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Importance – Performance Analysis (IPA) of metro service attributes during the COVID-19 pandemic

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ABSTRACT

Background: The study of user satisfaction with public transport services is of key interest for enhancing public transport ridership. However, the elevated risks of virus transmission on public transport associated with COVID-19 have resulted in a shift towards private vehicles. This issue is of concern to policymakers due to reduced levels of public transport use and increased private vehicle trips. Thus, it is relevant to re-evaluate attributes impacting user satisfaction during the COVID-19 pandemic to understand how this compares to related research undertaken before the pandemic.

Methodology: Through a survey of 507 Tehran Metro users, the structural patterns among 33 metro service attributes were determined using Exploratory Factor Analysis (EFA). A service quality model of the Tehran Metro service (including cleanliness, ventilation/temperature, congestion, operation hours, ticket, information, reliability, and safety) was then designed using Confirmatory Factor Analysis (CFA). Attributes and latent constructs were classified using Importance – Performance Analysis (IPA).

Findings: Attributes associated with general congestion in the metro, the performance of the metro during peak hours, cleanliness, and temperature/ventilation were found to be among the most influential attributes during the pandemic.

Conclusion: Before the COVID-19 pandemic, time and cost effectiveness were key attributes affecting the choice of travel mode. Due to the outbreak of the virus, safety and health have been identified as the main attributes affecting the choice of travel mode. In this research, with a case study of the Tehran metro, it was found that there is a shift in attributes affecting service quality towards cleanliness, congestion and temperature/ventilation. As a result, a range of policies is needed to deal with the effect of COVID-19 on metro services. These include: increasing the number of metro services, reducing the time interval between metro services, improving air conditioning, and regular cleaning of vehicles. Policymakers can use the results of this study to improve user satisfaction with metro services and increase ridership levels during the pandemic.

1. Introduction

Public transport system expansion is a key policy for supporting sustainable development objectives in both developed and developing countries (Li et al., 2018; de Oña, 2022). Investment in and use of public transport is associated with reduced road traffic, air pollution (Uusitalo et al., 2021), and fuel consumption (Errampalli et al., 2020).

The emergence of COVID-19 brought an unforeseen crisis across the world. Global closures forced quarantines, and various lockdowns were implemented, which also affected the use of public transport (Gkiotsalitis and Cats, 2021). In previous years, public transport was not seen as a primary contributor to virus outbreaks (Chen and Pan, 2020). However, people are usually close to each other in such settings and metros/buses are generally poorly ventilated, both of which facilitate the spread of infectious diseases during the COVID-19 pandemic (Dong et al., 2021). So public transport was identified as a key contributor to virus transmission, which resulted in passengers being discouraged from the system for fear of infection (Gutiérrez et al., 2020), locking down public transport and increasing the use of private vehicles (Fumagalli et al., 2021).

The emergence of new individual car-based routines (Beck et al., 2021) and declining public transport demand due to the COVID-19...
pandemic are a threat to policymakers and urban planners, especially in the post-COVID era (Coppola and De Fabiis, 2020). Viewing public transport as unhealthy can be sustained and have many negative economic and social effects (Tirachini and Cats, 2020). Furthermore, there is a change in perceptions of comfort, safety and satisfaction toward public transport, due to the COVID-19 pandemic (Przybylowska et al., 2021). As a result, it is inevitable that some extra interventions are needed to alyay the fear of infection and to recover the lost demand for public transport (Gkiotsalitis and Cats, 2021).

The first step in preparing for a post-COVID era with public transport is assessing user satisfaction during the pandemic to inform the development of policies to support safe and reliable services and to retain ridership levels. In this regard, studies on the impact of COVID-19 on public transport have been conducted separately in fields such as loyalty (Esmailpour et al., 2022), ticket validations, sales and passenger counts (Jenelius and Cehebauer, 2020), ridership, frequencies (Tiikkaja and Viri, 2021) and crowding perceptions (Aghabaky et al., 2021; Cho and Park, 2021). Given this, there is a need to integrate the effect of the COVID-19 pandemic on the service quality of public transport.

The research underlying this paper is based on a case study of Tehran’s metro system in Iran. Tehran is estimated to be among the world’s metropolises by 2030 (United Nations, 2018) with a forecast population of over 10 million. A key challenge for the long-term planning of city mobility in Tehran is an increased demand for travel in urban areas (Sharav et al., 2018). Taxis, buses and metros account for 23%, 20%, and 10% of all trips respectively in Tehran (Tehran Traffic and Transportation Organisation, 2018). Due to the relatively low mode share of the metro system and its importance in attracting passengers, it is essential to study the attributes impacting user satisfaction with the metro system in Tehran.

