an estimated population of 12 lakhs. Between 1981 and 1991, the population grew at a pace of 47.39 per cent, and the Corporation's total yearly revenue was Rs. 100 crores. Greater Vishakhapatnam Municipal Corporation will now manage the former Vishakhapatnam Municipal Corporation's boundaries, the Gajuwaka Municipality and 32 villages (including a few Panchayats) (GVMC). On November 21, 2005, the Government of Andhra Pradesh issued a Government Order (GO) that established the GVMC. Greater Vishakhapatnam will encompass major industries such as the Vishakhapatnam Steel Plant, Bharat Heavy Plate and Vessels, and Hindustan Zinc, which is currently part of the Sterlite group. The city's road network is developing in a radial pattern. The principal road network in the city region stretches about 126 kms. The total length of the road is 1007 kms. The city's recent growth pattern has been more in the north/south and west directions. The city is crossed by two national highways: NH5 (which connects Chennai and Kolkata on the south) and NH43 (which connects Raipur on the east). The Vishakhapatnam City's transport details are gathered from [37].
- iii) *Bhopal*: Bhopal, the capital of Madhya Pradesh and India's 16th largest city, is known as the "city of lakes" because of its numerous natural and artificial lakes. On the Malwa plateau, the city is located. According to the 2011 Indian census, Bhopal has roughly 23,68,145 people living in a total area of 2,772 square kilometres, resulting in a population density of 854 people per square kilometre. The national and state highways NH-12, SH-18, and SH-23 connect Bhopal to the rest of the country. During the 2000s, the Kolar municipality area in the southern part of the city, as well as adjacent residential areas such as Shahpura, Piplani, Barkhera Patani, and Lalghati, began to establish public transportation services, increasing in demand for public transportation. Due to the rise of commercial and industrial activity, transportation demand in Bhopal also developed fast. Bhopal's public transportation system consists of intercity buses for intercity travel

and BRTS and Minibus (in some areas) for intracity travel. Bhopal's bus system is based on the public–private partnership (PPP) paradigm (Public–Private Partnership). The BRTS (Bus Rapid Transit System) in Bhopal is managed by BCLL (Bhopal City Link Limited). BRTS Bhopal operates 225 buses covering a total distance of 186 kms. From [38], the transport information of Bhopal city is collected.

3.5.1 Data collection

Based on the created Questionnaire, data was collected from Bhopal, Indore and Vishakhapatnam. Observations were made for at least 10 persons a day to reach 500 persons, and their responses were analyzed and weighted concerning indicators. Persons are asked for their details. The collection of data was made in the form of questionnaires with a collection of questions related to the facility they prefer to travel to. Their convenience and trustiness to travel via public transport have been observed. The transport system is questioned for its cost-effectiveness and convenience during bad weather conditions. Observations are made for three months to analyze the transport facility before and after COVID-19.

The Questionnaire includes around 128 questions and is filled by a total of 1500 respondents (500 from each city). The Questionnaire has around five major portions to analyze Trustworthiness, Amenity, Receptivity, Assurance and Affinity. An almost equal number of respondents are given their opinion from every city. The gender of respondents from various cities is plotted. More than 50% of respondents are females. It is a strong notice in India, and females depend more on public transport than the male gender.

The questions asked to respondents from three different cities are given in Table 3. The detail of the respondents is illustrated in Table 4.

4 Results and discussion

Key Performance Indicator (KPI) for the sustainable development of the public transport system is determined in this research. The KPI for sustainability is selected based on five dimensions: Trustworthiness, Amenity, Receptivity, Assurance, and Affinity. The weightage for these five dimensions is equally distributed with 20% each. Each dimension includes various indicators, i.e., Trustworthiness, Amenity, Receptivity, Assurance, and Affinity, which have 21,16,14,10, and 9 indicators, respectively. Then the indicators of every dimension or parameter are formulated as an opinion question. Around 1500 respondents complete the response to this opinion from three cities like Indore, Bhopal and Visakhapatnam. Then for the effective analysis and to find the KPI, three multi-criteria decision-making techniques, hybrid COPRAS-TOPSIS, AHP and FAHP are modelled. The techniques are mathematically modelled and analyzed using MATLAB 2020b. Then the data are preprocessed to make it to the analysis of the KPI.

4.1 Justifications of selected indicators

A trustworthiness indicator is used as it analyzes and presents the bus information provided at every stop as trustworthy, and route maps at every stop are helpful. By checking the

