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Investigating the impact of COVID-19 on user perception for deriving policies and intervention areas for urban bus service in India

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ABSTRACT

The paper aims to investigate the impact of COVID-19 pandemic on the perception of travelers and identify new policies and intervention areas for improving urban bus service. This was carried out based on the perception data collected from travelers in the years 2018 (before pandemic) and 2020(in post lockdown scenario). Data was collected from the state of Kerala, India, and Importance-Satisfaction Analysis (ISA) with fuzzy c-means clustering was carried out to identify improvement areas for both scenarios. Results show a substantial increase in the number of priority areas as compared to the pre-pandemic scenario. Bus service attributes such as cleanliness, crowding level, and pedestrian environment emerged as new intervention areas of bus service during the pandemic. This is a clear reflection of the increased awareness of travelers about the prevailing pandemic scenario and the need for improvement in attributes related to social distancing and hygiene. The higher priority to information related attributes of bus service clearly shows the need for improvement in such attributes for the safe planning of trips during the pandemic. The work also estimated desired service levels of quantitative attributes to enhance the satisfaction levels of users. An evaluation of five bus routes in Kochi based on the desired levels shows the underperformance of attributes such as headway, punctuality, and crowding level. While the findings are city-specific, the methodology and experience may be adopted to enhance the service quality of buses and other public transport.

1. Introduction

Over the last few decades, transportation demand in emerging countries like India has increased rapidly due to population growth, urbanization, and commercial and industrial activities (Dandapat et al., 2017). The growth in two-wheeler and four-wheeler ownership in India from 2001 to 2010 was recorded as 164% and 192%, respectively (Vasudevan et al., 2021). Private vehicle ownership is projected to increase by 14-fold in the year 2050 (Singh et al., 2020). The rise in private vehicle usage coupled with limited road capacity has resulted in congestion, pollution and vehicular delay, especially in urban areas (Cheranchery and Maitra, 2017). Encouraging the use of public transport is recognized as an effective instrument for demand management. Historically, bus is the primary mode of public transport in India as it offers city-wide coverage and affordable service to users (Prasad et al., 2018). However, the inferior service quality of buses often discourages a section of commuters to use bus for their travel (Cheranchery and Maitra, 2019). It has now become necessary to improve the service quality of buses to arrest the shift of commuters to private vehicles and also to attract private vehicle users to bus service for mitigating vehicular delay, emission and congestion on road (Cheranchery and Maitra, 2018). Several studies highlight the importance of incorporating user perception for improving different types of services (Bordagaray et al., 2012; Cirillo et al., 2011).

With a greater aim to enhance the attractiveness of urban bus service, several studies have been carried out in Indian context to study the perception of travelers (Cheranchery and Maitra, 2017; Dandapat et al., 2017). Cheranchery et al. (2018) studied the perception of travelers for the improvement of bus services in Kolkata city. Another study in Kolkata city conducted by Dandapat et al. (2017) identified strategies for achieving the operational viability of private buses. As a reflection of findings from various investigations, the Government has taken several

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initiatives to improve the quality of buses in Indian cities. However, the spurt of COVID-19 has brought dramatic changes in the field of transportation, particularly in public transport (Pal et al., 2021). The risk of infection is perceived to be higher in public transport as it is difficult to maintain social distancing especially in the context of emerging countries where a significant number of travelers depend on bus service for their travel (Vickerman, 2021). Consequently, there is a rapid downfall in the ridership of buses, which is affecting the financial viability of the service (Das et al., 2021). Owing to the severe financial crisis, operators are forced to shut down the service in several Indian cities (Pal et al., 2021). Although there is a reduction in travel demand due to travel restrictions and work from home policies, there is a surge in private vehicle usage owing to the rapid decline of public transport (Vickerman, 2021). There is an urgent need to relook at the policies and study the impact of COVID-19 on travel behavior to regain the trust of potential bus users and to arrest their shift to private vehicles (Zhang et al., 2021). In the present work, an investigation is carried out to study the impact of COVID-19 pandemic on travelers' perception of bus service by comparing their preferences during pre-pandemic and post lockdown scenarios. Improvement areas are identified for urban bus service to develop bus as a demand management instrument for a greater benefit to society. It is also aimed to identify desired service levels of important attributes to enhance the satisfaction of travelers. The work is demonstrated with reference to Kochi metro city, India.

After the introduction, the theoretical background and methodology used for identifying improvement areas are discussed in the section named 'Theoretical background and methodology'. Details of the study area and the procedure adopted for data collection and development of database are reported in the section called 'Study area and data collection'. The intervention areas in pre-pandemic and post lockdown scenarios are discussed in the section titled 'Priority areas in pre-pandemic and post lockdown scenarios, and the policy implications of the study outcomes are included in the section named 'Policy Implications'. Finally, the work is concluded in the section named 'Conclusion' by summarizing key findings and the scope of future work.