Prior to the COVID-19 pandemic, research was undertaken to understand user satisfaction with the Tehran metro service (Soltanpour et al., 2020). Considering the prevalence of the virus and its impacts on public transport, the aim of this research is to understand how attributes influencing user satisfaction with the metro service during the pandemic compare with previous research. Importance – Performance Analysis (IPA) is used as a practical and straightforward technique for assessing user satisfaction with various attributes and identifying managerial actions to enhance service quality (Martilla and James, 1977). A better understanding of attributes impacting user satisfaction with the public transport during the pandemic can help policymakers prioritise improvements to the quality of public transport services to help manage the increased use of private vehicles (Cheranchery et al., 2021).

The remainder of this paper is organised as follows. Section 2 provides a review of attributes affecting public transport service quality. The survey design and analytical methods are then described in Section 3, followed by the case study and results in Section 4. A discussion of the results and policy implications is provided in Section 5, followed by a set of concluding remarks in Section 6.

2. Literature review on public transport service quality

The first studies on service quality were made in the late 20th century on aerial transport services and urban public transport services (De Oña and De Oña, 2015). Quality of service is reflective of the perceptions among passengers about transit performance (Ojha, 2020). With the emergence of new technologies in the 21st century and improved processing capacity of computers, advanced analytical methods were proposed to examine service quality. A key focus has been determining attributes that affect public transport service quality and passenger satisfaction to better inform measures to increase public transport ridership (Allen et al., 2020).

Many factors have been found to affect public transport service quality, of which Murray et al. (2010) identified 166 attributes. Although there is no defined and precise framework for categorising attributes (Allen et al., 2018), dimensions impacting public transport service quality and user satisfaction include (Ibrahim et al., 2020):

- Availability of services
- Accessibility of services
- Ticketing
- Information
- Travel time
- Customer service
- Comfort
- Safety.

Each of these dimensions is now briefly described.

2.1. Availability of services

The availability of services represents the extent to which public transport can be used. This dimension includes frequency of service, network coverage and operating hours. Frequency of service refers to the headway between public transport vehicles in which shorter and more anticipated headways result in a higher level of quality of travel, passenger satisfaction, use of public transport (Szczuraszek and Chmielewski, 2018) and equity (Gort et al., 2020). Network coverage is considered attractive for public transport to provide “door-to-door mobility” (Saif et al., 2019). Proper network coverage enables passengers to spend less time accessing services and waiting to travel from their origin to their destination, leading to more accessible travel and enhanced passenger satisfaction (Eboli et al., 2016). The last attribute in this dimension is Operating hours which represents when the metro station starts operating to serve passengers and when it closes (Machado-León et al., 2017).

2.2. Accessibility of services

Accessibility is a crucial concept in the field of network science, having been used over the last few decades in various applications (Kim and Song, 2018). Accessibility of services indicates passengers’ access to the transport infrastructure under various conditions (Derrible and Kennedy, 2010). Passengers’ opinions on the level of services at peak hours (Baek and Sohn, 2016) and ease of transfer are derived directly from their experience of using public transport. Such an experience may be affected by issues such as queue lengths at exit gates, walking times, access to escalators or elevators (Weinstein, 2000) and distances people walk to access public transport (van Soest et al., 2020).

2.3. Ticketing

This dimension indicates the price of tickets and the type of tickets available to passengers. In general, the lower price of a public transport ticket, the greater satisfaction there will be in using public transport (Brown, 2018). In another view according to De Witte et al. (2013), the level of satisfaction with ticketing varies according to the purpose and frequency of travel. Thus, defining different tickets according to the purpose and frequency of travel (e.g. special tickets for students or weekly/monthly tickets) is one of the attributes impacting user satisfaction.

2.4. Information

Up-to-date, reliable, and correct reporting of information is another dimension that affects user satisfaction with public transport. Such reporting includes information about stopping places, operating hours, costs, and contingencies for breakdowns (Machado-León et al., 2017). In addition to influencing user satisfaction, Leng and Corman (2020) indicate that information availability is also effective in supporting a mode shift towards public transport.
2.5. Travel time

Passengers typically aim to travel from their origin to their destination in the shortest time. However, choosing a system and perception of service quality depends on many factors (Ahanchian et al., 2019), including the span of operating hours, access time, waiting time, transfer time, and speed of travel. The time between the first and last scheduled service is called the span of operating hours which can directly affect passengers’ satisfaction (Osztier, 2017). The gap between actual departure and arrival times and the official timetable affects the reliability of public transport (Rietveld et al., 2001) and has a negative effect on passengers’ experience in using public transport. The time needed for passengers to access public transport stops and stations is another attribute impacting passenger satisfaction with public transport (Ibrahim et al., 2020) which is named Access time. Another attribute affecting passenger satisfaction is waiting time. This attribute is the amount of time passengers wait at stops and stations. Waiting time is a subset of travel time and directly affects the time it takes for a passenger to travel from their origin to destination (Soza-Parra et al., 2022).