Table 3 Questions asked to the respondents

Indicators	Questionnaires
Trustworthiness	<ul style="list-style-type: none"> ● Is the bus information and schedule is available at every stop? ● Whether the buses are strictly maintain schedule? ● Is the bus information with route maps is available at every stop? ● Is bus information with route maps is available in every bust station? ● Whether the bus service is reliable even in bad weather condition? ● Whether all buses are functioning on the weekend and holidays?
Amenity	<ul style="list-style-type: none"> ● Whether the buses are found to be hygienic and are maintained in a better way? ● Is the buses are considered as a model for a safe journey? ● Is the buses are determined to be an excellent system for the purpose of campaigning and advertising? ● Whether many eco-friendly buses are used by the government to reduce global warming? ● Is the bus stops are maintained in a better way? ● Is travel by train is safer and cleaner than the bus way?
Receptivity	<ul style="list-style-type: none"> ● Have a well-structured route plan for buses to reduce lengthy journey? ● Whether the average bus tickets are affordable? ● Whether the bus stops are conveniently located in every region? ● Is the number of stopping on government buses is less than the private bus service? ● Whether a separate officer is available at every station to receive complaints and take action in Government service? ● Whether there is large ticket price variation among each category of buses?
Assurance	<ul style="list-style-type: none"> ● Whether the drivers and conductors in private buses are courteous? ● Is the drivers and conductors in government buses are courteous? ● Whether there is a lot of safety measures against crime on public transport? ● Is the safety measure in private buses is better in intercity transit? ● Do you have better safety measure in government buses than intercity transit?
Affinity	<ul style="list-style-type: none"> ● Whether the government buses have a separate seat for senior citizen? ● Does the government buses have separate seats for physically challenged people? ● Is the private bus has a separate seat for senior citizen? ● Does the private bus has a separate seat for physically challenged? ● Whether the seats of special persons will be occupied by other people?

Table 4 Detail of respondents

City	Bhopal/Indore/ Vishakhapatnam
Name	Hirdya yadav
Gender	Male/Female/Other
Age	any
Marital Status	any
Education Level	any
Income Range Per Month	any
Occupation	any

bus service is reliable even in bad weather conditions. Also, during COVID situations, the function of buses at weekends and holidays is analyzed in this indicator.

Amenity indicator analyzed the sanitation in the bus. It analyzed its safety for passengers, the best mode for campaigning and its eco-friendly nature to the environment is analyzed in this indicator. Henceforth it is maintained to analyze amenity indicators.

The receptivity indicator analyzed the ticket price changes among all categories of buses that have a perfectly structured route plan for buses to minimize lengthy journeys, and bus tickets that are affordable with convenient locations for all the regions.

The assurance indicator is fundamental to guaranteeing the courteous of drivers and conductors to the passengers. Safety measures against crime that has public transport and intercity transit have safety measures analyzed.

Affinity indicator has assured that a separate seat is available for senior citizens, physically challenged, and other persons do not further occupy it.

Data Normalization: Most of the queries in the Questionnaire are rating based, as well as yes or no. So, these responses are represented by their equivalent numerals, as stated in Table 5.

Then the normalized pairwise matrix is calculated. Subsequently, the criteria weight using hybrid COPRAS-TOPSIS, AHP and FAHP is calculated for every attribute, which is given in Tables 5, 6, 7, 8 and 9. The trustworthiness analysis using hybrid COPRAS-TOPSIS, AHP and FAHP is given in Table 5.

Table 5 gives the criteria weight or weight indicator value of 21 indicators to analyze the Trustworthiness parameter. The analysis marked that the fourth indicator, "Bus information with route maps is available in every bus station", by hybrid COPRAS-TOPSIS, AHP and FAHP techniques are 0.161247863, 0.200459797 and 0.180285745, respectively. The indicator "Train facility is nearer to my shelter" marked the lowest weight by hybrid COPRAS-TOPSIS, AHP and FAHP as 0.014587412, 0.012216359 and 0.01497067, respectively. It is stated all the MCDM techniques have similar performance with fine variation in the weight value.

Table 6 shows the Amenity analysis by hybrid COPRAS-TOPSIS, AHP and FAHP. The analysis shows that the indicator "Buses are the best mode for advertising & campaigning" has the highest weight of 0.139845, 0.149745 and 0.141085 by hybrid COPRAS-TOPSIS, AHP and FAHP, respectively.

Table 7 shows the Receptivity analysis by hybrid COPRAS-TOPSIS, AHP and FAHP. The analysis shows that the indicator "Large ticket price variation among each category of buses" has the highest weight as 0.203235, 0.166644 and 0.132456 by AHP, FAHP and hybrid COPRAS-TOPSIS, respectively.

Table 8 shows the Assurance analysis by Hybrid COPRAS-TOPSIS, AHP and FAHP. The analysis shows that the indicator "Drivers & Conductors in private buses are courteous" has the highest weight as 0.245669, 0.205187 and 0.187654 by AHP, FAHP and hybrid COPRAS-TOPSIS, respectively.

Table 9 shows the Affinity analysis by Hybrid COPRAS-TOPSIS, AHP and FAHP. The analysis shows that the indicator "Government buses have a separate seat for senior citizen" has the highest weight as 0.23344, 0.194478 and 0.165874 by AHP, FAHP and hybrid COPRAS-TOPSIS, respectively.

In Tables 10 and 11, the weight measured by Hybrid COPRAS-TOPSIS, AHP and FAHP is given for the cases like Before vs. after the Covid-19 Pandemic and Recommendations by respondents, respectively. The analysis shows that the proposed Hybrid COPRAS-TOPSIS, FAHP and AHP have a similar performance in choosing the parameter and among them, the Hybrid COPRAS-TOPSIS weight value is less than the FAHP's and AHP's weight.

