ORIGINAL RESEARCH



Enhancing service quality of rural public transport during the COVID-19 pandemic: a novel fuzzy approach

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Accepted: 22 December 2022 / Published online: 5 April 2023 © The Author(s), under exclusive licence to Springer-Verlag GmbH Germany, part of Springer Nature 2023

Abstract

In order to encourage the use of public transportation, it is necessary to make it more appealing to commuters by conducting frequent Service Quality (SQ) evaluations and modifications. Understanding passengers' expectations of public transportation are important, and evaluating the SQ is an essential tool for assessing the overall performance of the public transportation system. The purpose of the present study was to examine the expectations and perceptions of core passengers regarding SQ in public bus transportation. By surveying 598 passengers in rural public transportation in India, the study results are illustrated and further discussed to guide possible bus SQ improvements in rural areas. In addition, the impact of these expectations and perceptions on satisfaction levels of rural public bus transportation services are explored by applying the Interval-Valued Pythagorean Fuzzy (IVPF). The outcomes of the survey indicated significant disparities among expectations and perceptions of passengers, as well as widespread dissatisfaction with the delivery of bus services in rural areas as a whole. The dependability and adaptiveness of the bus service have been critical in describing the overall quality of bus services in rural areas, and best practices from around the world were used to develop a set of recommendations for transportation operators and local officials.

Keywords Service quality · Expectations and perceptions · Rural public transport · Interval-valued Pythagorean fuzzy (IVPF) · COVID-19 pandemic

1 Introduction

Public transportation is a service that millions of people use all across the world. In addition, transportation has a direct impact on all aspects of rural life. Education, health, emergency services, and daily activities of farmers cannot be sustained

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without a stable and efficient transportation infrastructure. People in rural areas often rely on private or public transportation to carry out their daily life. As of 2015, most people were interested in living in urban areas due to the abundance of opportunities, such as technology, education, job opportunities, transportation, and significantly higher living standards (Li and Zhao 2018). Nowadays, the current generation occasionally even prefers to live in rural areas rather than cities due to increased environmental pollution of air and water as well as health issues, and several business opportunities. However, living standards are affected by different factors, one of which is transportation, which is an essential part of daily life (Kifle et al. 2018). Furthermore, people make key life decisions based on the availability of public transit, such as where they will attend school, work, and continue family life (Liu et al. 2022). Public bus transportation in rural areas faces many challenges, including safety and reliability problems (Sam et al. 2018). As a result, the public transportation systems in developing countries need to work more efficiently, improve, and update daily transportation, particularly in rural areas of the country (Mounce et al. 2018). It is obvious that metro cities have well-developed public transportation systems that give them a competitive advantage in terms of living standards compared to other parts of the country (Errampalli et al. 2020). Furthermore, more countries are facing several issues to manage and control public transportation in rural areas, including concerns about safety and reliability. In addition, it is critical to assess public transportation services in order to understand the current situation and develop strategies for further improvement. In addition, current passengers not only enjoy the services but are also concerned about the quality of the services from their experiences with public transportation.

Furthermore, a novel coronavirus (COVID-19) was identified or appeared in Wuhan, China in December 2019 (Sohrabi et al. 2020). The World Health Organization (WHO) had declared the COVID-19 pandemic in March 2020. The COVID-19 pandemic had quickly escalated into an unfortunate situation that had far-reaching consequences for global transportation and lifestyle, spanning from a significant reduction in travel to an extraordinary rise in work from home and teleworking (Zhang et al. 2021). Besides, service organizations, particularly software companies in developing countries, have been providing work-from-home options to their employees. Therefore, rural areas have been chosen by the public to be protected from the COVID-19 virus. These effects are typically made of both governmental precautions and individual decisions to avoid travel to minimize the risk of contamination (Tirachini and Cats 2020). As a result of these factors, public transportation utilization has decreased all across the world as the COVID-19 pandemic spreads (Liu et al. 2020). The pandemic outbreak has created significant challenges while also improving the rural infrastructure of public transportation networks around the country. In addition, the implementation of curfews in India had decreased the use of public transportation by the end of 2020. However, the use of public transportation systems was increased because of the normalization process and the reduction of the pandemic restrictions by governments from July 2021. Therefore, a few of these issues were necessitated, such as adjusting vehicle and station occupancy levels, using face masks, reducing travel time, maintaining social distance, and implementing stringent sanitary

regulations (Kamga et al. 2021). Simultaneously, implementing these rules and retaining customer satisfaction with quality services has thrown major challenges for both transportation service providers and governments.

When it comes to quality, it can be defined as describing the sum of customer satisfaction and it could be described by looking at specific Service quality (SQ) indicators (Narteh 2018). In addition, the sum of a customer's perceptions of their service experience is commonly used to define SQ (Hadiuzzaman et al. 2019; Chen et al. 2019). Moreover, organizations are trying to improve customer satisfaction by offering high-quality services while adhering to pandemic regulations (Ongel et al. 2018). Nowadays, every public transportation operator places a greater emphasis on customer satisfaction by offering better services to their passengers. As a result, assessing customer expectations and perceptions of SQ has become a requirement for all public transportation operators (Yaya et al. 2015). Therefore, the SQ dimensions identification and improvements of public transportation systems, as well as the result of SQ assessments, may encourage more people to use them. The local governments must analyze and monitor SQ and develop strategies to improve public transportation quality while also implementing pandemic regulations (Islam et al. 2016).

Numerous scholars have explored the advantages and effects of various priority strategies for public transportation. Most of the present literature focused on advanced cities as urban areas (Ingvardson and Nielsen 2022), metro cities (Wan et al. 2016), and developed countries (Govinder 2014), where advanced technology is widely deployed. In addition, few studies have been conducted on the effects of rural bus stops on travel time and reliability (Hansson et al. 2022), Šipuš and Abramović (2017) identified geographic and demographic factors for the possibility of using public transportation in the rural area, and developed models for rural bus transportation using a neural networks approach (Wagale et al. 2016), bus station design combined with mystery shopping (Voß et al. 2020), and Tripathi et al. (2012) analyzed the literature of the public transport system in India. Some of the significant observations based on the review of literature are as follows: most of the present literature has been conducted in developed countries and most studies are concentrated in the context of urban areas or city transportation (Yaya et al. 2015). Few studies have attempted the subject of rural transportation in different ways. However, such research could not provide passengers' expectations and perceptions of SQ in rural bus transportation. It can appear that there is no key or universal set of SQ items in the context of rural transportation to improve customer satisfaction during the COVID-19 pandemic (Imhof et al. 2020). Therefore, the present study addresses that gap by determining and analyzing different SQ dimensions in the context of passengers' expectations and perceptions in rural bus transportation during the COVID-19 pandemic. As a result, the Interval-Valued Pythagorean Fuzzy (IVPF) method, which is commonly used to evaluate SQ in various fields, is modified in accordance with the needs of the time. On the other hand, SQ is determined by human judgment. The novel fuzzy approach of IVPF to access SQ has the added advantage of dealing with vague human assessment. This is lacking in conventional SQ assessment techniques, and thus the novel IVPF method is introduced in the current study. Therefore, the aims of the present study are as follows:

- To identify the rural public transportation SQ dimensions by a systematic literature review.
- To determine the influence items of the SQ related to each other, and their relative importance from passengers' context during the COVID-19 pandemic.
- To examine how rural public transportation operators would benefit from IVPF analysis outcomes in terms of being able to allocate resources to each SQ dimension.