2. Theoretical background and methodology

Several studies have been carried out in the past to understand the perception of travelers in terms of importance to travelers of bus service attributes (Abenoza et al., 2017; Mahmoud and Hine, 2013). Such studies have largely used stated preference experiments, Analytic Hierarchy Process (AHP), rating, and ranking techniques depending upon the context of the study (Susilo and Cats, 2014; Mahmoud and Hine, 2013). Studies have also been conducted to investigate travelers' satisfaction with respect to the performance of bus attributes (Eboli and Mazzulla, 2007). Rating and ranking techniques, structural equation modelling, factor analysis, ordered Probit modeling are some of the techniques used for analyzing such data (Ingvardson and Nielsen, 2019; Eboli and Mazzulla, 2007). However, many recent studies clearly emphasize the need for analyzing the importance and satisfaction of the users for identifying service gaps to develop policies for the improvement of services in general (Das and Pandit, 2013). Importance-Satisfaction Analysis (ISA) is a widely accepted technique to analyze importance and satisfaction data collected using a Likert-type scale (Hemalatha et al., 2021). In ISA, users' importance of attributes is generally depicted on the x-axis in a two-dimensional matrix while the performance of attributes is depicted on the y-axis as shown in Fig. 1. The matrix is further divided into quadrants using single vertical and horizontal lines. The quadrants are named as concentrate here (high importance and low satisfaction), keep up good work (high importance and high satisfaction), possible overkill (low importance and high satisfaction), and least priority (low importance and low satisfaction) (Cheranchery et al., 2021). The attributes falling in concentrate here are generally identified as priority areas for improvement.

Over the years, ISA has evolved and several versions were used for

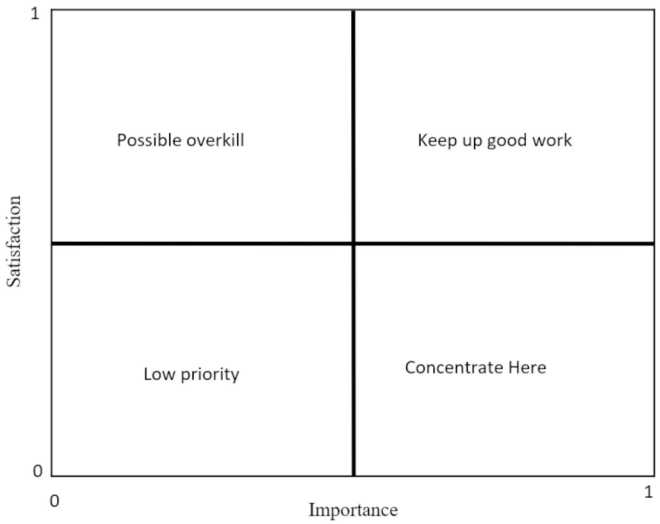


Fig. 1. Management Scheme based on Importance-Satisfaction Analysis.

analyzing the perception of users (Deng et al., 2008). One such revised version of ISA includes management scheme and factor structure (Deng et al., 2008). While the management scheme is related to the performance of service, factor structure talks about the classification of attributes into four satisfaction factors, namely basic factor, important performance factor, excitement factor, and unimportant performance factor. As mentioned earlier, the management scheme includes concentrate here, keep up good work, possible overkill, and least priority. In order to obtain factor structure, stated importance is depicted along the x-axis and derived importance is depicted along the y-axis. Factor structure includes quadrants of satisfaction factors namely, basic factor (high stated importance and low derived importance), important performance factor (high stated and high derived importance), excitement factor (low stated and high derived importance) and unimportant performance factor (low stated and low derived importance). The basic factors are the minimum requirements to be fulfilled, and it leads to dissatisfaction if not fulfilled but does not lead to satisfaction if fulfilled (Ban et al., 2016). On the other hand, the excitement factors cause satisfaction if fulfilled but do not lead to dissatisfaction if not fulfilled (Deng et al., 2008). Important performance factors have a direct linear relationship with satisfaction as it causes satisfaction with improved performance and dissatisfaction otherwise. Unimportant performance factors have the least effect on satisfaction (Deng et al., 2008). The placement of axis in ISA matrix is a tricky and challenging process as it determines the fate of attributes especially for those attributes close to the axis. In order to address the uncertainties involved in axis placement, Ban et al. (2016) proposed a framework for fuzzy C-means clustering in the context of ISA. In the present work, ISA with fuzzy C-means clustering is used for identifying factor structure and management scheme. Although the step-by-step procedure of ISA is well established in the literature, the same is briefly discussed here. A flowchart of the

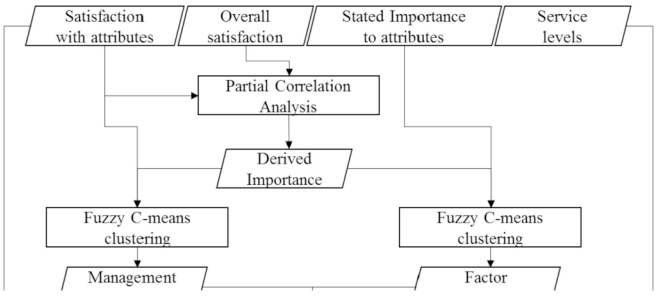


Fig. 2. Methodology.

methodology is presented in Fig. 2.

Step 1 (Data collection): Collect the following data from travelers. (i) stated importance of attributes (I_s) on Likert-type scale, (ii) satisfaction with attributes (S_a) on Likert-type scale, (iii) overall satisfaction with bus service (S_o) on Likert-type scale, and (iv) service levels of quantitative attributes (L_a). The stated importance to travelers of attributes indicates their perceived importance of attributes on Likert-type scale.

Step 2 (Derived importance): Perform partial correlation analysis between the logarithm of S_a (independent variable) and S_o (dependent variable). The partial correlation coefficient thus obtained is considered as the derived importance (I_d) to attributes of travelers. Several studies have used regression coefficient as derived importance (Cheranchery and Maitra, 2017). However, literature suggests the use of partial correlation coefficient as it helps to obtain the independent effect of independent variable on dependent variable (Cheranchery and Maitra, 2017).

Step 3 (Factor structure): Perform fuzzy C-means clustering with stated importance (I_s) and derived importance (I_d) of attributes as inputs using the framework proposed by Ban et al. (2016). The membership degree of various attributes to four clusters indicates the factor structure of travelers. The four clusters thus obtained include basic factor, important performance factor, unimportant performance factor, and excitement factor.