Table 5 Analysis of trustworthiness using Hybrid COPRAS-TOPSIS, AHP and FAHP

S. No	Analysis of Trustworthiness	Weight level indicators			Hybrid COPRAS-TOPSIS
		AHP	FAHP		
1	Bus information and schedule is available at every stop	0.083924253	0.058433999	0.050548231	
2	Buses are strictly maintaining schedule	0.073208316	0.054828181	0.048285647	
3	Bus information with route maps is available at every stop	0.054474531	0.04258161	0.038025678	
4	Bus information with route maps is available in every bus station	0.200459797	0.180285745	0.161247863	
5	Bus service is reliable even in bad weather condition	0.050643393	0.044612921	0.041321789	
6	All buses are functioning on the weekend and holidays	0.083273288	0.081562244	0.079287436	
7	Additional buses are functioning during festival season to reduce rush	0.033632379	0.031469923	0.031224568	
8	Buses facility is nearer to our shelter	0.027079247	0.026845412	0.024781236	
9	Buses are available only on time during peak hours	0.030329906	0.027702267	0.026547893	
10	Adequate Buses are available on time during peak hours	0.109568907	0.121305973	0.140014566	
11	Buses are available from my nearest station to every area in the city	0.025122156	0.029518561	0.029124786	
12	The frequency of buses is very high on every route	0.023605494	0.028605877	0.027846244	
13	Ticket fare is reasonable in public buses	0.022135655	0.023286379	0.023145796	
14	Private buses are also functioning for public transport	0.037782702	0.046831562	0.045324781	
15	Ticket fare of private buses are the same as a government vehicle	0.018408511	0.020488007	0.021247856	
16	The ticketing system is genuine in government buses	0.053439352	0.080250797	0.079854131	
17	The ticketing system is genuine in private buses	0.01505141	0.021506535	0.021157965	
18	A computerized ticketing system leaves little scope for cheating & bribing	0.0166454	0.024035719	0.023657489	
19	Train facility is nearer to my shelter	0.012216359	0.01497067	0.014587412	
20	Train ticket fare is affordable for me	0.019446734	0.027918897	0.027789456	
21	Private bus services maintain schedules better than government buses	0.009552211	0.01295872	0.011547899	

Table 6 Analysis of Amenity using Hybrid COPRAS-TOPSIS, AHP and FAHP

S. No	Analysis of Amenity	Weight level indicators			Hybrid COPRAS-TOPSIS
		AHP	FAHP		
1	Buses are clean and well maintained	0.123902	0.094963	0.11365	
2	Buses are a safe mode of transport	0.087688	0.068119	0.054478	
3	Buses are the best mode for advertising & campaigning	0.149745	0.141085	0.139845	
4	Eco-friendly buses are used in government	0.066866	0.056453	0.050596	
5	Eco-friendly buses are used in private	0.114098	0.112309	0.123650	
6	Bus stops are well maintained	0.053295	0.046804	0.045697	
7	Travel by train is safer and cleaner than the busway	0.05558	0.061313	0.063874	
8	Private buses are neat and well maintained	0.041508	0.045807	0.045024	
9	Government buses are neat and well maintained	0.070484	0.087334	0.086981	
10	Condition of government bus is based on its category	0.033029	0.034972	0.033687	
11	Passenger seats are clean and well maintained in Government buses	0.034793	0.038754	0.034878	
12	Passenger seats are clean and well maintained in Private buses	0.097009	0.097074	0.095478	
13	In private bus passengers, more than seat count will never be allowed	0.016065	0.027237	0.026578	
14	In government bus passengers more than seat count will never be allowed	0.023632	0.036406	0.035478	
15	Roads in the city limit are highly maintained to ensure better transportation	0.017166	0.029606	0.029032	
16	Train service is not necessary for intracity transit	0.01514	0.021763	0.021145	

Table 7 Analysis of Receptivity using Hybrid COPRAS-TOPSIS, AHP and FAHP

S. No	Analysis of Receptivity	AHP	FAHP	Hybrid COPRAS-TOPSIS
1	Large ticket price variation among each category of buses	0.203235	0.166644	0.132456
2	Have a well-structured route plan for buses to reduce lengthy journeys	0.091589	0.077722	0.065748
3	Average Bus tickets are affordable	0.098182	0.085574	0.795462
4	Bus stops are conveniently located in every region	0.051761	0.044967	0.039687
5	The number of stopping on government buses is less than the private bus service	0.094823	0.106244	0.101245
6	In Government service, a separate officer is available at every station to receive complaints and take action	0.059753	0.059968	0.060324
7	It is easy to report the complaint in private bus services	0.143553	0.166644	0.171644
8	Response time to resolve complaints is very low	0.044276	0.051868	0.053547
9	Government bus information is easily available through calls, SMS's & on the Internet	0.038226	0.04725	0.050364
10	Private bus information is easily available through calls, SMS's & on the Internet	0.097986	0.084293	0.075684
11	Private bus service providers are more friendly than the government staff	0.027594	0.027127	0.026874
12	Ticket concession is available in a city bus to advance book for the long term	0.018488	0.021604	0.024563
13	Private buses provide an extra offer for long term passengers	0.01632	0.030783	0.046871
14	Ticket concession in train is better than bus services	0.014215	0.029311	0.035689

