Prioritizing Metro Service Quality Attributes to Enhance Commuter Experience- TOPSIS Ranking and Importance Satisfaction Analysis methods

ABSTRACT

A metro infrastructure, facility and service quality investigation based on commuter perception was conducted in this study to explore and prioritize the key attributes influencing overall metro service quality in typical Indian context. Based on the critical state of the art review, 12 key attributes were identified and they were accommodated in a paper based questionnaire to elicit commuter perception of importance and satisfaction by using a five point Likert scale. Subsequently, TOPSIS, an extensively adopted Multi attribute decision making technique, was carried out to rank the attributes with respect to perceived importance and satisfaction. Then an importance satisfaction analysis (ISA) was conducted to further classify the attributes in four quadrants based on their perceived degree of importance and satisfaction using an ISA matrix. Finally, the derived results from the TOPSIS and ISA analysis were combined and compared to obtain a prioritized set of attributes requiring intervention for better metro service quality in Indian context. Results of this study clearly indicated the relative strengths and weaknesses of each metro service/infrastructure specific attribute and presented the probable role of metro authorities for each of them. Attributes such as, *Metro fare*, *Connection to metro* and *Metro frequency* were observed to be the most important but were not performing satisfactorily, indicating that more emphasis is required on these attributes for improving the overall quality of travel by metro rail in Indian context. Hence, this methodology would be instrumental to detect a set of priority areas of improvement in metro rail service, which could contribute to retain the existing commuters and attract new metro users.

Keywords: Metro rail; Service quality; Importance and Satisfaction; TOPSIS, ISA, Prioritization

BACKGROUND

Rapid urbanization has generated a fast growth in travel demand in Indian cities, but without adequate infrastructure, transport, and other public services (*1*) a significant imbalance between demand and supply is created in the transport sector. In order to address this demand supply imbalance in transportation sector, development of an efficient public transit system as a demand management instrument is necessary (*2*). In this regard, several initiatives have been taken in to consideration by the Government of India to improve the urban public transportation system. Recent policies initiated by the Government of India have clearly encouraged greater use of public transport in urban contexts. Although buses are the most popular means of transport in both rural and urban area, metro rail with a fixed guideway system, which allows for a higher density of passenger transport in the same amount of space has emerged as an effective public transportation alternative in India. Currently 12 Indian cities have fully functional metro railway systems. However, a successful metro rail system does not only depend on the extent of the metro network, location of stations, frequency of service, fare systems but also on the quality of metro infrastructures, facilities and services especially from the viewpoint of the users. Henceforth, public transport agencies should identify the areas for improvements related to service quality attributes for enhancing existing passenger's experience and also attract potential customers as public transport passenger's level of satisfaction substantially impacts their mode choice decisions (*3*).

Satisfaction derived from using a particular mode or product is the key motivator behind choosing a mode or repurchasing the same product again *(4)*. As a result, an evaluation of service quality requirements (*5*) from the user's perspective is necessary for metro authorities to identify and prioritize the attributes requiring further attention, which would be further instrumental in fulfilling customer expectations by improving service quality (*6*). Eboli and Mazzulla (*7*) in their study on evaluating transit service quality found that customers who have a better experience with transit may use transit services again, but users experiencing problems with service or infrastructure attributes may not use the transit services in Cosenza, Italy. Hence, improving service quality is important for retaining the existing travelers and for attracting new users. Therefore, an understanding of passenger satisfaction towards public transport service and infrastructure specific attributes is very important in Indian context as an improved public transport option would be instrumental in retaining the existing metro users and attracting potential commuters. This will not only increase the revenue but also would reduce the pollution levels attributed by personal motorized vehicles in India, where 13 out of 20 most polluted cities in the world situated. Even though this is seen as a real problem that needs some urgent attention, only a very few research studies have been made to understand the importance of various metro rail service and infrastructure related attributes from the commuters' perspective in urban India. This study attempts to address this gap by examining both importance and satisfaction of a set of metro-rail related service, facility and infrastructure attributes from commuters' perspective. In emerging countries such as India, where the financial resources are limited, it is necessary to prioritize the attributes as per their importance. Hyderabad, an Indian metropolitan city, which has recently introduced metro rail, has been selected as the case study location.

The paper begins with a brief review of existing literature and scope of the study. This section is followed by the methodology, data collection process. Subsequently, the relevant analysis is conducted and finally the results are discussed and concluding remarks are presented.