Step 4 (**Management scheme**): Perform fuzzy C-means clustering with derived importance (I_d) and satisfaction with attributes (S_a) as inputs. The membership degree of various attributes to four clusters thus obtained indicates the management scheme of bus service. The four clusters thus obtained include the schemes namely, concentrate here, keep up good work, possible overkill, and least priority.

Step 5 (Priority areas): Priority areas are identified by applying the following rationale. (1) Basic factors falling in "Concentrate here," (2) Basic factors falling in "Least priority," (3) Important performance factors falling in "Concentrate here," and (4) Excitement factors falling in "Concentrate here." The priority order of attributes within the cluster was established based on the highest membership degree. For instance, if two attributes fall in basic factor and also belong to the scheme concentrate here, then priority order was estimated based on their average membership degree to factor structure and management scheme.

Step 6 (Desired service levels): Desired service levels of quantitative attributes of bus service to enhance the satisfaction of travelers are identified using the 85th percentile method (Cheranchery and Maitra, 2019). The quantitative attributes which are emerged as intervention areas are considered for this process. The service levels (attribute levels, L_a) and corresponding satisfaction levels (S_a) of travelers are collected as discussed in step 1. Subsequently, attribute levels are grouped under each level of satisfaction. For instance, attribute levels (say, for headway) obtained under satisfaction level 1 are grouped under the head named 'satisfaction 1′, and the same procedure is continued for satisfaction levels 2, 3, 4, and 5 (Cheranchery et al., 2021). The attribute levels under each group are then arranged in ascending/descending order depending on the nature of the attributes. The attribute level corresponding to the 85th percentile is then obtained for each level of satisfaction, and the same is considered as desired service levels. This procedure was continued for all quantitative attributes identified as intervention areas.

3. Study area and data collection

The Kochi metro city, also known as the 'Queen of Arabian Sea', is located on the western coast of India in Ernakulam district of state Kerala. As per the reports of Census India, the population of Kochi in 2011 is 602,046. The major public transport modes of the Kochi city comprise of Buses, Metro, Taxis, Auto-rickshaws and Ferry boats. Around 54.5 % of people used bus as their primary mode of travel before the pandemic. Kochi is facing severe externalities such as congestion, pollution, vehicular delay on road due to increased private vehicle usage and limited road capacity, like any other metro city in emerging countries. These characteristics of the city provide a unique opportunity to select Kochi as the study area which represents the prevailing conditions of metro cities in emerging countries.

A survey instrument was developed to collect the perception of travelers. A comprehensive review of the literature was conducted to identify attributes pertinent to bus service. Several attributes have been used in the past for assessing the service quality of buses in various contexts. Previous studies have used qualitative and quantitative attributes of bus service to assess the service quality based on user perception. An exhaustive review of literature clearly revealed that adequate emphasis is given to quantitative attributes such as cost, travel time and comfort (Tavares et al., 2021; Yenny, 2020, Ramos et al., 2019; Luke and Heyns, 2020. Studies were also found focusing on attributes such as access time (Moslem et al, 2020), safety, security, staff behaviour (Luke and Heyns, 2020; Sinha et al., 2020), and cleanliness (Borjesson and Rubensson, 2019). Although attribute named information is considered in some of the studies, they were not specifically categorized to suit the context (Sinha et al., 2020; Roman et al., 2014; Redman et al., 2013). Overall, it was found that qualitative attributes of bus service were not given due attention especially in the context of emerging countries such as India. Giving due consideration to the qualitative and quantitative attributes of bus service, present study identifies 19 attributes as presented in Table 3. The present work considers ticketing system which is relevant in the context of pandemic scenario considering the risk of infection due to the exchange of money and ticket. Unlike previous studies, attribute named information is categorized as wayside information, pre-trip information, and on-board information. A paper–pencil questionnaire was designed to collect importance to travelers of attributes, satisfaction with attributes, and overall satisfaction with bus service. While importance of attributes was collected using Likert-type 5-point importance scale (where 1 is least important and 5 is most important) satisfaction data was collected using Likert-type 5-point satisfaction (where 1 is highly dissatisfied and 5 is highly satisfied). The adequacy of the questionnaire was checked by conducting several rounds of pilot surveys and suitable modifications were made to the instrument. Experienced enumerators and research scholars were employed for collecting data from various trip generators of the city. In the year 2018, data was collected with an aim to study the perception of travelers for identifying the intervention areas. This data is used for analysing the pre-pandemic scenario. A total of 832 samples were collected from Kochi by adopting a simple random sampling technique. After the spread of COVID-19 in the year 2020, it was decided to collect the perception of travelers again to study the difference in perception. The data collection process was started in January 2021. During this period, the operation of bus service returned to normal after lockdown and travelers begin to use bus service regaining confidence in service after a significant reduction in the number of COVID-19 cases in the state of Kerala. Data related to socio-economic and trip characteristics of the travelers were also collected along with the importance and satisfaction data. This data is used for analysing the post lockdown scenario. It may be mentioned that service levels of attributes were not collected along with importance and satisfaction data during the pre-pandemic scenario. However, the same was collected for identifying service levels during the post lockdown scenario. Owing to the social distancing norms and difficulty in collecting in-person interviews during this period, a mix of online and offline data collection was necessary to achieve a representative sample. A total of 659 responses were obtained by the end of March 2021 through online and offline modes of data collection. The socio-demographic details of the collected data during two scenarios are now summarized in Table 1 and Table 2 respectively.

Considering the population size, size of the sample collected during pre-pandemic and post lockdown scenarios were found to be well above the minimum required sample size (384) at 95% confidence level

Table 1
Socio-economic details of the collected data during pre-pandemic scenario.