2.6. Customer service

Customer service in public transport also influences passenger satisfaction (De Gruyter et al., 2019). Customer service satisfaction can be defined as the gap between received services and their expectations (Chan et al., 2020). Attributes influencing this dimension include the behaviour of drivers with customers, the way in which station staff interact with passengers and services offered in the metro like shops, restaurants, and bathrooms.

2.7. Comfort

Comfort is a key dimension that influences the quality of public transport services (De Gruyter et al., 2019). This dimension includes cleanliness, seat capacity, quality of vehicles, noise, temperature, and waiting conditions. Cleanliness is a key attribute affecting comfort (Weinstein, 2000). This attribute is relevant to both vehicles and public transport stops/stations. A vacant seat when using public transport is another attribute that can enhance the satisfaction of passengers with public transport (Mouwen, 2015). The vehicle’s quality refers to the comfort and cleanliness of the seats and the vehicle’s attractiveness, which can also affect passenger satisfaction (Weinstein, 2000). Passenger satisfaction is also influenced by the temperature (Shen et al., 2016) and sound (Yilmaz & Ari, 2017) produced by the vehicle during travel and when waiting at public transport stops/stations.

2.8. Safety

Safety is an essential requirement for passengers. Failure to meet this attribute can strongly affect user satisfaction with public transport (Coppola & Silvestri, 2020). Safety influences satisfaction from two aspects: the visible perspective (e.g. crashes and crime on the track or at stations) and the invisible perspective (e.g. psychological factors).

2.9. Other attributes

A number of attributes affect the quality of metro services that are not included in the previous eight dimensions. These attributes specifically relate to the architectural design of the metro and attention to the environment. In recent years, concerns about climate change have increased, and this has led public transport providers to pay attention to environmental issues in designing their systems. Vicente et al (2020) have shown that the promotion of these features by public transport providers can increase the loyalty of passengers to public transport.

2.10. Previous studies assessing metro service quality

A number of studies have been conducted prior to the COVID-19 pandemic to understand attributes affecting the quality of metro services. For example, in reviewing the Algiers metro service, Machado-Leon et al. (2017) found that availability, time, safety, and comfort were key attributes influencing service quality. Majumdar et al. (2020) studied metro services in an Indian context finding that ticket price, service coverage as well as frequency affect the quality of metro services.

Previous research has also been undertaken to investigate the quality of the Tehran metro service. Solampour et al. (2020) used Structural Equation Modeling (SEM) to analyze 300 questionnaires from users of Line 3 of the Tehran metro. They found that travel time, waiting time, ticket cost, and access to metro stations influenced the quality of the metro service.

Due to the prevalence of COVID-19 and behavioural changes associated with public transport use (Kospandani and Wahyudi, 2021), there is a need to re-examine attributes affecting the quality of metro services. This paper seeks to fill that gap using a case study of Tehran’s metro service.

3. Methodology

In this study, Exploratory Factor Analysis (EFA) was used to identify the relationship between observed variables and the latent constructs. For both performance and importance scores, two principal component analyses were run, which resulted in a more acceptable and logical structural pattern in performance scores. This was predictable given the social desirability bias and generally high scores on the importance scale, which resulted in some counter-intuitive structural patterns extracted from importance scores. As a result, structural patterns extracted from performance scores were used to design the service quality model. Scale diagnostics have also been calculated covering the Kaiser Meyer Olkin (KMO) test of sampling adequacy and Bartlett’s test of sphericity.

The validity of the constructs and goodness-of-fit (GOF) of the service quality model were examined using Confirmatory Factor Analysis (CFA). The following measures were used in this regard:

- Minimum Discrepancy per Degree of Freedom (CMIN/DF): the acceptable value for confirming the model GOF is 3, in which ratios <3 indicate that the model fits the data better (Chen et al., 2008).
- Comparative Fit Index (CFI): the feasible range of CFI is from 0 to 1, in which larger measures indicate a better GOF of the model. A CFI value greater than 0.9 is considered acceptable (Hoelter, 1983).
- Root Mean Square Error of Approximation (RMSEA): this criterion improves the chi-square (χ^2) statistic for rejecting models with low sample size. Lower RMSEA values indicate a better GOF of the model. Researchers recommend RMSEA values of <0.08 (Browne & Cudeck, 1992).