Table 8 Analysis of Assurance using Hybrid COPRAS-TOPSIS, AHP and FAHP

S. No	Analysis of Assurance	AHP	FAHP	Hybrid COPRAS-TOPSIS
1	Drivers & Conductors in private buses are courteous	0.245669	0.205187	0.187654
2	Drivers & Conductors in government buses are courteous	0.133815	0.116341	0.098755
3	There is a lot of safety measures against crime on public transport	0.130659	0.13312	0.136987
4	Safety measure in private buses is better in intercity transit	0.128638	0.128886	0.132478
5	Safety measure in government buses is better in intercity transit	0.07996	0.076	0.072998
6	Safety measure in private buses is better in intracity transit	0.079493	0.08075	0.082654
7	Safety measure in government buses is better in intracity transit	0.066226	0.075484	0.080047
8	Safety measure in a train journey is better than buses	0.054517	0.066113	0.071645
9	Drivers in private buses are more sensible to avoid accidents	0.044039	0.058017	0.062547
10	Drivers in government buses are more sensible to avoid accidents	0.036983	0.060101	0.090354

Table 9 Analysis of Affinity using Hybrid COPRAS-TOPSIS, AHP and FAHP

S. No	Analysis of Affinity	AHP	FAHP	Hybrid COPRAS-TOPSIS
1	Government buses have a separate seat for senior citizen	0.23344	0.194478	0.165874
2	Government buses have separate seats for physically challenged	0.158046	0.134461	0.123658
3	The private bus has a separate seat for senior citizen	0.181797	0.180942	0.179854
4	The private bus has a separate seat for physically challenged	0.120799	0.120568	0.120124
5	The seats of special persons will never be occupied by other people	0.099712	0.103541	0.106874
6	Private buses are always safe for young mothers	0.044663	0.041162	0.036485
7	Government buses are always safe for young mothers	0.06734	0.086191	0.098756
8	Every private bus a first aid kit	0.053323	0.07462	0.086527
9	Every government bus a first aid kit	0.040882	0.064037	0.087965

Table 12 summarises key performance indicators based on the Hybrid COPRAS-TOPSIS AHP and FAHP analysis. The KPI here is selected based on its weight value and the indicator is selected at least it has average weight either in Hybrid COPRAS-TOPSIS, AHP or FAHP. In our system, the KPI from the transport data is categorized into five dimensions Trustworthiness, Amenity, Receptivity, Assurance, and Affinity. These five dimensions are equally weighted to maintain a sustainable system. After that, among Hybrid COPRAS-TOPSIS, AHP and FAHP, Trustworthiness is selected as the 7 KPI among 21 indicators. The KPI for Trustworthiness is selected if the indicator has a minimum of 0.05 weight in either Hybrid COPRAS-TOPSIS, AHP or FAHP. The respondents trusted the public transport system because of its transparent information

Table 10 Weight level indicators before vs. after COVID-19 pandemic using Hybrid COPRAS-TOPSIS, AHP and FAHP

S. No	Before Vs After Covid-19 Pandemic	AHP	FAHP	Hybrid COPRAS-TOPSIS
1	There is no change in the number of government buses services	0.157225	0.128772	0.106478
2	There is no change in the number of private buses services	0.131223	0.11626	0.096478
3	Waiting time is increased due to the limited number of seats	0.100617	0.090066	0.084569
4	I reduced the usage of public transport after the pandemic	0.146383	0.139068	0.136045
5	Buses are not on time after the pandemic	0.078203	0.07328	0.070215
6	I felt safe to travel on public transport	0.073752	0.077223	0.080647
7	Private buses are charging more after the pandemic	0.064147	0.067837	0.070684
8	Government buses provide the same services to every area	0.051006	0.052581	0.054566
9	Private buses services to some areas are limited after the pandemic	0.069573	0.075176	0.078456
10	The train journey is still safe after the pandemic	0.041128	0.055363	0.062546
11	Government buses are cleaner and more hygienic after the pandemic	0.033263	0.045071	0.058794
12	Road traffic gets reduced after the pandemic	0.030345	0.046178	0.060546
13	Usage of own vehicles has increased after the pandemic	0.023134	0.033126	0.040365

Table 11 Weight level indicators of Recommendation based Hybrid COPRAS-TOPSIS, AHP and FAHP