Characteristics	*Data size*
Total responses	832
Male	516 (62)
Female	316 (38)
Age (years)	
<20	83 (10)
20–40	399 (48)
40–60	324 (39)
>60	26 (3)
Car ownership (number of cars owned)	
0	549 (66)
1	266 (32)
2	17 (2)
>2	0 (0)
Travel frequency (number of trips/week)	
<3	125 (15)
3–4	150 (18)
5–6	275 (33)
>6	282 (34)
Predominant mode of travel	
Bus	557 (67)
Private car	183 (22)
Taxi	33 (4)
Auto	42 (5)
Other	17 (2)

Note: Values in the parentheses indicate the percentage of data under each characteristic.

Table 2
Socio-economic details of the collected data during post lockdown scenario.

Post lockdown scenario	
Characteristics	*Data size*
Total responses	659
Male	435 (66)
Female	224 (34)
Age (years)	
<20	53 (8)
20–40	382 (58)
40–60	198 (30)
>60	26 (4)
Car ownership (number of cars owned)	
0	461 (70)
1	185 (28)
2	13 (2)
>2	0(0)
Travel frequency (number of trips/week)	
<3	132 (20)
3–4	125 (19)
5–6	204 (31)
>6	198 (30)
Predominant mode of travel	
Bus	395 (60)
Private car	185 (28)
Taxi	39 (4)
Auto	40 (6)
Other	20 (2)

(Cheranchery and Maitra, 2021). Moreover, total share of predominant bus users (around 67% and 60% respectively in pre-pandemic and post-lockdown scenario) as obtained from the sample is comparable with the corresponding share in population which is 54.5%. Overall, the sample is found to be adequate and representative of the population of the city. A reduction in the number of travelers considering bus as the predominant mode of transport (from 67% to 60%) was evident from the socio-economic characteristics of respondents as reported in Table 1 and Table 2. The socio-economic details also show an increase in the share of travelers considering private car and taxi as predominant modes. Thombre and Agarwal (2021) found a substantial shift towards private

Table 3
Membership degree of attributes to factor structure in pre-pandemic scenario

Attributes	Membership Function to Factor Structure			
	Performance factor (Unimportant)	Excitement factor	Basic factor	Performance factor (Important)
Safety (SA)	0	0	0	**0.99**
Access & Egress time (AT)	0.04	**0.91**	0.02	0.03
Bus stop facilities (BSF)	**0.88**	0.03	0.08	0.02
Cleanliness (CL)	0	0	0	**1**
Crowding (CR)	0.02	0.04	0.03	**0.9**
Fare (FA)	0.01	0.01	0.01	**0.96**
Headway of Service (HW)	0.01	0.01	**0.97**	0.01
In-vehicle travel time (IVTT)	0.03	0.03	0.08	**0.86**
Number of transfer (NT)	**0.91**	0.03	0.05	0.02
Onboard info (OI)	0	**0.99**	0	0
Pedestrian Environment (PE)	**0.82**	0.09	0.05	0.03
Pre-trip info (PI)	0	**1**	0	0
Punctuality (PU)	0.04	0.01	**0.93**	0.02
Security (SE)	0.08	0.02	**0.86**	0.04
Span (SP)	0.05	0.02	**0.86**	0.07
Staff behavior (SB)	**0.89**	0.04	0.05	0.02
Ticketing system (TS)	**0.91**	0.03	0.05	0.02
Transfer time (TT)	**0.53**	0.2	0.18	0.1
Way side info (WI)	0.02	**0.95**	0.01	0.02

vehicle in Indian cities mainly due to the risk of infection in public transport. A recent study conducted by Das et al. (2021) found 18% shift of travelers from public transport to car based on the sample data collected from the northeastern region of India. Bhaduri et al. (2020) also indicate a significant reduction (from 16.40% to 11.40% and 18.6% to 7.2% for work trips and discretionary trips) in the share of work trips and discretionary trips using public transport in Indian cities due to COVID-19.

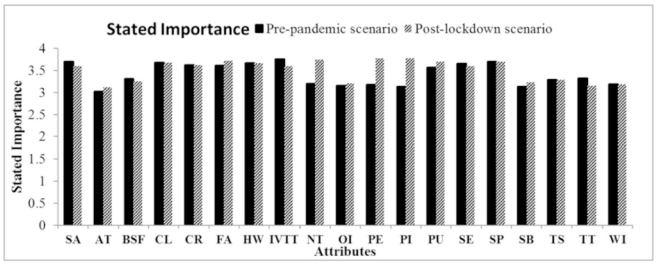
4. Priority intervention areas in pre-pandemic and post lockdown scenarios

Improvement areas of bus service in the order of priority for the pre-pandemic and post lockdown scenarios are identified and discussed in this section. As mentioned earlier, the stated importance of trip attributes was calculated as the arithmetic mean of the Likert Scale rating while the derived importance was estimated using partial correlation analysis. The stated importance, derived importance, and performance of attributes in pre-pandemic and post lockdown scenarios are summarized in Fig. 3.

The factor structure of travelers and the management scheme of bus service for these two periods are discussed in the following sub sections.