Ultimately, after CFA, Cronbach’s alpha coefficient was measured for latent variables in both importance and performance scales. This coefficient measures the reliability or internal consistency of each construct. Measures above 0.7 are considered good, while measures between 0.6 and 0.7 are also acceptable (Gliem & Gliem, 2003). For factor analysis, IBM SPSS26 was used for the exploratory part and IBM AMOS24 software was used for the confirmatory part.

After CFA, Importance – Performance Analysis (IPA) was applied for both attributes and dimensions (i.e. constructs) confirmed from CFA. IPA was first proposed in 1977 by Martilla and James (1977) to introduce a technique for making marketing planning decisions. IPA is a key analytical method used by policymakers and provides a chart with four quadrants (Fig. 1) suggesting where to direct managerial actions according to the performance and importance scores given to each attribute.
attribute. IPA has also been used in the field of transportation and policy prioritisation (Cao and Cao, 2017; Chaisomboon et al., 2020; Esmailpour et al., 2020; Putra, 2013; Xu et al., 2020; ZHANG and JIA, 2019).

Quadrants of the IPA chart were determined using the data-centred quadrants approach, in which the thresholds of the quadrants are the grand mean of the users’ importance and performance scores. Also, in order to prioritise attributes located in each quadrant of the IPA chart, the gap between the scores of importance and performance was calculated, and the greater the difference, the higher the priority. The gap was calculated according to the following formula:

\[
\text{Gap} = \text{Performance score} - \text{Importance score}
\]

3.1. Survey design

In order to evaluate passenger satisfaction, a questionnaire was designed with two sections. The first section collected information about various socio-demographic characteristics and users’ experience of the metro system. This covered gender, age, education, employment status, car ownership, trip purpose, the main mode of transport, frequency of metro use, and main metro line used. In the second section, respondents were asked to directly assess the importance and performance of 8 groups of attributes of the metro service on a five-point scale. Table 1 lists the service quality attributes asked in the survey. The survey has eight attributes which are Temperature/Ventilation, Information, Cleanliness, Safety, Ticket, Operation hour, Reliability, and Congestion, which were adapted from Ibrahim et al. (2020), with some changes made due to the COVID-19 pandemic and local context of the Tehran metro system.

4. Application to the case study and results

4.1. Case study

Tehran’s metro was the first metro system to be built in Iran. Planning commenced in 1971, whereby a 7-line metro system was later proposed in 1974 in response to traffic problems (Tehran Traffic and Transportation Organisation, 2018). French companies began construction of Line 1 but ceased operations in 1982 due to the Iran-Iraq War. Construction restarted in 1987 with the first metro project completed in 1989, comprising Line 1 (Mirdamad - Haram-e-Motahhar), Line 2 (Dardasht - Sadeghieh), and Line 5 (Tehran - Golshahr suburban route), with a total length of 90 km and 52 stations (Tehran Traffic and Transportation Organisation, 2018). Line 5 was later expanded to Karaj in 1999. Since then, parts of the Tehran metro system have been

![Fig. 1. The standard IPA chart (Martilla & James, 1977).](image-url)
expands every year. Today, the Tehran metro covers a total of 205 km, served by 137 stations and a fleet of 66 trains. A total of 9.6 billion trips have been recorded from the opening of the metro system to early 2020 (Tehran Traffic and Transportation Organisation, 2018). Fig. 2 shows the Tehran metro map in 2021.

To evaluate passenger satisfaction with Tehran’s metro system, and given the challenges of physically distributing questionnaires due to COVID-19, an online survey was conducted from February to March 2021 (after the start of metro operations and before the start of public vaccination in the country). In order to reach metro users, the online survey was published through social networks and with the help of popular advertising Persian channels in Telegram. Before people could respond, they were asked if they had used the metro during the COVID-19 pandemic, and if they had, they were invited to participate in the survey. A total of 507 valid survey responses were obtained for analysis. The data from the first section, which aimed to collect socio-demographic characteristics, is summarised in Table 2. While there is no official data available from the Tehran Metro to assess the representativeness of the survey sample, the socio-demographic characteristics follow a similar distribution to previous surveys of Tehran metro users (Soltanpour et al. 2020).