Although there is extensive literature on the SQ concept, a consensus has yet to be established on the dimensions or methods for SQ measurement in the case of public transportation. The existing study approaches have been conducted against the perceived SQ measurement either for scale development or empirical research in various sectors for the passenger's point of view. In addition, an effort is made to observe the in-depth analysis of the SQ dimension of rural public transportation by adopting an extended IVPF approach. It has been widely used to identify SQ dimensions and analyze main SQ aspects in different sectors (Zheng et al. 2020). Hence, we are summarizing the main contribution of the present study as follows: this study's results provide important service dimensions to consider in analyzing the value of the service process in attracting a favorable passenger's perspective. In doing so, the theoretical explanation as to where is the gap between the passenger's expectations and perceptions of SQ has been addressed to understand whether customers are likely to respond negatively or positively to rural public transportation. Our conceptual conclusions, based on the previous literature, are wide enough to consider existing research on SQ and measurement trade-offs and to evaluate the following scenarios that have yet to be properly resolved. In addition, the outcomes of this study support the mechanism of the process. The findings also help public transportation management to determine appropriate levels of service for passengers by pushing them to examine their passenger's mindsets. Meanwhile, the operators should take advantage of specific situations in which they may offer the services (i.e., while their customers tend to be in an abstract mindset).

2 Research motivation

The perception and knowledge of passenger behavior in relation to SQ are critical in examining any transportation mode (Lai and Chen 2011). There is a wide range of literature available on methods for analyzing the perceived SQ in transportation modes. These studies were mostly focused on the discussion and application of the most well-known and commonly utilized approaches: SERVPERF (Fragoso and Espinoza 2017) and SERVQUAL (Sam et al. 2018). Future, alternative approaches have been applied such as the utilization of mixed data derived from passenger perceptions and performance metrics by transportation agencies (Carvalho and Medeiros 2021), the use of neural networks (Ma et al. 2018), structural equations (Díez-Mesa et al. 2018), discrete choice models (Quddus et al. 2019), and classification tree techniques (Güner 2018). An extensive review on SQ can be found in the study of Imaz et al. (2015). Although they are in a distinct context, we found clear

examples of the significance of selecting the ideal dimensions to measure SQ in the study conducted by Sam et al. (2018). They held a focus group to identify the important aspects and factors for measuring the quality of service for private bus transportation (Brands et al. 2022). They discovered that it is necessary to incorporate additional parameters to the standard procedure to adapt it to the situations of different countries. As will be discussed later, in the local train services, empathy and responsiveness have a significant bearing on the important SQ aspects by the passengers.

The first researches about the quality of the bus services that the authors are aware of are from the early 1990s, and they are all about regulating the services (Mützel and Scheiner 2022). In most of these studies, SQ is measured in terms of passenger's waiting time, which is an important factor used in the market research of public transportation to design, modelling (Huang et al. 2020). However, the passenger's perceptions and considerations of some different variables other than waiting time have not been studied as thoroughly. This finding was validated by Monmousseau et al. (2020) who included satisfaction as a latent factor among the explanatory factors in mode selection on the interface to international transportation. There were significant specifications and estimations to demonstrate that customer satisfaction has a significant impact on the quality of service in both private and public transportation, although few studies have examined the impact of perceived quality on the demand for public transportation in rural areas. Wan et al. (2016) noted that despite the security of publications on the issue, several small towns across the global level periodically examine the SQ prevailing perception in public transportation. In addition, they further state that no studies have demonstrated that the dimensions used in these works accurately reflect the true quality perceived by passengers. The importance of SQ has recently increased because of the emergence of new competitors in the transportation sector. Errampalli et al. (2020) evaluated the competition among public and private bus operators in developing countries context. This study used two case studies from India and examined the progression of customer complaints. The results of this study confirmed that quality services have considerably decreased the complaints by the customers or the specific complaints about facilities and services. Further, Narteh (2018) found that the improvement in SQ was leading to a high customer satisfaction.

Present studies have addressed a link between the passenger's perceived performance and SQ dimensions as well as their socioeconomic variables (Awasthi et al. 2011; Sam et al. 2018; Tumsekcali et al. 2021). Ongel et al. (2018) analyzed the public transportation services in developed nations. In addition, Tumsekcali et al. (2021) applied the SERVQUAL-based method, and Lai and Chen (2011) employed a Structural Equation Modeling (SEM)-based method to analyse the SQ in public transportation. Those studies' findings were constrained by the case study context of SQ in different developed countries. Furthermore, those works identified operators' behavior as an important dimension, among others, to improve both SQ and customer loyalty, and they stated that ticket prices were statistically significant only for rural area passengers. Two of the several works dealt with a broad range of aspects for assessing SQ and used data from China's car transportation sector to weigh the SERVPERF method and analyze the perceived quality and customer satisfaction. They have grouped five dimensions with 22 factors, such as assurance, empathy, reliability, tangibility, and responsiveness in the driver's context. The driver's route expertise was a major factor (they emphasize that this is to be assumed as it dictates the duration of the trip or how much the trip costs, and the client placed a high value on all factors connected to safe driving. In addition, the relevance of these factors is supported by Islam et al. (2016). They used entropic weighting to determine each quality factor's relative weight, as well as the well-known fuzzy TOPSIS analysis (Awasthi et al. 2011) to identify each explanatory factor's satisfaction index. More than twenty factors were explained and the quadrant approach was used to mix the two dimensions and analyze the findings. Based on this approach, the academics suggested the improvement of aspects related to information, driver behaviour, and operator reply. Fu et al. (2018) also mentioned the importance of corporate image as a significant factor in improving customer loyalty in public transportation.