S. No	Recommendation	AHP	FAHP	Hybrid COPRAS-TOPSIS
1	Public transport is always better than its own vehicle journey	0.387121	0.337271	0.305644
2	The service quality of government buses is good for daily usage	0.097193	0.088782	0.081546
3	Availably of government buses during peak hours is enough	0.067712	0.069857	0.070548
4	Information public bus station is easily accessible and understandable	0.121127	0.120164	0.119787
5	Private buses are available during peak hours	0.047232	0.051488	0.054789
6	Passenger density in government buses is higher than in private buses	0.041667	0.045681	0.048456
7	Private buses are looks cleaner than government buses	0.12256	0.129099	0.135478
8	Ticket price is lower in government buses than private buses	0.028123	0.032283	0.035468
9	Concession in government buses is helpful to me	0.024703	0.028246	0.033546
10	Train facility is not adequate for regular usage	0.029351	0.040389	0.051265
11	The train journey is more convenient to cover the maximum distance to reach my Destination	0.033211	0.05674	0.06545

and availability during the all-weather condition. The KPI for Amenity is selected if the indicators have a minimum of 0.06 weight is either Hybrid COPRAS-TOPSIS, AHP or FAHP. People prefer public transport because of its cleanness, and safety and they

Table 12 Summary of KPI

Dimension	Key Performance Indicator with weight (AHP/FAHP/ Hybrid COPRAS-TOPSIS)
Trustworthiness (7/21) (0.05)	Bus information with route maps is available in every bust station (0.200459797/0.180285745/0.161247863)
	Adequate Buses are available on time during peak hours (0.109568907/0.121305973/0.140014566)
	Bus information and schedule is available at every stop (0.083924253/0.058433999/0.050548231)
	Buses are strictly maintaining schedule (0.073208316/0.054828181/0.048285647)
	All buses are functioning on the weekend and holidays (0.083273288/0.081562244/0.079287436)
	The ticketing system is genuine in government buses (0.053439352/0.080250797/0.079854131)
	Bus service is reliable even in bad weather conditions (0.050643393/0.044612921/0.041321789)
Amenity (8/16) (0.06)	Buses are the best mode for advertising & campaigning (0.149745/0.141085/0.139845)
	Eco-friendly buses are used in private (0.114098/0.112309/0.095785)
	Buses are clean and well maintained (0.123902/0.094963/0.085789)
	Passenger seats are clean and well maintained in Private buses (0.097009/0.097074/0.095478)
	Buses are a safe mode of transport (0.087688/0.068119/0.054478)
	Government buses are neat and well maintained (0.070484/0.087334/0.086981)
	Eco-friendly buses are used in government (0.066866/0.056453/0.050596)
Travel by train is safer and cleaner than the busway (0.05558/0.061313/0.063874)	
Receptivity (6/14) (0.07)	Large ticket price variation among each category of buses (0.203235/0.166644/0.132456)
	It is easy to report the complaint in private bus services (0.143553/0.166644/0.171644)
	Average Bus tickets are affordable (0.098182/0.085574/0.795462)
	Private bus information is easily available through calls, SMS's & on the Internet (0.097986/0.084293/0.075684)
	The number of stopping in government buses is less than the private bus service (0.094823/0.106244/0.101245)
Assurance (4/10) (0.1)	Have a well-structured route plan for buses to reduce lengthy journeys (0.091589/0.077722/0.065748)
	Drivers & Conductors in private buses are courteous (0.245669/0.205187/0.187654)
	Drivers & Conductors in government buses are courteous (0.133815/0.116341/0.098755)
	There is a lot of safety measures against crime on public transport (0.130659/0.13312/0.136987)
Affinity (4/9) (0.11)	Safety measure in private buses is better in intercity transit (0.128638/0.128886/0.132478)
	Government buses have separate seats for senior citizens (0.23344/0.194478/0.165874)
	The private bus has a separate seat for senior citizens (0.181797/0.180942/0.179854)
	Government buses have separate seats for the physically challenged (0.158046/0.134461/0.123658)
The private bus has a separate seat for the physically challenged (0.120799/0.120568/0.120124)	

prefer it for advertising & campaigning. Then the KPI for Receptivity is selected with a minimum of 0.07 weights, the public transport system is comfortable, and the public feels that the ticket price is affordable with various options.

In public transport, the passengers' complaints are encouraged with proper passenger support service for complaints and bus information. In the case of government buses, the number of stops is comparatively lesser than the number of private services. The KPI for Assurance has selected the indicators with at least 0.1 weight. The passengers in public transport are more confident about their security and safety against crime. However, a major portion of passengers prefers private service for intercity transport. There are four among nine indicators selected as KPI for Affinity. The selected indicators have a minimum of 0.11 weights either in Hybrid COPRAS-TOPSIS, AHP or FAHP.

Regarding affinity analysis, passengers give importance to separate seat availability for senior citizens and the physically challenged. Most passengers agreed that government and private–public transport have seating facilities for those special persons. But passengers give less weight to private services, unsafe for young mothers, and government services do not maintain first aid kits. This analysis shows that the public transport contributed by private and government services is only 42% sustainable with 33% of trustworthiness, 50% of Amenity, 43% of Receptivity, 40% of Assurance and 44% of Affinity. Some recommendations are noted to improve the sustainability of public transport in the middle-class city.

4.2 Computational complexity

In computer science, the computational complexity or simply complexity of an algorithm is the amount of operations required to run the MCDM technique. In this model, the evaluated computational complexity is in terms of the number of pairwise comparisons needed to estimate relative preferences of criteria and alternatives. The lower operations taken by the MCDM result in a faster and better computational speed of the technique. Particular focus is given to computation time and memory storage requirements.