4.1. Factor structure of travelers in pre-pandemic and post lockdown scenarios

The factor structures of travelers in pre-pandemic and post lockdown scenarios were identified as per the discussed methodology. Travelers'



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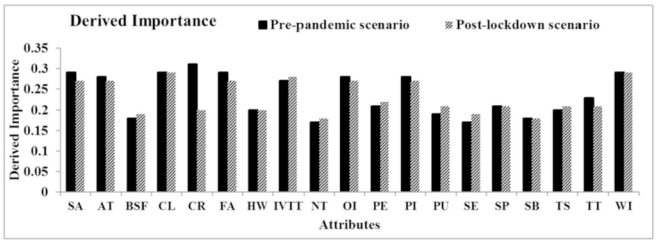

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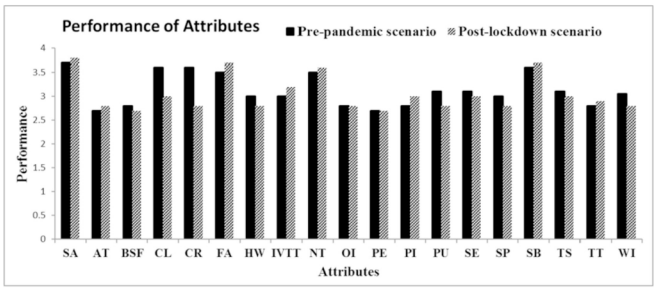

c

Fig. 3. (a) Stated importance to travelers of attributes (b) Derived importance to travelers of attributes (c) Performance of attributes.

stated importance and derived importance of attributes were the inputs. The output of the clustering includes membership degree of each attribute to the four clusters of factor structure. The attributes are assigned to each cluster based on their highest membership degree. Table 3 summarizes the output of factor structure estimation.

The factor structure of travelers in the pre-pandemic scenario is also presented in a two-dimensional graph in Fig. 4 which shows the placement of each attribute in the factor structure.

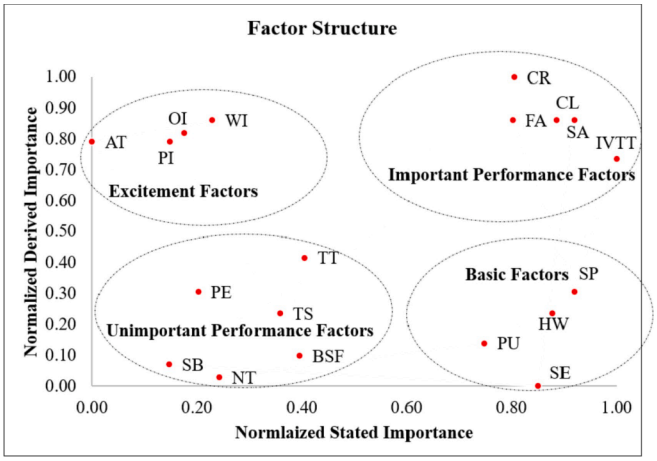

Fig. 4. Factor structure of travelers in pre-pandemic scenario.

Similarly, factor structure of travelers was also obtained for the post lockdown scenario as presented in Fig. 5. The factor structure of travelers in pre-pandemic and post lockdown scenarios are compared and summarized in Table 4.

Table 4 shows notable changes in travelers' factor structure in pre-pandemic and post lockdown scenarios. A significant increase in the number of basic and important performance factors during the pandemic is evident from Table 4. Basic and important performance factors are generally considered to be policy-relevant as they cause substantial dissatisfaction to travelers if not fulfilled their expectations. Thus, the increase in the number of basic and important performance factors is an indication of the change in perception of travelers due to pandemic and most importantly, an indication of the increased sensitivity of attributes to the overall satisfaction of travelers. Unimportant performance factors such as number of transfers and pedestrian environment are identified as basic factors during the pandemic. The attribute named crowding, which was identified as an important performance factor in the pre-pandemic scenario, now belongs to the basic factor. It is interesting to note the transformation of pre-trip information from excitement factor to important performance factor during the pandemic. Apart from the addition of a few attributes, all other attributes previously identified as basic and important performance factors remained under the same factor groups. This is an indication of the temporal stability of factor structure except for the addition of a few attributes owing to the pandemic. This further validates the study outcomes.

4.2. *Management schemes of bus service in pre-pandemic and post lockdown scenarios*

In this section, management schemes of the bus service in the pre-pandemic and pandemic scenarios are identified. Travelers' derived importance and satisfaction with attributes are the inputs to derive management scheme. The output of the clustering includes membership degree of each attribute to the four clusters of management scheme. Table 5 summarizes the output of management scheme estimation.

The management scheme of urban bus service during pre-pandemic scenario is also presented in Fig. 6.

Similarly, the management scheme was identified in the post lockdown scenario as presented in Fig. 7. Although relocation of attributes is visible within the cluster, the management scheme of the attributes remains nearly the same except for one or two attributes.

Table 6 includes a summary of the management schemes of urban bus service in pre-pandemic and post lockdown scenarios. It is worth noting that only two attributes viz., cleanliness and crowding, relocated respectively from 'keep up good work' to 'concentrate here' and 'least

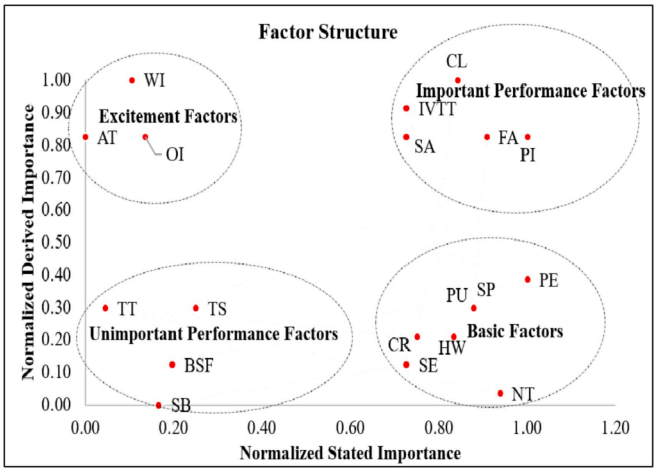

Fig. 5. Factor structure of travelers in post lockdown scenario.