As can be seen, there are various methodologies for assessing the SQ of public transportation. The importance of the service dimensions is evaluated in the metropolitan and urban context rather than the rural public bus transportation. Moreover, the passenger's expectations and perceptions of SQ dimensions have not been thoroughly investigated. The current study attempts to fill that gap by examining rural public transportation SQ from the passenger's perspective.

3 Methodology of this study

3.1 Research design

The purpose of this cross-sectional survey in this section is to identify SQ expectations and perceptions of public bus passengers to determine their satisfaction level with rural public transportation services. Furthermore, Tumsekcali et al. (2021) used SERVQUAL to assess SQ in the transportation sector and offered methodological limitations. Lee et al. (2019) used the Retail Service Quality Scale (RSQS) approach to interpret the SQ in public transportation for urban areas, although this method has uncertainties in converting passenger expectation scores. Zia (2020) investigated the SQ of transportation in metropolitan areas by combining the RSQS and SERVQUAL approaches. In addition, they stated that those two methods, as well as a combination of RSQS and SERVQUAL approaches, fail to determine and provide the SQ-important dimensions from the passenger's perspective. As a result, using the theory of IVPF numbers, the perception and expectation scores of the SQ dimensions are analyzed. A membership function, as mentioned by Zheng et al. (2020), characterizes a noteworthy theory of fuzzy sets (FSs). Since then, the FS theory has been successfully applied for multi-attribute decision making issues in various fields. In reality, the IVPF method can be used in a different context (Rahman et al. 2017), including petroleum sludge treatment technology evaluation and selection (Johnson and Affam 2019), and supply chain performance (Ayyildiz and Gumus 2021). Furthermore, extended FSs have been constructed, such as IVPFs (Fu et al. 2020). IVPF sets are an extension of Pythagorean FSs and have lot of potential for efficiently managing uncertainty in real-world applications (Rahman et al. 2019). An interval-valued rough fuzzy set is an effective extended method of the interval-valued intuitionistic fuzzy set for dealing with the uncertainties in the data (Rahman et al. 2019). As a result, the IVPF approach was used in this study to analyze data from rural public transportation passengers using a research methodology flow as shown in Fig. 1.

3.2 Sampling procedure

Based on this study's objectives, the data were collected from different parts of India, especially, the largest states: Andhra Pradesh, Telangana, and Pondicherry (union territory). The rural area of the states is 2437 Sq.kms and with approximately 26.38 million inhabitants. It can serve as a key transportation node in the region. There are roughly 37,457 public bus transportation routes operating each day. The total length of the bus transportation network lines is 16059 km. The average number of bus routes is over 20,000, with most of those covering the region's rural areas. The inventory structure age was 17.28 years (https://morth.nic.in/basic-road-stati stic-india). Such a rural public bus transport system serves as an important network. This fact should be remembered to comprehend the obtained results.



Fig. 1 The proposed research methodology for the study

The assessment of SQ items was carried out between 2020–2021 at twenty-four bus terminals in the rural public bus transport system of the selected territory. Of which, there are eleven bus terminals in the central area of Andhra Pradesh, six terminals in the Northern part of Telangana, and the remaining bus terminals are from the Western part of Pondicherry. That includes passengers from various regions of India to present a detailed examination of the rural public transportation system from the passenger's perspective. The questionnaire was prepared twofold: The first part of the questionnaire was related to passengers' gender, age, marital status, employment, trip purpose, etc. In the second part, the responders were giving their opinion on each defined item (Table 1) in terms of satisfaction and importance.

One service-related item that is missing on this list of 22 items, although it is important, is bus service accessibility for people economically underprivileged and students from extremely small villages. For a long time, advanced nations have been

Service dimension	Description of questionnaire item
Reliability	
RE1	Buses arrive on time
RE2	Buses never break down while travelling
RE3	It is quite simple to obtain bus tickets
RE4	Requests from passengers are immediately met
RE5	Buses run on a set timetable
Assurance	
AS1	Passengers' belongings are secured
AS2	Staff are always polite
AS3	Staff have in-depth job training and knowledge
AS4	Staff behaviour instils confidence in passengers
Tangibility	
TA1	Staff appear neat and smart
TA2	Buses are accessible to all categories of passengers
TA3	Buses are spacious, safe, and comfortable
TA4	Buses are always clean
Empathy	
EM1	Passengers' interests are prioritised
EM2	Bus schedules are convenient
EM3	Bus service information is readily available and accessible
EM4	Staff are always on hand to serve passengers
EM5	The ticket office and other facilities are easily accessible
Responsiveness	
RS1	Staff provide individualised attention to passengers
RS2	Service availability and changes are communicated in advance
RS3	Services are timely and efficient
RS4	Staff act promptly and are ever ready to assist passengers

Table 1 List of the service quality dimensions in public transportation

working on "barrier-free" transportation. This issue still exists in India and it seems to not have been solved within a couple of years due to economic concerns. And yet, there is a narrative drawback in the domains of designing, planning, and developing infrastructure noting that accessibility principles were not followed. As a result, students are traveling to their school or college on foot or in their own vehicles from very small villages in rural areas of India. This group of people might be the most useful in assessing accessibility, but it was not possible to survey them at bus terminals, considering that this study ignored this SQ item from the list. According to the author, accessibility for those without access to bus services is an important item of SQ and ought to be looked into in some of the next studies. The following sections are discussing the SERVQUAL model development, identification of SQ dimensions, and the IVPF analysis process.

3.3 SERVQUAL model

Based on the present literature available on public transportation, the SERVQUAL measure was used to assess the expectations and perceptions of SQ from respondents. The test examined statements on 22 items spanning five main SQ dimensions such as reliability, assurance, tangibility, empathy, and responsiveness on a 5-point Likert scale. The 5-point Likert scale has been proven to yield consistent test results (Ulkhaq et al. 2019). As per Sam et al. (2018) the five SQ dimensions are the following:

- Reliability: the ability of public bus transport operators to perform their services accurately.
- Assurance: the employees' knowledge and courtesy, as well as their ability to convey trust and confidence.
- Tangibility: the physical appearance of the operator vehicles, employees, and other facilities.
- Empathy: entails providing passengers with personalized care and attention.
- Responsiveness: the promptness with which services are provided.

It is possible to get a total score ranging from 22 to 110 on each subscale (for example, the expectancy and perception scales). When a greater score is achieved on the expectation subscale, it suggests a higher level of anticipated SQ, whereas a higher score on the perception subscale shows a higher level of positively perceived SQ. According to the scale reliability tests, the perception and expectancy subscales each had Cronbach alpha values of 0.76 and 0.86, respectively, indicating that they had excellent internal consistency, which is extremely good. Table 1 lists all of the scale elements (both expectation and perception) in their entirety.