The computational complexity of the AHP, FAHP and hybrid COPRAS-TOPSIS are evaluated for the five parameters such as trustworthiness, amenity, receptivity, assurance and affinity by illustrating the graphical representation from Figs. 4, 5, 6, 7 and 8. The total evaluated computational complexity based on the number of operations for AHP, FAHP and hybrid COPRAS-TOPSIS are 450, 350 and 132. In this validation, the hybrid

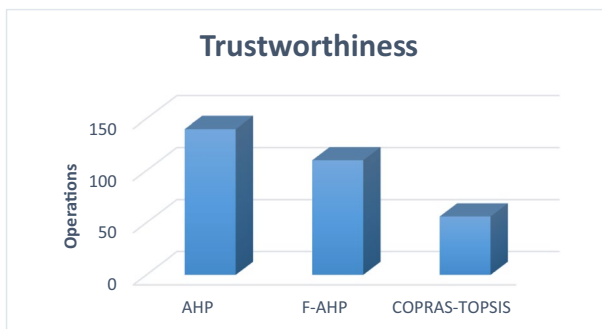


Fig.4 Computational Complexity for trustworthiness parameter with AHP, FAHP and Hybrid COPRAS-TOPSIS

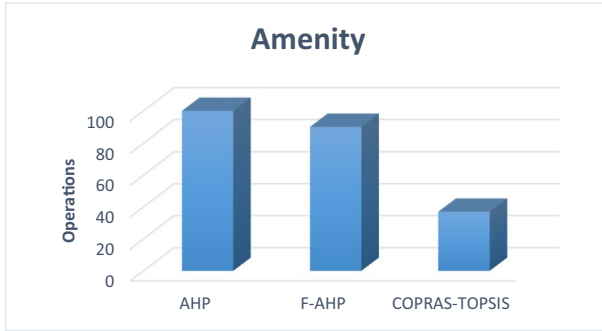


Fig.5 Computational Complexity for amenity parameter with AHP, FAHP and Hybrid COPRAS-TOPSIS

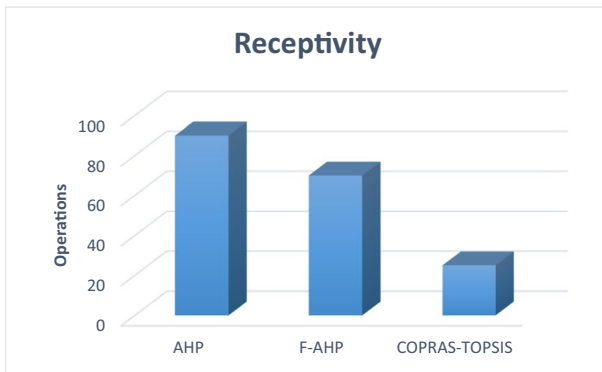


Fig.6 Computational Complexity for receptivity parameter with AHP, FAHP and Hybrid COPRAS-TOPSIS

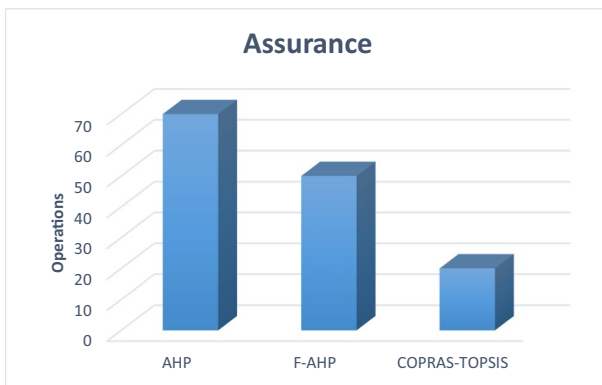


Fig.7 Computational Complexity for Assurance parameter with AHP, FAHP and Hybrid COPRAS-TOPSIS

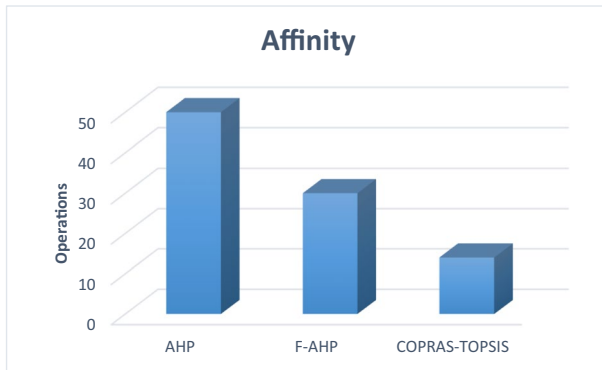


Fig. 8 Computational Complexity for Affinity parameter with AHP, FAHP and Hybrid COPRAS-TOPSIS

COPRAS-TOPSIS method has low computational complexity. Hence, this model can run with the minimum resource requirement.