In the following, Tables 3 and 4 present the mean scores of respondents to relevant questions. Table 3 presents the mean performance and importance scores for each metro service quality dimension. The highest mean performance scores were found for Ticket (3.67 out of 5), Cleanliness (3.56) and Information (3.56), while the lowest scores were reported for Congestion (2.29), Safety (3.14), and Temperature/Ventilation (3.30). The highest mean importance scores were found for Cleanliness (4.38), Safety (4.38), and Reliability (4.32), while the lowest were reported for Ticket (4.00), Operation hour (4.18), and Information (4.19). The largest gap in performance and importance was found for Congestion (-1.91), Safety (-1.24), and Temperature/Ventilation (-1.00), respectively. Across all dimensions, the mean importance score was consistently higher than the mean performance score. Table 4 details the mean performance and importance scores for each individual metro service quality attribute. The highest mean performance scores were found for Ticket1 (4.07 out of 5), Reliability6 (3.88), and Cleanliness2 (3.87), while the lowest scores were reported for Congestion2 (1.81), Congestion3 (1.94), and Congestion1 (2.13). The highest mean importance scores were found for Reliability6 (4.45), Cleanliness2 (4.44), and Cleanliness3 (4.42), while the lowest scores were reported for Ticket3 (3.68), Ticket2 (3.93), and Congestion5 (4.12). The largest gap in performance and importance was found for Congestion2 (-2.45), Congestion3 (-2.25), and Congestion1 (-2.13). Across all attributes, the mean importance score was consistently higher than the mean performance score.

4.2. Exploratory Factor Analysis (EFA) results

As shown in Table 5, the KMO value was higher than 0.6 and Bartlett’s test was significant (p < 0.001). Total variance explained by the components and the rotated component matrix are presented in Tables 6 and 7, respectively. Table 6 shows that eight components had an eigenvalue higher than 1, so eight factors were therefore selected for the service quality model. Although some service quality attributes...
indicated some degrees of cross loading (Reliability1 and Reliability3), the decision to keep or remove them was made at the CFA stage. As shown in Table 7, the eight components obtained were: Temperature/Ventilation, Information, Cleanliness, Congestion, Reliability, Safety, Ticket, and Operation hour.

### Table 4
Mean performance and importance scores for metro service quality attributes.

| Attribute            | Mean performance | Mean importance | Gap    |
|----------------------|------------------|-----------------|--------|
| Operation hour1      | 3.53             | 4.15            | −0.62  |
| Operation hour2      | 3.58             | 4.20            | −0.62  |
| Ticket1              | 4.07             | 4.17            | −0.10  |
| Ticket2              | 3.73             | 3.93            | −0.21  |
| Ticket3              | 3.64             | 3.68            | −0.04  |
| Ticket4              | 3.25             | 4.21            | −0.96  |
| Information1         | 3.78             | 4.17            | −0.39  |
| Information2         | 3.75             | 4.12            | −0.37  |
| Information3         | 3.51             | 4.21            | −0.70  |
| Information4         | 3.65             | 4.21            | −0.58  |
| Information5         | 3.13             | 4.24            | −1.11  |
| Reliability1         | 3.42             | 4.25            | −0.83  |
| Reliability2         | 3.42             | 4.13            | −0.71  |
| Reliability3         | 3.60             | 4.29            | −0.69  |
| Reliability4         | 3.10             | 4.41            | −1.31  |
| Reliability5         | 3.76             | 4.41            | −0.66  |
| Reliability6         | 3.88             | 4.45            | −0.57  |
| Cleanliness1         | 3.50             | 4.37            | −0.87  |
| Cleanliness2         | 3.87             | 4.44            | −0.57  |
| Cleanliness3         | 3.71             | 4.42            | −0.71  |
| Cleanliness4         | 3.15             | 4.27            | −1.12  |
| Congestion1          | 2.13             | 4.26            | −2.13  |
| Congestion2          | 1.81             | 4.26            | −2.45  |
| Congestion3          | 1.94             | 4.19            | −2.25  |
| Congestion4          | 2.81             | 4.15            | −1.35  |
| Congestion5          | 2.75             | 4.12            | −1.37  |
| Temperature1         | 3.38             | 4.28            | −0.90  |
| Ventilation1         | 3.21             | 4.31            | −1.10  |
| Temperature2         | 3.28             | 4.30            | −1.02  |
| Ventilation2         | 3.05             | 4.31            | −1.26  |
| Safety1              | 3.13             | 4.39            | −1.26  |
| Safety2              | 3.30             | 4.34            | −1.04  |
| Safety3              | 2.98             | 4.40            | −1.42  |

### Table 5
Goodness of fit measures.

| Scale diagnostics             | Measure  |
|-------------------------------|----------|
| Kaiser-Meyer-Olkin Adequacy   | 0.919    |
| Bartlett’s Test of Sphericity | Approx. Chi-Square | 9001.720 |
| df                            | 528      |
| Sig.                          | 0.000    |