3.3.1 Identification of service quality dimensions

The first task is to explore the SQ dimensions of public transportation from the selected perspectives. This assessment led to the exploration of primary items of

SQ in the transportation sector. The literature on SQ from various contexts is shown in Table 1. This study's systematic review of literature from various contexts with regard to SQ has identified 22 items, which are shown in Table 1. A couple of items were not selected randomly. On the other side, through a systematic review of literature, it was discovered that any SQ dimension in public transportation, especially in the context of rural bus transportation, may be grouped as a set of 22 items. Ingvardson and Nielsen (2022) discussed the driver's performance in services of bus transportation. In addition, Kamga et al. (2021) determined that improving SQ results in decreased buses arriving on time, expanding economies of scale, and attracting more passengers to public buses in rural areas. Huang et al. (2020) reported that responsiveness is an important measure of quality in train transportation. Islam et al. (2016) argued that the tangibility items were correlated with service performance, it is strongly associated with customer loyalty. Wan et al. (2016) explained the methods in which reliability elements of public buses would help to improve service performance. Narteh (2018) studied how empathy is associated with customer satisfaction. The pricing disparities between different assurances have been explored, and they are independent of the SQ items (Lee et al. 2019). In addition, the aggregate demand for transportation services is determined by their quality of service (Díez-Mesa et al. 2018). One of the most important aspects of SQ in bus transportation is that the buses are clean (Wan et al. 2016). Sam et al. (2018) identified the five SQ dimensions in urban and metro cities, such as the dimensions that measure assurance, empathy, tangibles, responsiveness, and reliability. Among these items, the most important factor is reliability. It was identified that responsiveness had a significant effect on customer loyalty. The systematic review of the literature overview for identified items has been given a proper discussion as shown in Table 1.

3.3.2 Procedure and theory of interval valued Pythagorean fuzzy numbers

The capacity of public bus transportation providers to provide accurate service, the physical appearance of the operator, staff, and other things make up the business responsiveness to customer needs and timeliness of service delivery.

Suppose X is a universal set. Then, using Eq. (1), the interval values of the Pythagorean fuzzy set \tilde{P} is defined as follows (Zheng et al. 2020):

$$\widetilde{\mathbf{P}} = \left(\left[\mu_{\widetilde{\mathbf{p}}}^{-}(x), \mu_{\widetilde{\mathbf{p}}}^{+}(x) \right], \left[v_{\widetilde{\mathbf{p}}}^{-}(x), v_{\widetilde{\mathbf{p}}}^{+}(x) \right] \right) | x \in X$$
(1)

where the functions $\mu_{\tilde{p}}^{-}(x)$, $\mu_{\tilde{p}}^{+}(x)$, $v_{\tilde{p}}^{-}(x)$, $v_{\tilde{p}}^{+}(x)$: X \rightarrow [0, 1]. $\mu_{\tilde{p}}^{-}(x)$ and $\mu_{\tilde{p}}^{+}(x)$ are the lower and upper degrees of membership, $v_{\tilde{p}}^{-}(x)$ and $v_{\tilde{p}}^{+}(x)$ are the lower and upper degrees of non-membership, respectively.

degrees of non-membership, respectively. The set \tilde{P} should satisfy the condition $0 \le \left(\mu_{\tilde{P}}^+(x) + \upsilon_{\tilde{P}}^+(x)\right) \le 1$. Equation (2) measures the lower and upper degrees of indeterminacy, respectively.

$$\pi_{\widetilde{P}}^{-}(x) = \sqrt{1 - \mu_{\widetilde{P}}^{+}(x) - v_{\widetilde{P}}^{+}(x)} \text{ and } \pi_{\widetilde{P}}^{+}(x) = \sqrt{1 - \mu_{\widetilde{P}}^{-}(x) - v_{\widetilde{P}}^{-}(x)}$$
(2)

Table

Then, the operations on IVPF fuzzy numbers are evaluated using the following process. Let $\widetilde{P} = ([\mu^-, \mu^+], [v^-, v^+]), \quad \widetilde{P}_1 = ([\mu_1^-, \mu_1^+], [v_1^-, v_1^+])$ and $\widetilde{P}_2 = ([\mu_2^-, \mu_2^+], [v_2^-, v_2^+])$ be three IVPF numbers, then the operations are defined as follows (Zheng et al. 2020):

$$\widetilde{P}_{1} \oplus \widetilde{P}_{2} = \left(\left[\sqrt{\left(\mu_{1}^{-}\right)^{2} + \left(\mu_{2}^{-}\right)^{2} - \mu_{1}^{-} \times \mu_{2}^{-}}, \sqrt{\left(\mu_{1}^{+}\right)^{2} + \left(\mu_{2}^{+}\right)^{2} - \mu_{1}^{+} \times \mu_{2}^{+}} \right], \left[\upsilon_{1}^{-} \times \upsilon_{2}^{-}, \upsilon_{1}^{+} \times \upsilon_{2}^{+}\right] \right)$$
(3)
$$\widetilde{P}_{1} \otimes \widetilde{P}_{2} = \left(\left[\mu_{1}^{-} \times \mu_{2}^{-}, \mu_{2}^{+} \times \mu_{2}^{+}\right], \left[\sqrt{\left(\upsilon_{1}^{-}\right)^{2} + \left(\upsilon_{2}^{-}\right)^{2} - \upsilon_{1}^{-} \times \upsilon_{2}^{-}}, \sqrt{\sqrt{\left(\upsilon_{1}^{+}\right)^{2} + \left(\upsilon_{2}^{+}\right)^{2} - \upsilon_{1}^{+} \times \upsilon_{2}^{+}} \right] \right)$$

$$\tilde{\mathbf{P}} = \left(\left[\sqrt{1 - (1 - (\mu^{-})^{2})^{k}}, \sqrt{1 - (1 - (\mu^{+})^{2})^{k}} \right], \left[(\nu^{-})^{k}, (\nu^{+})^{k} \right] \right), \text{ where } k > 0$$

$$\tilde{\mathbf{P}} = \left(\left\lfloor \sqrt{1 - \left(1 - (\mu^{-})^{2}\right)^{k}}, \sqrt{1 - \left(1 - (\mu^{+})^{2}\right)^{k}} \right\rfloor, \left\lfloor (v^{-})^{k}, \left(v^{+}\right)^{k} \right\rfloor \right), \text{ where } k > 0$$
(5)

$$\widetilde{P}^{k} = \left(\left[(\mu^{-})^{k}, (\mu^{+})^{k} \right], \left[\sqrt{1 - \left(1 - (v^{-})^{2} \right)^{k}}, \sqrt{1 - \left(1 - (v^{+})^{2} \right)^{k}} \right] \right), \text{ where } k > 0$$
(6)

Equations (3, 4, 5, 6) are used to measure the various operations of IVPF numbers. The expectation and perception scores of the SQ dimensions are estimated using the theory of IVPF numbers after measuring the operation of IVPF numbers. The four computational steps used to calculate the gap scores are as follows.