Table 4
Comparison of factor structure in pre-pandemic and post lockdown scenarios

Factors	Pre-pandemic	Pandemic
Basic	Headway (0.97) Punctuality (0.93) Span of operation (0.86) Security (0.86)	Headway (0.99) Punctuality (0.96) **Crowding (0.94)** Security (0.87) **Number of transfers (0.86)** **Pedestrian environment (0.76)** Span of operation (0.60)
Important performance	Cleanliness (1.00) Safety (0.99) Fare (0.96) **Crowding (0.90)** In-vehicle travel time (0.86)	Fare (0.96) In-vehicle travel time (0.93) Cleanliness (0.93) Safety (0.91) **Pre-trip information (0.88)**
Excitement	**Pre-trip information (1.0)** Onboard information (0.99) Wayside information (0.95) Access and egress time (0.91)	Access and egress time (0.96) Onboard information (0.94) Wayside information (0.94)
Unimportant performance	Ticketing system (0.91) **Number of transfers (0.91)** Staff behavior (0.89) Bus stop facilities (0.88) **Pedestrian environment (0.82)** Transfer time (0.53)	Bus stop facilities (0.98) Staff behavior (0.89) Ticketing system (0.87) Transfer time (0.85)

Table 5
Membership degree of attributes to management scheme in pre-pandemic scenario

Attributes	Membership Function to Management Scheme			
	Concentrate here	Keep up good work	Least priority	Possible overkill
Safety (SA)	0.0155	**0.9558**	0.0121	0.0166
Access & Egress time (AT)	**0.9099**	0.0244	0.0496	0.0161
Bus stop facilities (BSF)	0.0774	0.0286	**0.8261**	0.0679
Cleanliness (CL)	0.0019	**0.9951**	0.0014	0.0017
Crowding (CR)	0.018	**0.9589**	0.011	0.0122
Fare (FA)	0.0226	**0.9482**	0.0142	0.015
Headway of Service (HW)	0.0038	0.0016	**0.9908**	0.0039
In-vehicle travel time (IVTT)	**0.8394**	0.0555	0.0772	0.0279
Number of transfer (NT)	0.0013	0.0017	0.004	**0.9931**
on board info (OI)	**0.9818**	0.0057	0.0093	0.0032
Pedestrian Environment (PE)	0.2217	0.0474	**0.6587**	0.0721
Pre-trip info (PI)	**0.9879**	0.0036	0.0064	0.0021
Punctuality (PU)	0.0398	0.0233	**0.8375**	0.0994
Security (SE)	0.0634	0.041	**0.6651**	0.2305
Span (SP)	0.0342	0.0121	**0.9292**	0.0244
Staff behavior (SB)	0.005	0.008	0.013	**0.974**
Ticketing system (TS)	0.041	0.0218	**0.8702**	0.0671
Transfer time (TT)	0.3068	0.0477	**0.584**	0.0615
Way side info (WI)	**0.7553**	0.119	0.0854	0.0404

priority'. Apparently, these two attributes are the most relevant attributes in the context of the pandemic as travelers perceived the risk of infection due to higher crowding and unhygienic surrounding. Overall, the findings clearly indicate the increased awareness of travelers about

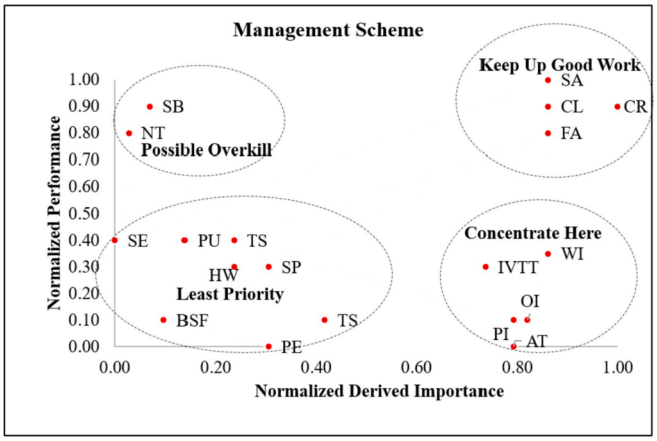

Fig. 6. Management scheme of bus service in pre-pandemic scenario.

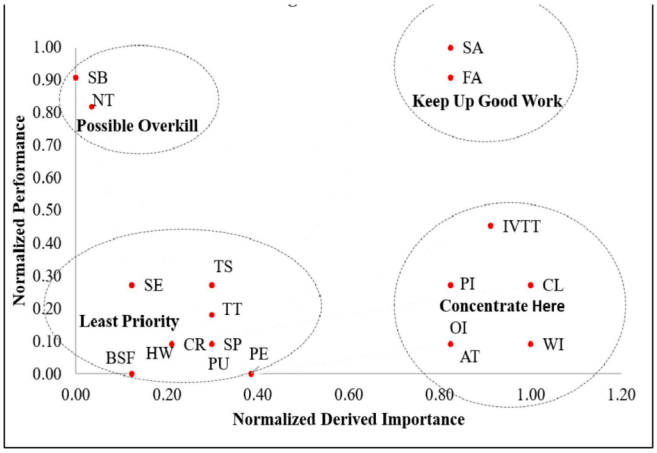

Fig. 7. Management scheme of bus service in post lockdown scenario.