#### 4.3. Confirmatory Factor Analysis (CFA) results

Fig. 3 shows the designed service quality model and Table 8 shows the Goodness-of-fit (GOF) of the service quality model. According to the obtained measures, the model has efficiently fitted the data: the model has a Minimum Discrepancy per Degree of Freedom (CMIN/DF) of <3, the Comparative Fit Index (CFI) is greater than 0.9, and the Root Mean Square Error of Approximation (RMSEA) is <0.08. Table 9 shows the power and significance of the relationships between attributes and dimensions for the service quality model. All the load factors are above 0.5 except for one attribute in the performance scale (Ticket3), which was between 0.4 and 0.5. Since the model fits the data well, this attribute was retained for modelling purposes. IPA was performed for each of the attributes and dimensions based on the above-approved constructs. Table 10 shows the Cronbach’s alpha values of dimensions for both importance and performance scales. Cronbach’s alpha values of all constructs in performance were above 0.7, except for Ticket with a value of 0.674, which was accepted in line with Gliem & Gliem (2003) who suggested a range of 0.6 to 0.7. This confirms the reliability of the constructs.

#### 4.4. Importance – Performance Analysis (IPA) results

Attributes were distinguished based on the mean importance and
performance scores given by survey respondents. The colour scheme shown in Fig. 4 was used to denote which quadrant of the IPA chart each attribute belonged to. Fig. 5 illustrates the IPA results for service quality attributes. A total of 8 attributes fall in quadrant 2 (possible overkill) with Ticket2 having the highest performance and importance in this quadrant. Only five attributes fall in quadrant 3 (low priority) with Ticket4 having the highest performance and importance. The remaining 10 attributes fall in quadrant 4 (concentrate here), with Congestion2, Congestion1, and Safety3 having the lowest performance, thereby representing the greatest priority areas for improvement.

5. Discussion

Using a case study of Tehran, this study aimed to evaluate attributes impacting user satisfaction with metro services during the COVID-19 pandemic. The context of this study is in a developing country with many challenges associated with the pandemic. Elevated concerns with using public transport, given its virus-transmitting potential, resulted in an increase in private vehicle trips and reduced public transport use (Aghabayk et al., 2021). In such conditions, conducting a survey to assess user satisfaction with metro services to help identify priority actions for improvement is considered necessary.

A total of 507 participants who had used the metro service during the pandemic responded to an online survey. The results showed that Safety was the most critical dimension for users, followed by Temperature/Ventilation. It is also noteworthy that despite Congestion falling in quadrant 3 (low priority), the largest gap in performance and importance was found for this dimension. Given that the main cause of transmission of COVID-19 is by air and because the metro service includes ‘closed’ underground trains, air conditioning as well as population control on metro trains and the performance of metro services at
Fig. 3. Service quality model for Tehran metro system. (Correlations between structures are not shown due to image clutter).
peak hours are important for metro users. This issue is observed by the perceived importance of the Congestion and Temperature/Ventilation dimensions in the participants’ responses.

Attributes affecting the service quality have a variety of categories, among which attributes related to cleanliness (Cleanliness1, Cleanliness2) and performance of the metro service during peak hours (Congestion2) are some of the most important attributes affecting service quality. In addition to these attributes, those related to time (Reliability4 and Reliability6) are also considered important by metro users. However, prior to COVID-19, for the Tehran metro, travel time, waiting time, ticket price, and access time to the station were considered to be the most important (Soltanpour et al., 2020). In our study, attributes located in quadrant 4 (concentrate here), which indicate the greatest priority areas for improvement, were Congestion2 (passenger congestion in trains), Congestion1 (availability at peak hours), and Safety3 (safety from possible crime in trains). These results highlight how metro service quality attributes prioritised for improvement have changed in response to the COVID-19 pandemic.