4.3 Agility in the decision process

The word agility means fast moving, agile, active and the ability to move quickly and easily to think fast in a clever way. But in the current environment, agility means reacting effectively to a changing and unpredictable environment and using those changes as opportunities for organisational advancement.

Based on the operations, the agility in decision making for AHP, FAHP and COPRAS-TOPSIS for five parameters such as trustworthiness, amenity, receptivity, assurance and affinity evaluated by illustrating the graphical representation from Figs. 9, 10, 11, 12, and 13. In this model, the total operations taken for all the parameters for the proposed COPRAS-TOPSIS model is 1245 which results in the ability to move quickly for different operations to accurately predict the unpredictable environmental factors. The total operations that occurred for all the five parameters by the Hybrid COPRAS-TOPSIS, AHP and FAHP are 605 and 950.

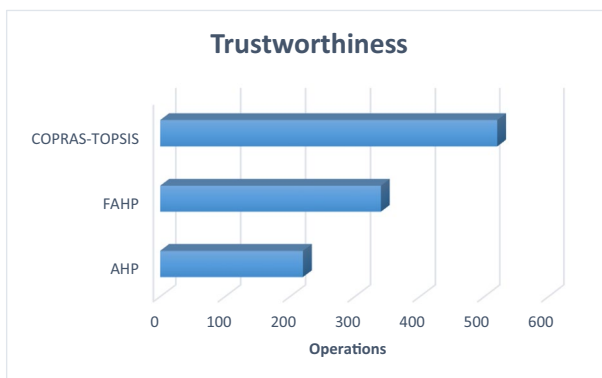


Fig. 9 Agility in the decision for Trustworthiness parameter with AHP, FAHP and Hybrid COPRAS-TOPSIS

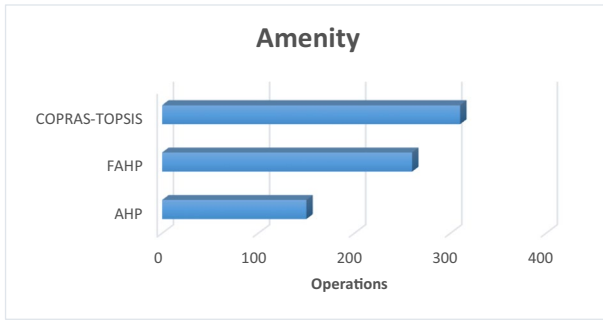


Fig. 10 Agility in the decision for Amenity parameter with AHP, FAHP and Hybrid COPRAS-TOPSIS

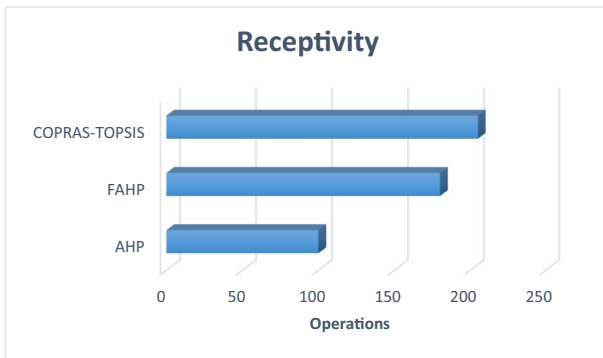


Fig. 11 Agility in the decision for Receptivity parameter with AHP, FAHP and Hybrid COPRAS-TOPSIS

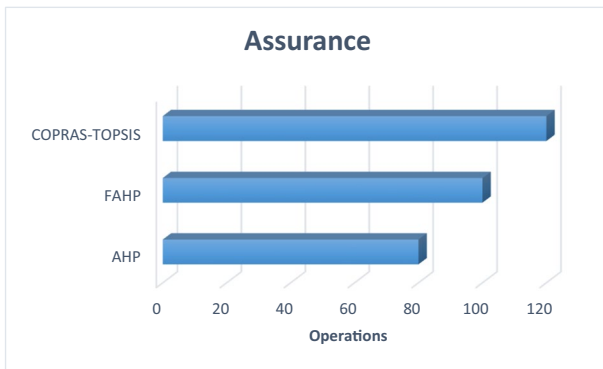


Fig. 12 Agility in the decision for Assurance parameter with AHP, FAHP and Hybrid COPRAS-TOPSIS

Table 13 depicts the comparisons made among algorithms utilized in this proposed approach and other algorithms called Random search (RS) and Pre-Requesting Search (PRS).