LITERATURE REVIEW AND SCOPE OF THE STUDY

This section presents a brief review of existing research related to the evaluation of passenger importance and satisfaction towards metro rail service quality attributes in both international and Indian contexts and subsequently, the research gaps for this study are identified. Among the notable existing passenger quality-analysis studies, Doi et al. (*8*) conducted a research on Metro service in Manila, Philippines and identified the most significant attribute of customers' dissatisfaction in Metro-rail to be congestion at stations, expensive fares, lack of proper connections and feeder-modes. In another study, Schmöcker et al. (*9*) identified the strategies used by operators in order to investigate the attributes that are crucial for providing high level of metro rail service. They proposed to put more emphasis on travel reliability as metro passengers value that aspect. In this study, Schmöcker et al. analysed and compared the

performances and service qualities of six metros including three European, two American, and one Asian city (*9*). Cavana et al. (10) developed zones of tolerance for evaluating passenger rail service quality and identified that reliability and convenience as the key service attributes based on SERVQUAL analysis, a service quality measuring instrument for Wellington, New Zealand. While investigating passengers' satisfaction with rail travel, a study found out that the quality of the station and the access/egress facilities had significant influence on the general perception of rail travel in Netherlands (*11*). In another study, Nathanail (*12*) measured the quality of service for passengers on the Hellenic railways in Greece and found that itinerary accuracy and system safety were the most significant attributes influencing rail travel quality of commuters. In their study, Lai and Chen (*13*) identified that vehicle safety, facility cleanliness, and complaint handing have significant influences on public transport passenger behavioral intentions in Kaohsiung, Taiwan. Awasthi et al. (*14*) demonstrated a hybrid approach for evaluating transportation service quality in metro service of Montreal. The strength of their approach lies in its' ability to perform assessment of quality of service of transportation systems when limited information is available. Celik et al. (*15*) evaluated customer satisfaction level for the rail transit network of Istanbul, Turkey and observed crowdedness and density in the train, air-conditioning system, noise level and vibration, and phone services as the key attributes requiring improvements. Putra et al. (*16*) investigated the performance of public transport services with respect to the satisfaction of public transport users, and observed flexibility, reliability and comfort to be key attributes for improvement in Indonesia. Upon analyzing transit service quality based on cluster analysis, frequency and punctuality was found to be the most important attributes, whereas accessibility was identified as a variable having limited relevance for users in Granada, Spain (*5*). Bajcetic et al. (*17*) used Quality Function Deployment (QFD) method to identify urban public transport users' needs and related to public-transport in Belgrade and concluded that service reliability, frequency and vehicle elements need to be considered carefully for improving the quality of public-transport travel. Saw (*18*) studied passenger satisfaction towards metro infrastructures, facilities and services in Tyne and Wear Metro, UK, and found ticket cost, general cleanliness of station, condition of station and cleanliness inside the train to have performed inadequately from user perspective. Overall, a set of performance indicators for service quality assessment were provided by Third edition of Transit Capacity and Quality of Service Manual (*19*).

Among Indian studies, Vanniarajan and Stephen (*20*) concluded that the three most important dimensions of railway quality are reliability, assurance and empathy. Gupta and Datta (*21*) found that waiting time, security and travel-related facilities to be the three most underperforming attributes at railway-travel. In another interesting study, Sadhukhan et.al. (*22*) investigated various transfer facility attributes in and around metro station in Kolkata, India and observed that pedestrian environment and visual communication were perceived more important than metro fare. In another similar study, Gupta and Datta (*23*) concluded that adequacy, visibility of the system, and time of travel are the main attributes to be improved, followed by functional amenities, adequate station furniture and sanitation for better rail travel quality in India. The study by Saygaonkar (*24*) investigated the level of passenger satisfaction with respect to the station area design in India. They focused on commuters, and found out inter-modal connectivity and unreliability were key limitations of public-transport use in India.

For a better understanding of the discussed researches, a tabular summary of the reviewed studies is presented in Table 1. Based on a brief review of existing literature related to studies on commuter satisfaction towards various public-transit modes, the following observations were identified:

- Firstly, it is observed that significant research has been conducted in the developed countries focusing on improving transit capacity and service quality, whereas only a limited number of studies have been conducted in India focusing on the influences of commuter satisfaction on metro specific attributes. *This means that there is no general consensus on what attributes to improve in a typical Indian metro system.*
- Secondly, the majority of the previous research have only investigated attributes that were related to commuter's satisfaction; a lack of studies was observed, where both importance and satisfaction associated with an attribute is evaluated simultaneously. *In a country such as India, where budget is a constraint, evaluating attributes in terms of importance and satisfaction is necessary for taking more informed decisions*.