Step 1: Conversion of numerical variables calculation. The numerical variables given by the passengers from the response to the questionnaires are transferred to the corresponding IVPF numbers using Table 2.

Step 2: Computation of mean/average scores are estimated. Therefore, let us consider $\tilde{\widetilde{B}}ei = \left(\left[\mu_{\widetilde{B}ei}^{-}, \mu_{\widetilde{B}ei}^{+}\right], \left[v_{\widetilde{B}ei}^{-}, v_{\widetilde{B}ei}^{+}\right]\right)$ and $\widetilde{B}pi = \left(\left[\mu_{\widetilde{B}pi}^{-}, \mu_{\widetilde{B}pi}^{+}\right], \left[v_{\widetilde{B}pi}^{-}, v_{\widetilde{B}pi}^{+}\right]\right)$ as the interval valued Pythagorean fuzzy expectation and perception of SQ of the ith passenger (where i = 1, 2, ..., n) and jth SQ item (where j = 1, 2, ..., m), respectively. Let M $_{\rm e}$ and ${\rm M}$ $_{\rm p}$ be the IVPF mean/average perception and expectation of SQ on the jth item of all passengers. Equations (7, 8) are used to compute the mean scores of perceptions and expectations of all the items. Then, the IVPF mean scores of each item are determined by applying the following equations (Rahman et al. 2017):

Table 2 Numerical variables and corresponding IVPF numbers	Numerical variables	Interval valued Pythagorean fuzzy numbers
	5	([0.8,0.9],[0.1,0.2])
	4	([0.7,0.8],[0.2,0.3])
	3	([0.5,0.6],[0.4,0.5])
	2	([0.3, 0.4], [0.6, 0.7])
	1	([0.1, 0.2], [0.8, 0.9])

$$\begin{split} \widetilde{\mathbf{M}}_{\mathrm{e}} &= \left(\left[\sqrt{1 - \prod_{i=1}^{n} \left(1 - \mu_{\widetilde{\mathrm{Bei}}}^{-2} \right)^{\frac{1}{n}}}, \sqrt{1 - \prod_{i=1}^{n} \left(1 - \mu_{\widetilde{\mathrm{Bei}}}^{+2} \right)^{\frac{1}{n}}} \right], \left[\prod_{i=1}^{n} v_{\widetilde{\mathrm{Bei}}}^{-\frac{1}{n}}, \prod_{i=1}^{n} v_{\widetilde{\mathrm{Bei}}}^{+\frac{1}{n}} \right] \right) \end{split}$$
(7)
$$\\ \widetilde{\mathbf{M}}_{\mathrm{p}} &= \left(\left[\sqrt{1 - \prod_{i=1}^{n} \left(1 - \mu_{\widetilde{\mathrm{Bpi}}}^{-2} \right)^{\frac{1}{n}}}, \sqrt{1 - \prod_{i=1}^{n} \left(1 - \mu_{\widetilde{\mathrm{Bpi}}}^{+2} \right)^{\frac{1}{n}}} \right], \left[\prod_{i=1}^{n} v_{\widetilde{\mathrm{Bpi}}}^{-\frac{1}{n}}, \prod_{i=1}^{n} v_{\widetilde{\mathrm{Bpi}}}^{+\frac{1}{n}} \right] \right) \end{aligned}$$
(8)

Step 3: The Defuzzified mean/average scores are calculated. The computed IVPF mean scores (for both expectation and perception of the SQ) of each item are Defuzzified to compute the Defuzzified mean/average scores. Let $\widetilde{M}e_j = \left(\left[\mu_{\widetilde{M}e_j}^-, \mu_{\widetilde{M}e_j}^+\right], \left[v_{\widetilde{M}e_j}^-, v_{\widetilde{M}e_j}^+\right]\right)$ and $\widetilde{M}p_j = \left(\left[\mu_{\widetilde{M}p_j}^-, \mu_{\widetilde{M}p_j}^+\right], \left[v_{\widetilde{M}p_j}^-, v_{\widetilde{M}p_j}^+\right]\right)$ be the IVPF mean/average expectation and perception of the jth SQ item. Then, the Defuzzified mean/average perception D_{p_j} and expectation D_{e_j} of the jth SQ item are computed using Eqs. (9, 10) shown below (Karasan et al. 2019):

$$D_{pj} = \frac{\left(\mu_{\widetilde{M}pj}^{-2} + \mu_{\widetilde{M}pj}^{+2} + \left(1 - \pi_{\widetilde{M}pj}^{-4} - v_{\widetilde{M}pj}^{-2}\right) + \left(1 - \pi_{\widetilde{M}pj}^{+4} - v_{\widetilde{M}pj}^{+2}\right) + \left(1 - \pi_{\widetilde{M}pj}^{-4} - v_{\widetilde{M}pj}^{-2}\right) + \left(1 - \pi_{\widetilde{M}pj}^{-4} - v_{\widetilde{M}pj}^{-4}\right) + \left(1 - \pi_{\widetilde{M}p$$

$$D_{ej} = \frac{ \begin{pmatrix} \mu_{\widetilde{M}ej}^{-2} + \mu_{\widetilde{M}ej}^{+-2} + \left(1 - \pi_{\widetilde{M}ej}^{-4} - v_{\widetilde{M}ej}^{-2}\right) + \left(1 - \pi_{\widetilde{M}ej}^{+-4} - v_{\widetilde{M}ej}^{+-2}\right) + \\ \mu_{\widetilde{M}ej}^{-} \mu_{\widetilde{M}ej}^{+} + \sqrt[4]{\left(1 - \pi_{\widetilde{M}ej}^{-4} - v_{\widetilde{M}ej}^{--2}\right) \left(1 - \pi_{\widetilde{M}ej}^{+-4} - v_{\widetilde{M}ej}^{+-2}\right)} \\ 6 \end{pmatrix}$$
(10)

Step 4: Finally, the computation of the gap scores between perceptions and expectations of passenger's are finalized. Let G_j be the gap score between the perception and expectation of the SQ of the jth item of all passengers. Then, the score gaps are analyzed by using Eq. (11):

$$G_j = D_{pj} - D_{ej}$$
, where $j = 1, 2, 3 \dots m$ (11)