Table 6
Comparison of management scheme in pre-pandemic and post lockdown scenarios

Management Scheme	Pre-pandemic scenario	Post lockdown scenario
Concentrate here	Pre trip information (0.99) On board information (0.98) Access and egress time (0.91) In-vehicle travel time (0.84) Wayside information (0.75)	Way side information (0.92) Pre-trip information (0.93) Onboard information (0.90) Access and egress time (0.93) **Cleanliness (0.92)** In vehicle travel time (0.68)
Keep up good work	**Cleanliness (0.99)** Safety (0.96) **Crowding (0.96)** Fare (0.95)	Fare (0.99) Safety (0.99)
Possible overkill	Number of transfers (0.99) Staff behavior (0.97)	Number of transfers (0.99) Staff behavior (0.99)
Least priority	Headway (0.99) Span of operation (0.93) Ticketing system (0.87) Punctuality (0.84) Bus stop facility (0.83) Security (0.67) Pedestrian environment (0.66) Transfer time (0.58)	Headway (0.99) **Crowding (0.99)** Span of operation (0.98) Punctuality (0.98) Transfer time (0.96) Bus stop facilities (0.89) Ticketing system (0.85) Pedestrian environment (0.85) Security (0.81)

social distancing and hygiene.

4.3. Priority areas and discussion

Priority intervention areas were identified for pre-pandemic and post lockdown scenarios by following step 5 of the methodology. The priority order for the improvement of attributes based on travelers' perception is summarized in Table 7.

Overall, there is a substantial increase in the priority areas of interventions (from nine to twelve) for urban bus service after the pandemic which may be attributed to the increased awareness of travelers regarding the causes and risk of infection. All the nine priority areas before the pandemic remained as priority areas during the pandemic. However, attributes such as crowding, pedestrian environment, and cleanliness emerged as new intervention areas. Apparently, the difference in the order of priority is marginal for both scenarios, which can be attributed to the addition of these three attributes. None of the basic factors falls in concentrate here in both scenarios (pre-pandemic and pandemic) while a majority of them falls in the least priority. However, as mentioned in the methodology section, underperforming basic factors irrespective of their position in the management scheme should be given priority over other attributes as they cause significant dissatisfaction to travelers. Accordingly, basic factors such as headway, punctuality, span and security were identified as intervention areas in the pre-pandemic scenario. In addition to these basic factors, crowding and pedestrian environment were the other basic factors identified as priority areas in the post lockdown scenario. Identification of cleanliness and pedestrian environment as intervention areas clearly shows the change in perception of travelers towards such attributes due to the pandemic. In emerging countries like India, such qualitative attributes are often neglected in the process of quality improvement while giving due attention to quantitative factors. It is interesting to see headway and punctuality as of top priority to the travelers even during the pandemic. It may be noted that information and security-related attributes are identified as interventions areas in both scenarios. Traditionally, these attributes were not given adequate weightage in the development process of bus service in emerging countries like India. It may be noted that pre-trip information is given priority over in-vehicle travel time as opposed to the pre-pandemic scenario. Reliable real-time information was a priority for the travelers even before the pandemic. However, no reliable sources of real-time information are presently available for travelers to plan the journey using bus service. In fact, a printed schedule of the bus arrival is unavailable in most cases. The consequent uncertainty in the arrival of buses at stops often discourages travelers to choose buses for their travel. With the present pandemic scenario, waiting in a crowded place like bus stops with uncertainty in the arrival of bus increases the fear of getting infected. Therefore, the priority given to pre-trip information over in-vehicle travel time is a clear reflection of the awareness of travelers about social distancing and hygiene. It has now become imperative to provide real-time information and also to enhance hygiene at bus stops. In short, it is important to take measures for improving the qualitative and quantitative attributes which are identified as intervention areas.

Table 7
Priority areas in pre-pandemic and post lockdown scenarios

Priority order	Pre-pandemic scenario	Post lockdown scenario
1	Headway (0.98)	Headway (0.99)
2	Punctuality (0.885)	Punctuality (0.97)
3	Span of operation (0.895)	Crowding (0.96)
4	Security (0.765)	Security (0.84)
5	In-vehicle travel time (0.85)	Pedestrian environment (0.805)
6	Pre-trip information (0.995)	Span of operation (0.79)
7	Onboard information (0.985)	Cleanliness (0.925)
8	Access and egress time (0.91)	Pre-trip information (0.905)
9	Wayside information (0.85)	In-Vehicle Travel Time (0.805)
10		Access and egress time (0.945)
11		Wayside information (0.93)
12		Onboard information (0.92)

5. Desired service levels in the post lockdown scenario

While it is important to identify improvement areas for bus service, it is also pertinent to estimate the desired improvement levels for attributes identified as interventions areas. Desired service levels of attributes such as headway, punctuality, span of operation, crowding, average journey speed, and access-egress time were estimated following the procedure discussed in the methodology section. The estimation of desired levels of access-egress time is shown in Fig. 8.

The desired levels of the selected attributes are reported in Table 8. After identifying the desired service levels, a set of five routes were selected from Kochi city for evaluating the present service level. The evaluation is summarized in Table 9. The service levels of the bus routes in terms of the selected attributes were collected from the field and average service levels for each attribute were calculated as reported in Table 9.

The evaluation clearly shows that the performance of the routes in terms of these attributes falls well short of travelers' expectations as the present service levels in most of the cases are reported to be in the range of 'Dissatisfaction'. Attributes such as span of operation and access-egress time are performing reasonably well in these routes. Overall, the evaluation shows the importance of improvement in quantitative attributes for attracting travelers towards urban bus service.