In order to address these research-gaps and augment the research literature on the subject of improving passenger demand to public transport services with particular attention to metro rail service, a methodology was designed in this study to identify the key attributes related to the service and infrastructure facilities, and prioritize them based on commuters' importance and satisfaction associated with them.

Identification and prioritization of key attributes influencing metro service quality is essential for formulation of appropriate policies aimed at improving overall metro-service quality. For prioritization of attributes, several Multi attribute decision making (MADM) approaches have been adopted in the existing literature. Among them, Analytical Hierarchy Process (AHP) was extensively used by researchers (*25; 26*). Cheng and Li (*25*) suggested that the AHP method may not be practical for surveys using large samples as 'cold-called' respondents may have a greater tendency to provide arbitrary responses that may high degrees of inconsistency. Moreover, the AHP also suffers from the problem of rank reversal (*27*). Since the primary objective of this study was to analyze user perception on metro-services, techniques that can handle large volume of rating data should be used. Among the available techniques such as TOPSIS, RIDIT, GRA, ELECTRE, VIKOR; TOPSIS has been selected for prioritization analysis in this study. The technique for order preference by similarity to ideal solution (TOPSIS) is one of the extensively adopted MADM techniques (*28*). Among other methods, TOPSIS provides the best alternative to be nearest to the positive ideal solution and farthest from the negative ideal solution (*22*). Based on TOPSIS, the attributes could be ranked based on their relative importance or satisfaction, but the results cannot be combined. However, for better policy level decision making based on user perception, both importance and satisfaction should be analyzed simultaneously, such that attributes which are important from user perspective but are performing poorly could be identified and necessary intervention measures could be planned. In this regard, Importance-Satisfaction-Analysis (ISA) is adopted in this study. Importance-Satisfaction Analysis (ISA) has been extensively adopted in the past in hospitality and tourism research. Tonge and Moore (*29*) proposed ISA instead of Importance-Performance analysis (IPA), as analysis on satisfaction rather than performance would enable commuters' general perception towards metro-service specific attributes to be more precisely captured and analyzed. The ISA is basically considered as the IPA as defined by Martilla and James (*30*), where "performance" was replaced by "satisfaction" (*29*). The means of importance and satisfaction for each attribute provides the coordinates for placement in a two-dimensional matrix. Hence, this study aims at evaluating the metro-infrastructure attributes from user perceived degree of importance and satisfaction using both TOPSIS and ISA, respectively. Finally, the results from both techniques were compared when selecting the final set of attributes that can be used for decision makings. The following section presents the brief methodology adopted in this study.

METHODOLOGY

In this section, a methodology adopted for this study is briefly demonstrated considering five steps.

Step-1: Identification of metro rail service and infrastructure attributes: In this step, based on the brief literature review, an exhaustive set of metro rail service and infrastructure specific attributes were identified. These attributes were further evaluated based on commuters' perceived importance and satisfaction associated with them.

Step-2: Data collection: In the second step, a paper based questionnaire was developed to elicit user perceived importance and satisfaction associated with the set of identified attributes in a typical Likert scale format. Subsequently, responses were collected from users and a database was developed.

Step-3: Prioritization of attributes: In this step, TOPSIS, was used to prioritize the attributes with respect to perceived importance and satisfaction. The derived rankings would be instrumental to develop specific policy measures for improving the service quality of the particular attribute.

Step-4: Importance Satisfaction analysis (ISA): Subsequently, an ISA was conducted to classify the attributes in four clusters based on their perceived degree of importance and satisfaction. This clustering would enable planners to identify a set of attributes to focus on further improvement in service quality.

Step-5: Comparison of Prioritization and ISA methods: In the final step of the methodology, the results obtained from step-3 and step-4 were compared to achieve the final selection of attributes requiring intervention for better metro service quality in Indian context.

IDENTIFICATION OF METRO-RAIL SERVICE AND INFRASTRUCTURE ATTRIBUTES

In this section, based on literature-review, a set of metro-rail-service specific attributes were identified for evaluation (Table 1 presents the list of attributes). Subsequently, a typical Likert scale was used to elicit commuter perception towards these attributes. The following section presents the data collection procedure in brief.