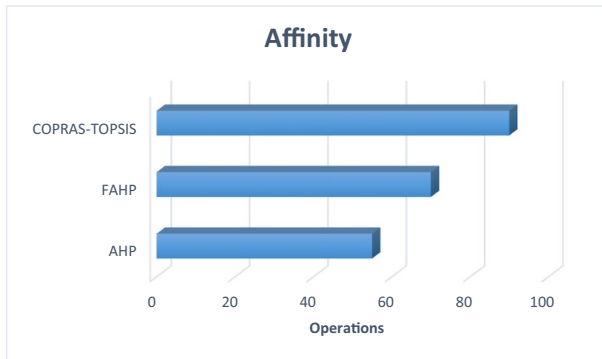


Fig. 13 Agility in the decision for Affinity parameter with AHP, FAHP and Hybrid COPRAS-TOPSIS

Table 13 Comparison of the proposed approach with other algorithms

Indicators	AHP	FAHP	COPRAS-TOPSIS	PRS	RS
Trustworthiness	150	126	49	157	153
Amenity	127	105	32	136	130
Affinity	56	32	11	64	59
Assurance	74	51	17	86	77
Receptivity	93	76	30	99	95

4.4 Discussion

The blended traffic stream trademark in non-industrial nations like India is not the same as homogeneous traffic conditions. This way, the current methodologies can be supported by thinking about the intricacy of the assistance quality idea and distinguishing the real needs of travellers. Transport management is unmistakable from others as it recognizes a bunch of quantitative measures liberated from abstract and target attributes. Henceforth, it was not difficult to clearly order the characteristics that are harder to deliver fulfilment and to distinguish the variety of various transport methods. This examination likewise helps the examination of inspirations and hindrances to various modes of transport. The findings in Table 8 show that 15% of the road segments are category subventions that provide consumers with safe and convenient driving facilities.

In the same way, 30 and 20% of rail transport segments are allocated. Based on talks with a few car drivers and stakeholders, the minor frustration was mainly due to a public disturbance while in the lane. In addition, inadequate scheduling and travelling services substantially reduce bus users in the segments above. The private bus category allocates 15 and 10% of the segments. Mainly because of business practices on the roadside and inadequate capabilities on private and public buses. Furthermore, the satisfaction levels of travellers have detrimental consequences on adequate ticket price, cleanliness, bus in bad weather conditions and weekends. These street segments do not provide enough road, medium barriers, adequate street lighting, or the above factors.

Bus information and schedules are available at every stop. Buses are strictly maintain a schedule, Bus information with route maps is available at every stop, Large ticket price

variation among each category of buses, Have a well-structured route plan for buses to reduce lengthy journeys, Average Bus tickets are affordable, Bus stops are conveniently located in every region, and Drivers & Conductors in private buses are courteous were measured. Some key factors are that public transport is always better than its vehicle journey, and the service quality of government buses is good for daily usage. The availability of government buses during peak hours is enough, and information on public bus stations is easily accessible and understandable. Such causes are very common in Indian cities for the extremely mixed traffic flow; however, they vary substantially from uniform traffic conditions. From this analysis, it is noted that, even though they are locally segregated, the complexities of the service quality principle and the real need for travelers in Indian urban clusters are identical.

In light of the diversity of people living in developing the transport model, these results are expected to be useful for forecasting urban road segments in other Indian cities and promoting a user-friendly infrastructure in developing countries. This evaluation can, in many ways, be useful to planners and decision-makers. Firstly, the measuring attribute order will serve as a useful strategy in implementing many construction alternatives by defining particular road characteristics, which should be given priority to improving road infrastructure operational quality. This proposed solution helps transport authorities to understand the need for more transport improvements. Therefore, upgrade budgets can be tailored to achieve the required performance of road infrastructure, and priority would be given to poor links based on their index levels in the road network, which need upgradation.

5 Conclusion

As cities grow out of control for the population as well as transport, one of the new domains being studied throughout the world is the development of urban transportation facilities through the analysis of indicators. Cities may choose to use sustainable evaluation indicators concerning their local conditions and requirements. According to the current sustainability testing practices, a technical analysis approach is discovered to be highly difficult collaboratively and completely that meets with local statements. Indore, Bhopal, and Vishakhapatnam are developing urban centres with increasing population and transportation needs yearly. As a result, developing an indication evaluation approach to address these issues has become unavoidable. A complete transport assessment indicators index such as trustworthiness, Amenity, Receptivity, Assurance, and Affinity for the cities was developed in this study to be beneficial for city researchers. Among 500 responders, five variables were developed that might affect and shape the performance of urban public transportation.

Hybrid COPRAS-TOPSIS, Analytical Hierarchical Process (AHP) and Fuzzy AHP (FAHP) were used to assess the quantitative weight to analyze the complicated process of perceived service quality and Key Performance Indicators (KPIs). AHP and FAHP assigned a unique score to each user, and each dimension's attributes were shared. As a result, the suggested technique was more accurate than the traditional one. It was utilized to assist decision-makers in the long-term building and planning of transportation networks based on priority. Based on these variables, the current work successfully develops and applies KPI analysis prediction of public transportation systems. This study analyses KPI for the public transport system in mid-populated cities in India. The performance obtained such as computational complexity and agility in decision making by the hybrid

COPRAS-TOPSIS are 132 and 1245, which is better than the AHP and FAHP but the identified KPI is only suitable for the mid-populated city. It won't suit large or metro cities, because population and transport facilities are more in these cities. So it can vary from the small cities. Thus in future, the system should expand by conducting surveys in metro cities to find the KPI to suit all cities in India.

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Code availability Not applicable.

Declarations

This article is a completely original work of its authors; it has not been published before and will not be sent to other publications until the journal's editorial board decides not to accept it for publication.

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