6. Policy implications

The identified priority areas clearly indicate the need for improvement in quantitative attributes such as headway and punctuality. This was further justified by the evaluation of bus routes based on the desired service levels, which shows travelers are dissatisfied with the headway of almost all selected routes. The frequency of service in such routes may be enhanced giving due consideration to the demand and financial viability aspects, and further investigations may be carried out in this regard. Punctuality/schedule adherence depends largely on the traffic congestion on the road which is often unexpected. However, punctuality may still be improved by giving proper directions to drivers to avoid unnecessary delays at stops expecting more passengers to board. Crowding level during peak hours is a serious concern especially in conventional ordinary buses. Given the pandemic scenario, adequate emphasis is necessary to mitigate offboard and onboard crowding. Increasing the frequency of buses giving due consideration to the financial viability is important to address this concern. Moreover, the crowding could also be controlled by providing real-time dynamic information to travelers about the occupancy of buses. These two methods

Fig. 8. Desired level of access-egress time correspoding to 'Highly Satisfied'

Table 8
Desired levels of selected attributes

Satisfaction Levels	Access-egress time (minutes)	Crowding level(Average number of passengers per seat)	Average Journey Speed (km/h)	Span of operation (Hour)	Headway (minutes)	On-time performance (%)
Highly satisfied (HS)	<10	<1.1	>25	>18	<12	>80
Satisfied (S)	10–19	1.1–1.3	18–25	16–18	12–18	62–80
Neutral (N)	19–30	1.3–1.5	14–18	12–16	18–24	43–62
Dissatisfied (D)	30–45	1.5–1.8	10–14	10–12	24–38	26–43
Highly dissatisfied (HD)	>45	>1.8	<10	<10	>38	<26

Access-egress time: Time required to travel from origin to bus stop and bus stop to destination

Table 9
Evaluation of five selected routes based on the desired levels

Route	Access-egress time	Crowding level	Average Journey Speed	Span	Headway	On-time Performance
Route 1	N (25)	D (1.7)	D (12)	N (14)	D (38)	D (40)
Route 2	N (30)	D (1.6)	D (13)	N (14)	HD (40)	N (50)
Route 3	N (22)	D (1.6)	D (13)	S (16)	D (25)	N (50)
Route 4	N (28)	D (1.6)	D (13)	S (16)	D (25)	N (50)
Route 5	N (20)	D (1.6)	D (13)	HS (18)	N (22)	N (50)

Note: The values reported within the parentheses are average service levels of the attributes based on field investigation. Route 1: Aluva to Chottanikkara; Route 2: Aluva to Kumbanam; Route 3: Kacheripadi to Vytila; Route 4: Airport to fort kochi; Route 5: Ernakulam to Airport

require further investigation focusing on the service design aspects with help of demand models and Willingness to Pay (WTP) values of travelers. In order to enhance the security system in urban bus service, CCTV surveillance may be provided at bus stops and inside the vehicle. The system is available in some of the newly introduced premium buses but is not functional at times. Improvement of pedestrian environment can be ensured by making proper interventions in sidewalk, crosswalk, and passenger waiting shed. Several studies are available as a benchmark for the improvement of these pedestrian facilities. Information is another qualitative attribute which emerged as an intervention area. A majority of the newly introduced premium buses are GPS enabled, and this gives a unique opportunity to provide dynamic/real-time information to travelers at bus stops (wayside information) as well as through websites (pre-trip information). For the conventional ordinary buses, a GPS may be installed or as an immediate measure, reliable static information shall be provided at bus stops and through the website. Further investigation is necessary to study the cost of improvement, willingness to pay of travelers, potential shift of car users to bus, to list a few. On the other hand, a benchmark is necessary for the improvement of quantitative attributes of bus service which is discussed below.

7. Conclusion

An attempt is made to study the impact of the COVID-19 pandemic on the perception of travelers and also to identify new policies and intervention areas for improving urban bus service. The study was carried out after collecting user perception data from travelers of Kochi, in the years 2018 and 2021. Priority areas of interventions were identified using Importance-Satisfaction Analysis (ISA) giving due considerations to user's factor structure and management scheme of bus service. Analysis shows a substantial increase in the intervention areas as compared to the pre-pandemic scenario which is a reflection of the change in perception of travelers towards bus service. Although there is a marginal difference in the order of priority, improvement areas before pandemic remained as priority areas during the pandemic with the addition of a few attributes. This is a clear indication of the temporal stability and the validity of the results. Attributes such as cleanliness, pedestrian environment, and crowding were emerged as new intervention areas. This may be attributed to the increased awareness of travelers about social distancing norms and hygiene to prevent the spread of virus infection. The results also indicate the need for improvement in information attributes which were identified as intervention areas in the pre-pandemic and post lockdown scenarios. Web-based or mobile-based real-time information of bus schedules may be provided with proper economic analysis to address this concern. The desired service levels of quantitative attributes are also identified for enhancing the satisfaction of travelers. This could be useful as a benchmark for the improvement of bus service. An evaluation of bus routes in Kochi indicates that the service is presently performing well below the desired levels of travelers. Improvement in these attributes is necessary to enhance the satisfaction of users, and further investigations are required to study the effect of improvement on demand share, willingness to pay of travelers, cost of improvement, etc. The findings of the present work are case-specific and could be used for improving the quality of bus service in the study area. However, the methodology and the experience from the present work may encourage policymakers to study the perception of users in different scenarios for the improvement of services in various contexts.

CRediT authorship contribution statement

Munavar Fairooz Cheranchery: Conceptualization, Methodology, Funding acquisition, Software, Project administration. **Meenu G. Krishnan:** Validation, Formal analysis, Investigation, Writing – review & editing. **Asif Navas K R:** Resources, Data curation. **Mohamed Shahid P A:** Writing – original draft, Visualization. **Revathy Suresh:** Visualization, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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