DATA COLLECTION

For data collection, Khan *(32)* described a set of different physical forms of survey instrument, namely CAPI (Computer Assisted Personal Interview), PAPI (Pen and Pencil Interview), Postal Survey, Internet Survey etc. Among them PAPI/ Face to face interview is an orthodox manual method and may induce bias or error in the survey response, but is the only method, where complex hypothetical scenarios could be explained to the respondents by the surveyors. PAPI generally results into a relatively higher response rate and is associated with very little cost component, making it a plausible form of survey instrument. In this study, respondents were approached while they were travelling on a metro train completing a trip. Initially, respondents were approached and were asked about their willingness to participate in the survey. For the interested respondents, face to face interviews were conducted. For conducting such surveys, a team of experienced survey enumerators and researchers were deployed on Hyderabad metro rail. A questionnaire consisting of three parts (Parts A, B, and C) was designed.

1. Part-A was to make respondents familiar about the mentioned attributes and their definitions.
2. Part-B was used to collect respondent's current-trip and socioeconomic-characteristics.
3. Part-C was designed to collect respondent's perceived importance and satisfaction associated with each attribute against five-point importance and five-point satisfaction scale (Table 2).

Respondents were asked to provide their perceived degree of importance and satisfaction associated with each attribute in the provided format (Table 2). All surveys were on-board surveys; however, if an interview remained incomplete due to the respondent alighting from the train, the interview was then completed in the respective metro stations. Among all the collected responses, 90% of them were conducted completely on-board and the rest 10% were conducted as a combination of on-board as well as on-station survey. A simple random sampling technique was adopted for the data collection procedure. In this study, a total of 500 responses were collected, among them responses of several respondents were excluded due to incomplete questionnaires. Finally, 414 responses were used for TOPSIS based prioritization and ISA. Table 2 presents the list of attributes along with the percentage of respondents with respective degree of importance and satisfaction scale. Subsequently, the consistency of collected data was checked and a high significant Cronbach's alpha could be estimated, which indicates a high level of internal consistency for our scale with this specific sample.

Based on preliminary observation from Table 2, a basic understanding of the attributes could be achieved. For example, almost 61% commuters perceived that *Metro fare* was very important to them. None of the users perceived that the *Metro fare* as either "not so important" or "not at all important" indicating that "*Metro fare*" is a very important attribute. On the other hand, only 5% users were observed to perceive that it is a very satisfactory attribute for them. Similarly, all other attributes could also be interpreted. Thus, a preliminary analysis of the attributes can be useful to provide initial observations on strength and weakness associated with each attribute.

Descriptive statistics of the data are provided in Table 3 with respect to gender, age and trip frequency. In this paper, the population under study includes metro users in Hyderabad. However, Census in India or any other secondary sources do not provide any information on socio-demographic profile of metro-users. Hence, based on the collected data, some inferences on the socio-demographic profile of the metro-users are drawn. Initial observation on the descriptive summary of the respondents clearly indicates a significantly higher number of male and young respondents compared to female and relatively elder commuters. Initially while collecting data, almost 750 respondents were approached for the survey, among which 500 agreed to respond to the survey. Among the non-responsive samples, a significant number were either female or elder commuter (age more than 25 years), who were relatively less interested in being interviewed by the study team. As a result, the samples were found to be relatively skewed with male and younger commuters. However, the final sample size of the study (414) is found to be more than the minimum sample size (385) required for adequately representing an infinite or unknown population. In this study, by assuming a 95% confidence level, the minimum sample sized required is estimated as 385 *(33)*. Furthermore, for a better understanding of the influence of socio-demographic parameters on user perception and satisfaction, separate analyses are conducted for a total of six user sub-groups, namely, (1) male, (2) female, (3) Users with age up to 25, (4) Users with age more than 25 years, (5) Frequent users and (6) Infrequent users and subsequently, the results are compared for better inference.

The following section presents the prioritization of the attributes based on TOPSIS, an extensively adopted MCDM technique.