Several factors have become more important when it comes to quality of service, while others have become less critical. As such, it is consistent with health practices designed to combat COVID-19, demonstrating that metro users’ expectations are in line with the knowledge and awareness provided to combat the spread of the virus. Furthermore, because public transportation is recognized as one of the main centres of disease transmission, the question of how long people spend in the metro system has become important since metro users

Table 8
Goodness of fit measures of service quality model.

| Measure                                | Value          |
|----------------------------------------|----------------|
| Minimum Discrepancy per Degree of Freedom (CMIN/DF) | 2.233 (<3)     |
| Comparative Fit Index (CFI)            | 0.935 (greater than0.9) |
| Root Mean Square Error of Approximation (RMSEA) | 0.049 (<0.08) |

Table 9
Confirmatory Factor Analysis (CFA) results.

| Load Factor | Estimate | Std. coeff. | Std. error. | Z-value | p-value |
|-------------|----------|-------------|-------------|---------|---------|
| Operationhour |          |             |             |         |         |
| Operationhour2 | 1.333    | 0.916       | 0.114       | 11.647  | <0.001  |
| Ticket       |          |             |             |         |         |
| Ticket1      | 0.946    | 0.658       | 0.094       | 10.039  | <0.001  |
| Ticket2      | 1.182    | 0.726       | 0.113       | 10.441  | <0.001  |
| Ticket3      | 0.772    | 0.456       | 0.098       | 7.87    | <0.001  |
| Ticket4      | 1        | 0.572       |             |         |         |
| Information  |          |             |             |         |         |
| Information1 | 0.772    | 0.613       | 0.068       | 11.392  | <0.001  |
| Information2 | 0.83      | 0.672       | 0.067       | 12.325  | <0.001  |
| Information3 | 0.936     | 0.687       | 0.075       | 12.473  | <0.001  |
| Information4 | 0.908     | 0.712       | 0.071       | 12.838  | <0.001  |
| Information5 | 1         | 0.659       |             |         |         |
| Reliability  |          |             |             |         |         |
| Reliability1 | 1         | 0.565       |             |         | <0.001  |
| Reliability2 | 0.918    | 0.55        | 0.093       | 9.831   | <0.001  |
| Reliability3 | 1.172     | 0.728       | 0.107       | 10.954  | <0.001  |
| Reliability4 | 1.34      | 0.719       | 0.114       | 11.71   | <0.001  |
| Reliability5 | 1.143     | 0.689       | 0.1         | 11.296  | <0.001  |
| Reliability6 | 0.997     | 0.631       | 0.093       | 10.77   | <0.001  |
| Cleanliness  |          |             |             |         |         |
| Cleanliness1 | 1         | 0.894       |             |         | <0.001  |
| Cleanliness2 | 0.769     | 0.76        | 0.04        | 19.035  | <0.001  |
| Cleanliness3 | 0.873     | 0.841       | 0.04        | 21.56   | <0.001  |
| Cleanliness4 | 0.799     | 0.676       | 0.049       | 16.421  | <0.001  |
| Congestion   |          |             |             |         |         |
| Congestion1 | 1         | 0.531       |             |         | <0.001  |
| Congestion2 | 0.933     | 0.515       | 0.1         | 9.317   | <0.001  |
| Congestion3 | 1.036     | 0.577       | 0.109       | 9.485   | <0.001  |
| Congestion4 | 1.741     | 0.817       | 0.16        | 10.871  | <0.001  |
| Congestion5 | 1.719     | 0.815       | 0.153       | 11.248  | <0.001  |
| Ventilation/Temperature |     |             |             |         |         |
| Temperature1 | 0.936     | 0.805       | 0.053       | 17.818  | <0.001  |
| Ventilation/Temperature2 | 1.049 | 0.843       | 0.052       | 20.126  | <0.001  |
| Ventilation/Temperature3 | 0.908 | 0.802       | 0.04        | 22.507  | <0.001  |
| Safety       |          |             |             |         |         |
| Safety1      | 0.981     | 0.862       | 0.049       | 20.229  | <0.001  |
| Safety2      | 0.787     | 0.731       | 0.048       | 16.302  | <0.001  |
| Safety3      | 1         | 0.849       |             |         |         |

Table 10
Cronbach’s alpha values for importance and performance constructs.

| Dimension          | Performance | Importance |
|--------------------|-------------|------------|
| Operation hour     | 0.795       | 0.566      |
| Ticket             | 0.674       | 0.750      |
| Information        | 0.830       | 0.904      |
| Reliability        | 0.815       | 0.875      |
| Cleanliness        | 0.871       | 0.932      |
| Congestion         | 0.804       | 0.879      |
| Temperature/Ventilation | 0.890   | 0.940      |
| Safety             | 0.831       | 0.929      |

Fig. 4. IPA chart according to the colour scheme.
prefer to spend as little time as possible in the metro system. Accordingly, attributes relating to the temperature in stations and trains, and air conditioning (Temperature1, Temperature2, Ventilation1, and Ventilation2) during the pandemic were also shown to be of priority for users. Cleanliness of stations (Cleanliness2) and in trains (Cleanliness3), speed of trains (Reliability6), and time spent travelling on the metro from origin to destination (Reliability5) were also rated as important attributes by users during the pandemic. The performance of these attributes was also rated as acceptable by users, falling in quadrant 1 (keep up the good work).