4 Results and discussions

4.1 Socio-demographics

To select the bus terminals, this study has applied a multistage sampling strategy that includes purposive and simple random sample techniques. The study was introduced to potential passengers at bus terminals. Contracted assistants were inviting them to engage in a questionnaire survey as described in Sect. 3.2. Moreover, in order to gain accurate impressions of public bus services, the respondents were expected to meet the requirements for selection, such as their mandatory use of public transportation or a bus in rural areas at least three times every week. The sample was gathered in the rural area-based public bus terminals in India, the passengers provided opinions for SQ items on their expectations and perceptions. The passengers responded to numerical variables from 1 to 5 for each item. We have received a total sample of 657 public bus transport passengers from the different terminals. In the data screening, the set of 598 (91.01%) questionnaires was identified as a valid sample and used for the future data analysis process. The remaining questionnaires (59) were rejected due to their incompleteness, and a few passengers are not using the service on a regular basis (less than three times a week).

From Table 3, it is observed that 391 (65.4%) of the research participants are male, whereas just 207 (34.6%) are female. Young people accounted for 284 (47.5%), middle-aged people accounted for 243 (40.7%), and the elderly accounted for 71 (11.8%). Furthermore, 325 (54.4%) of the population are unmarried, and 220 (36.8%) have completed tertiary education. More than 292 (48.8%) of those who took part in the study made daily excursions to and from their places of employment.

Table 3 Demographics of respondents	Socio-demographics	n	%	
	Gender			
	Male	391	65.4	
	Female	207	34.6	
	Age			
	Young	284	47.5	
	Middle age	243	40.7	
	Old age	71	11.8	
	Marital status			
	Unmarried	325	54.4	
	Married	273	45.6	
	Education			
	Non-formal	94	15.7	
	Basic	81	13.5	
	Secondary	203	34	
	Tertiary	220	36.8	
	Employment			
	Unemployed	244	40.8	
	Employed	354	59.2	
	Trip purpose			
	Workplace	292	48.8	
	Market/shopping	139	23.3	
	Schools	64	10.7	
	Others	103	17.2	

4.2 Passengers' expectations and perceptions of service quality

Tables 4 and 5 show the participants expected and perceived IVPF and defuzzied values. Awasthi et al. (2011) analyzed each SQ attribute to prioritize important SQ enhancement by competing with the customer's needs and supports resource allocation. According to Table 3, which summarizes the respondents' opinions on SQ dimensions, the majority of the male passengers heavily criticized the present services offered by the public bus operators in their regions. A higher expectation of SQ than the actual service provided resulted in gaps (demonstrated by negative gap scores). The mean scores for expected and perceived public bus SQ in rural areas varied among the 22 SQ dimensions. Table 1 shows a description of the SERVE-QUAL model. The IVPF expectations and perceptions are shown in Table 4.

Service dimensions	Interval valued Pythagorean fuzzy expectation	Interval valued Pythagorean fuzzy perception
Reliability	[0.6237,0.7371][0.0789,0.1603]	[0.6055,0.7177][0.0909,0.1759]
RE1	[0.6334,0.7477][0.0730,0.1531]	[0.5978,0.7102][0.0952,0.1822]
RE2	[0.6286,0.7411][0.0752,0.1537]	[0.6288,0.7403][0.0751,0.1525]
RE3	[0.6375,0.7505][0.0708,0.1485]	[0.6315,0.7442][0.0738,0.152]
RE4	[0.6055,0.7184][0.0905,0.1766]	[0.5751,0.6865][0.1124,0.2056]
RE5	[0.6136,0.7276][0.0849,0.1697]	[0.5944,0.7073][0.0981,0.1872]
Assurance	[0.6028,0.7150][0.0926,0.1785]	[0.5721,0.6836][0.1151,0.2091]
AS1	[0.596,0.7083][0.097,0.185]	[0.5829,0.6946][0.1064,0.1976]
AS2	[0.5825,0.6948][0.1073,0.1997]	[0.5338,0.6441][0.1452,0.2485]
AS3	[0.6195,0.7316][0.0812,0.1623]	[0.5968,0.7091][0.0968,0.1849]
AS4	[0.6132,0.7252][0.0847,0.1668]	[0.5748,0.6865][0.1121,0.2052]
Tangibility	[0.6271,0.7404][0.0779,0.1585]	[0.5792,0.6918][0.1118,0.2057]
TA1	[0.5918,0.7044][0.0995,0.1886]	[0.5607,0.6714][0.1238,0.2206]
TA2	[0.6678,0.7806][0.0537,0.1222]	[0.6242,0.7377][0.0776,0.1582]
TA3	[0.6423,0.757][0.0674,0.145]	[0.607,0.7218][0.0903,0.1789]
TA4	[0.6065,0.7197][0.0909,0.1783]	[0.5249,0.6364][0.1556,0.2651]
Empathy	[0.6056,0.7180][0.0912,0.1767]	[0.5641,0.6756][0.1218,0.2183]
EM1	[0.6354,0.7472][0.0709,0.1465]	[0.5845,0.6962][0.1034,0.1921]
EM2	[0.6333,0.7463][0.0724,0.1503]	[0.5902,0.702][0.1005,0.189]
EM3	[0.5984,0.7106][0.0949,0.1816]	[0.5689,0.6815][0.1175,0.2142]
EM4	[0.5753,0.6876][0.113,0.2081]	[0.5234,0.6331][0.1565,0.264]
EM5	[0.5857,0.6984][0.1049,0.1971]	[0.5536,0.6653][0.1309,0.2322]
Responsiveness	[0.5847,0.6966][0.1065,0.1983]	[0.5368,0.6466][0.1447,0.2487]
RS1	[0.5780,0.6909][0.1120,0.2079]	[0.5235,0.6327][0.1569,0.2642]
RS2	[0.5547,0.6658][0.1291,0.2286]	[0.5107,0.62][0.168,0.2785]
RS3	[0.6001,0.7115][0.0941,0.1798]	[0.553,0.6627][0.1294,0.2267]
RS4	[0.6058,0.7181][0.0909,0.1768]	[0.5601,0.671][0.1244,0.2218]

Table 4 Interval valued Pythagorean fuzzy expectations and perceptions

Service dimension	Defuzzified expectation values	Defuzzified perception values	Gap value
Reliability	0.6146[2]	0.5923[1]	-0.0223[1]
RE1	0.6270[5]	0.5829[5]	-0.0441[11]
RE2	0.6198[7]	0.6194[2]	-0.0004[1]
RE3	0.6311[3]	0.6235[1]	-0.0076[2]
RE4	0.5924[13]	0.5563[11]	-0.0361[8]
RE5	0.6028[9]	0.5794[7]	-0.0234[4]
Assurance	0.5890[4]	0.5536[3]	-0.0354[2]
AS1	0.5809[16]	0.5654[10]	-0.0155[3]
AS2	0.5654[19]	0.5109[18]	-0.0545[18]
AS3	0.6086[8]	0.5819[6]	-0.0267[5]
AS4	0.6009[10]	0.5561[12]	-0.0448[12]
Tangibility	0.6192[1]	0.5635[2]	-0.0557[5]
TA1	0.5762[17]	0.5399[14]	-0.0363[9]
TA2	0.6685[1]	0.6151[3]	-0.0534[16]
TA3	0.6381[2]	0.5956[4]	-0.0425[10]
TA4	0.5940[11]	0.5034[19]	-0.0906[22]
Empathy	0.5928[3]	0.5450[4]	-0.0478[3]
EM1	0.6276[4]	0.5668[9]	-0.0608[21]
EM2	0.6259[6]	0.5737[8]	-0.0522[14]
EM3	0.5835[15]	0.5503[13]	-0.0332[6]
EM4	0.5574[21]	0.5007[20]	-0.0567[19]
EM5	0.5694[18]	0.5334[16]	-0.036[7]
Responsiveness	0.5682[5]	0.5147[5]	-0.0481[4]
RS1	0.5611[20]	0.5005[21]	-0.0606[20]
RS2	0.5339[22]	0.4879[22]	-0.046[13]
RS3	0.5851[14]	0.5308[17]	-0.0543[17]
RS4	0.5925[12]	0.5395[15]	-0.053[15]

Table 5Defuzzified expectationand perception gap scores

For instance, it is observed that,

i. Passengers' expectations of service quality items: In terms of the expectation of passengers, the first item is TA2 (0.6685, "buses are accessible by all category of passengers"), the second item is TA3 (0.6381, "buses are spacious, safe and comfortable"), the third item is RE3 (0.6311, "it is quite simple to obtain bus tickets"), and the fifth item is EM1(0.6276, "passengers' interests are prioritized"), RE1 (0.627, "buses arrive on time"). The passengers have at least five expectations in EM5 (0.5694, "ticket office and other facilities are easily accessible"), AS2 (0.5654, "staff are always polite"), RS1 (0.5611, "staff provide individualized attention to passengers"), EM4 (0.5574, "staff are always on hand to serve passengers"), and RS2 (0.5339, "service availability and changes

are communicated in advance"). In terms of expectations in dimensions of SQ, the highest to lowest are tangibility (0.6192), reliability (0.6146), empathy (0.5928), assurance (0.5890), and responsiveness (0.5682).

- Passengers' perceptions on service quality items: According to the perception of passengers of public service transportation, the first item is RE3 (0.6235, "it is quite simple to obtain bus tickets"), RE2 (0.6194, "buses never break down while traveling"), TA2 (0.6151, "buses are accessible by all categories of passengers"), and TA3 (0.5956, "buses are spacious, safe and comfortable"). The lowest perceptions of SQ items are AS2 (0.5109, "staff are always polite"), TA4 (0.5034, "buses are always clean"), EM4 (0.5007, "staff are always on hand to serve passengers"), RS1 (0.5005, "staff provide individualized attention to passengers"), and RS2 (0.4879, "service availability and changes are communicated in advance"). In accordance with the perceptions of SQ dimensions in public bus transportation, the first dimension is reliability (0.592), the second dimension is tangibility (0.5635), followed by assurance (0.5536), empathy (0.5450), and the final dimension is responsiveness (0.5147).
- Passenger service gap score for public bus transportation: The gap score is iii. defined as the difference between the perceived score and the predicted score of the passengers. A positive gap score indicates that passengers are more satisfied than they expected to be with the services provided by public transportation, a negative gap score indicates that passengers are no longer satisfied with the services, and a zero-gap score indicates that passengers are simply satisfied with the services. From Table 5, we can observe that passengers are just satisfied with the services RE2 (-0.0004, "buses never break down while traveling") and RE3 (-0.0076, "it is quite simple to obtain bus tickets") since the gap scores are approximately zero. The top five of the items people are most dissatisfied with are the services of public service transportation AS2 (-0.0545, "staff are always polite"), EM4 (-0.0567, "staff are always on hand to serve passengers"), RS1 (-0.0606, "staff provide individualized attention to passengers"), EM1 (-0.0608, "passengers' interests are prioritized"), and TA4 (-0.0906, "buses are always clean"). In terms of SQ dimensions, with which passengers of public transport are not satisfied from lowest to highest: reliability (-0.0223), assurance (-0.0354), empathy (-0.0478), responsiveness (-0.0481), and tangibility (-0.0557). The results of the Defuzzified expected, perception, and gap scores are presented in Table 5.

The present study results revealed that in terms of expectations of the passengers, the top five service expectations are: "buses are accessible by all categories of passengers", "buses are spacious, safe and comfortable", "it is quite simple to obtain bus tickets", "passengers' interests are prioritized", and "buses arrive on time". In terms of expectations in dimensions of SQ, the highest to lowest are tangibility, reliability, empathy, assurance, and responsiveness. The passengers have different perceptions towards public bus transportation. In addition, this study's findings determined that the top five items towards the perceived satisfaction are: "it is quite simple to obtain bus tickets", "buses never break down while traveling", "buses are accessible by all categories of passengers", and "buses are spacious, safe and comfortable". In accordance with the perception of SQ dimensions in public bus transportation, the dimensions perceived by passengers from highest to lowest are reliability, tangibility, assurance, empathy, and responsiveness. The overall SQ was measured by taking the gap score between passenger's expectations and perceptions. The passengers are satisfied with the SQ items "buses never break down while traveling" and "it is quite simple to obtain bus tickets". Similarly, the most dissatisfied items are "staff are always polite", "staff are always on hand to serve passengers", "staff provides individualized attention to passengers", "passengers' interests are prioritized", and "buses are always clean". The study's results reveal that the transporters focus on responsiveness and tangibility.