Based on the findings, four key policy implications have been identified for enhancing user satisfaction with metro services during the pandemic:

Given that Congestion2 (passenger congestion in trains) and Congestion1 (availability at peak hours) were identified as the greatest
priority areas for improvement, falling in quadrant 4 (concentrate here), it is critical that the performance of the metro during peak hours is improved and that passenger congestion is reduced. This can be achieved through increasing the number of train services and therefore decreasing the headway between services. This will also help to reduce passenger waiting time (Reliability4), an attribute that was also identified as a priority for improvement (quadrant 4: concentrate here). However, it should be noted that there are limitations for policymakers with decreasing headways between services because infrastructure capacity is often close to saturation during peak hours (Coppola and De Fabris, 2021). The presence of Safety3 (safety from possible crime in trains) in quadrant 4 (concentrate here) of the IPA chart is also an important finding, given that the pandemic has elevated rates of unemployment and poverty. Thus, supportive policies for alleviating adverse economic impacts associated with the pandemic should be introduced.

In the shorter term, measures such as increased police presence and greater use of CCTV will help to enhance public safety in stations and on trains. A number of Temperature/Ventilation attributes in quadrant 4 (concentrate here) suggest that greater priority should be given to improving air conditioning and temperature control systems in stations and trains to improve user satisfaction with metro services. This is also relevant to COVID-19, given its mode of transmission by air. Finally, cleanliness inside trains and at stations were also identified as important attributes by metro users. These fell in quadrant 1 (keep up the good work), indicating that performance is also acceptable in this area. Regular disinfection of surfaces has been recognised as a key tool for preventing further transmission of COVID-19, so it is critical that current cleaning regimes within metro trains and stations are maintained.

This study has provided an understanding of attributes that impact user satisfaction with metro services during the COVID-19 pandemic. Future research should seek to understand how user satisfaction with other forms of public transport has been affected during the COVID-19 pandemic and how this may change over the longer term.

6. Conclusion

Public transport has been identified as a key contributor to virus transmission during the COVID-19 pandemic, resulting in increased use of private vehicles and a reduction in public transport use. Dealing with COVID-19 and preparing for a post-COVID era with public transport requires a new user satisfaction assessment during the COVID-19 pandemic.

Through a survey of 507 Tehran Metro users during the COVID-19 pandemic, it was found that there is a shift in the importance of attributes affecting service quality. Attributes associated with time, safety, and ticket have been shifted to attributes associated with cleanliness, congestion, and temperature/ventilation. As a result, a range of policies for dealing with the effects of COVID-19 on metro services is needed. These include: increasing the number of metro services, reducing the time interval between metro services, improving air conditioning, as well as regular cleaning of vehicles. Policymakers can use the results of this study to improve user satisfaction with metro services and increase ridership levels during the pandemic.

In this study, first, to determine the state of Metro service before the outbreak of COVID-19 and compare it to the post-infection conditions regulated by COVID-19, another questionnaire was collected from people who do not currently use the Metro service but used it before the outbreak of COVID-19. Using the collected data and reviewing the results, it was discovered that respondents subconsciously prioritized key attributes very similar to those who answered the questionnaire considering the conditions of the COVID-19 pandemic. Consequently, it has been shown that for respondents, it is no longer possible to simulate the pre-COVID state and then compare their results with those collected during COVID-19 due to the psychological effects of the COVID-19 outbreak.

Furthermore, in this study, it is noted that the evaluation of attributes affecting user satisfaction was done through direct questioning of users. This method was chosen since direct and scale-based approaches are generally more reliable than indirect and coefficient-based methods and have more prediction power (Bacon, 2003). However, direct measurement is mostly associated with social desirability bias. It is therefore suggested that future studies also consider the role of indirect methods for assessing user satisfaction with public transport services. Also, considering that new technologies such as information mobility and flow control technologies have not been used in the Tehran metro, it is suggested for future studies that the effect of these new technologies on the perception of the quality of public transport are investigated. Finally, a key challenge affecting Tehran-based studies is that there is no official data on metro users. Future research is therefore needed to address this issue.

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CRediT authorship contribution statement

Mohammad Aghajanzadeh: Investigation, Methodology, Data curation, Writing – original draft. Kayvan Aghabayk: Conceptualization, Investigation, Methodology, Writing – review & editing, Supervision. Javad Esmailepour: Data curation, Writing – original draft, Investigation. Chris De Gruyter: Investigation, Writing – review & editing.

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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