This study determined that there are notable discrepancies between the passengers' expectations and perceptions of SQ in rural public transportation of India, resulting in a general dissatisfaction with the services received during the COVID-19 pandemic. This is particularly so as these services were deemed unreliable and less empathic contrary to the expectation. In addition, this study also determined that tangibility is the most important SQ dimension for rural bus transportation. Therefore, the bus operators and local governments should focus on the items of tangibility to improve customer satisfaction. They must develop their operational plans according to passengers' expectations from time to time. These study results also determine that staff appearance, bus timings, safety and comfort, and cleanness of the bus are the most important items from the passenger's viewpoint. Therefore, this study suggests that public bus operators could incorporate those items into their daily operations. If they do so, there is a chance to improve customer satisfaction in rural areas of India. If the bus operators and governments will implement or incorporate those SQ items, it could increase their revenues. Therefore, the public bus operators would get an opportunity to improve their infrastructure and connectivity with the rural areas. The studies established represent critical service improvement needs and thus should inform future public bus transport service modifications and overcome the COVID-19 pandemic. Doing this will not only serve the interest of the present customers but also attract potential passengers, resulting in increased usage of public bus transportation in the rural areas of India.

5 Conclusion and implications

SQ is an essential aspect in increasing the usage of public transportation in any country, particularly in rural areas. Passengers' expectations and perceptions are the most important factors to consider when analyzing the quality of service among public transportation systems. The high quality of service has been encouraging for the public to use public transportation systems, which can help to alleviate various issues such as air and sound pollution, petroleum consumption, and traffic congestion. The IVPF method is one of the most widely used in various sectors to evaluate SQ evaluation approaches for this purpose. The IVPF method is used in the present study to assess the quality of service provided by rural public transportation

networks while keeping passenger concerns in mind. Nowadays, due to a lack of infrastructure and advanced technology, it is critical for any country to implement SQ measures in rural public transportation systems to compete successfully with other technically sophisticated public transportation systems, and customer loyalty is indeed critical to any sector's growth and the advancement of society. Furthermore, it is difficult to consider the world's most pressing issue, the COVID-19 pandemic, when identifying the SQ dimensions of a public transportation system. As a result, this study used a novel IVPF method to evaluate the SQ of rural public transportation from the passenger's context.

The present study results reveal that in terms of expectations of passengers the top five items are: "buses are accessible by all categories of passengers", "buses are spacious, safe and comfortable", "it is quite simple to obtain bus tickets", "passengers' interests are prioritized", and "buses arrive on time". In terms of expectations in dimensions of SQ, the highest to lowest are tangibility, reliability, empathy, assurance, and responsiveness. In addition, tangibility items are noted as the highest priority dimensions and responsiveness items were identified as the highest SQ dimension from the passengers during the COVID-19 pandemic in rural regions. However, the staff of public bus transportation needs to provide individualized attention to their passengers and offer services on time. Finally, this study proposed the IVPF approach to measure the effectiveness of the previous study methodologies (SERV-QUAL and TOPSIS methods). Those studies' methodological limitations were addressed by the proposed IVPF approach in the present study. However, the most important SQ dimension with SERVQUAL and TOPSIS was assurance, and the next-best dimension was tangibility. The sequence of the other three SQ dimensions is not matched; the IVPF methodology revealed that it is the same. According to this study's findings, the best public transportation SQ dimensions for rural areas are tangibility and reliability. Based on these findings, the suggestions are the following:

The study's practical implications are to evaluate the SQ of passengers' context for rural public transportation systems using the novel IVPF approach, considering the impact of the COVID-19 pandemic, identifying passengers' interests and compliance, safety, and travel issues. Furthermore, the passengers are pleased with their public transportation experience because hygiene standards were strictly enforced during the pandemic era. In addition, the customer can get the services they need right away without wasting time or dealing with complicated processes while considering the passenger's expectations in the public transportation system. As a result, there is a chance to improve their customer satisfaction indirectly through their SQ. If bus operators could improve the quality of the rural bus transportation system, the usage rate and thus the operator's revenue rises, which had fallen due to the pandemic. In addition, there is an opportunity to improve public living in the rural areas, which will lead to a growth of the country's economy. Furthermore, this method could be used by managers who ensure passenger satisfaction in the bus transportation system to resolve passenger complaints and safety issues. The public transport network, which adapts to the COVID-19 pandemic process, the used methodology and demonstrated customer satisfaction with a high SO strengthens rural areas' competitiveness and economic growth.

This study's contributions are the following: (1) different dimensions of SQ have been included in the SERVQUAL model to adapt it to the implementation of the COVID-19 pandemic measure and to meet the needs of the passengers. As a result, a novel IVPF approach is presented that can be used to improve service strategies by rural public transportation operators; (2) the most significant characteristics of SQ in public transportation are to recognize and determine the gaps between the expectations and perceptions from the passenger's context; (3) SQ evaluation is carried out for rural public transportation, which is ignored by existing literature; (4) a literature review on SQ dimensions and IVPF and other methodologies is presented; (5) this IVPF methodology evaluated the gaps among SQ criteria, as well as their sub-criteria (inner levels); (6) based on our knowledge, this study is the first time an IVPF approach has been used to analyze the difference between passengers' perceptions and expectations in public transportation. (7) the IVPF approach was used to assess the efficacy of the SERVQUAL and TOPSIS methods, and the results were compared to previous research.

There are several limitations to this study. First, the study's primary objective is to understand the passenger's expectations and perceptions in the context of public transportation, especially in rural areas of India. This study's findings are not effective if applied or generalized to other areas or countries. Furthermore, only five different SQ dimensions are analyzed, and identified gaps between the passenger's expectations and perceptions, which are frequently preferred by existing studies to improve the quality of service and are drawn exclusively from public bus transportation. Second, this study was conducted during a period of restriction due to the COVID-19 pandemic. As a result, the number of people who use public transportation has decreased. Only a small group of passengers from the public transportation system was included in the analysis. These passengers were primarily from rural areas. Cooperation and experience sharing in rural areas are also critical in the management of the COVID-19 pandemic crisis, as they are in any global problem. In this context, there are few studies in various countries throughout the world for public transportation operations, which are crucial in terms of providing a reference for others dealing with the COVID-19 pandemic. Moreover, this study was conducted for the rural areas of India's public transportation system during the COVID-19 pandemic. As a result, this study's outcomes cannot be generalized to other developing countries. In addition, the five dimensions of SQ chosen for this study as well as the proposed approach might be revised and used not just during the COVID-19 pandemic, but also after the pandemic when the number of passengers is high. The proposed study could be applied to assess the various dimensions of SQ in various public institutions. This proposed approach will also be used for other modes of transportation, such as air travel, train transportation, and taxis. This study method will also be used for intercity transportation. Finally, future studies will be expanded by incorporating a large level of input from various experts or countries who use public transportation.

Data availability The used primary data that were used for analysis in this study are available from the corresponding author upon request.

Declarations

Conflict of 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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