PRIORITIZATION OF ATTRIBUTES USING TOPSIS

In this section, a brief background of TOPSIS is presented. The TOPSIS method presented in this study consists of the following steps (*22*):

Step 1: Formulate a decision matrix (d) for the ranking. The matrix structure is as follows:

$$d = \begin{array}{c|cccccc} & B_1 & B_2 & \dots & B_j & \dots & B_n \\ A_1 & f_{11} & f_{12} & \dots & f_{1j} & \dots & f_{1n} \\ A_2 & f_{21} & f_{22} & \dots & f_{2j} & \dots & f_{2n} \\ : & : & : & \dots & : & \dots & : \\ : & : & : & \dots & : & \dots & : \\ A_i & f_{i1} & f_{i2} & \dots & fi_j & \dots & f_{in} \\ : & : & : & \dots & : & \dots & : \\ A_j & f_{j1} & f_{j2} & \dots & fi_j & \dots & f_{jn} \end{array}$$

where A_j represents the alternatives j=1,2,….J; B_i represents i^{th} attribute or criterion, i= 1, 2, ….,n; and f_{ij} is a likert-scale score indicating the performance rating of each alternative A_i with respect to each criterion B_j.

Step 2: Estimate the normalized decision matrix R (=[r_{ij}]) as the following:

$$r_{ij} = \frac{f_{ij}}{\sqrt{\sum_{j=1}^{J} f_{ij}^2}} \quad \text{where, j=1,2,….J and i= 1, 2, ….,n}$$

Step-3: Estimate the weighted-normalized decision-matrix by multiplying the normalized decision matrix (r_{ij}) by its associated weights (w_{ij}). The weighted normalized value xij is calculated as:

$$x_{ij} = r_{ij} * w_{ij}$$

Step 4: Determine the positive ideal solution (S+) and negative ideal solutions (S−)

$$S^+ = \{x_1^+, x_2^+, x_3^+, \dots\dots, x_n^+\}, maximum\ values$$

$$S^- = \{x_1^-, x_2^-, x_3^-, \dots\dots, x_n^-\}, minimum\ values$$

Step 5: Estimate the separation measures, based-on the n-dimensional Euclidean-distance. Calculate the separation of each alternative from the positive ideal solution and negative ideal solution as following:

$$d_j^+ = \sqrt{\sum_{i=1}^{n}(x_{ij} - x_i^+)} \quad ^2, \text{ j=1,2,3,…..J}$$

$$d_j^- = \sqrt{\sum_{i=1}^{n}(x_{ij} - x_i^-)} \quad ^2, \text{ j=1,2,3,…..J}$$

Step 6: Estimate the relative-closeness to the idea solution and rank the performance order. The relative closeness of the alternative A_j can be expressed as:

$$C_j^* = \frac{d_j^-}{d_j^- + d_j^+}$$

The closeness index value lies between 0 and 1, higher the value, higher it is prioritized (*22*). In the subsequent sub-section, the TOPSIS analysis is conducted for user perceived rankings of attributes based on degree of importance and degree of satisfaction.

In TOPSIS analysis, twelve attributes were considered as alternatives and fit across in the TOPSIS model the respective degree of importance and satisfaction (i.e., 1, 2, 3, 4, and 5) were assumed to be selection criteria of preference to an attribute (*22*). All five levels were weighted equally to represent equal probability of choosing. TOPSIS analysis was conducted by maximizing the value levels 3, 4, 5, considering them as positive, whereas minimizing the importance/satisfaction levels 1 and 2 by making them negative in a positive ideal solution. Similarly, the negative ideal solution was conducted with minimization of importance levels 3, 4, 5, considering them as negative, and maximization of importance levels 1 and 2 by making them positive. Subsequently, TOPSIS scores (C_j^*) were estimated against each of the twelve attributes considering positive ideal solutions and negative ideal solutions for both importance and satisfaction data. All C_j^* values obtained from the TOPSIS analysis are summarized in Table 4.

Based on TOPSIS analysis, user perception towards the metro facility attributes in terms of importance and satisfaction could be clearly observed. With respect to satisfaction based prioritization, users were observed to be satisfied with *Facility for buying tickets* (C_j^*=0.688) *Cleanliness of station* (C_j^*=0.652), and *Cleanliness inside train* (C_j^*=0.630) as they are ranked first, second and third respectively. On the other hand, *Metro fare* (C_j^*=0.460), *Amount of standing room inside train* (C_j^*=0.455), *Availability of seats and its condition* (C_j^*=0.317) were observed to be associated with significantly lower degree of satisfaction, indicating further improvement for better quality of service of these attributes. Results derived from importance based prioritization also clearly indicates that which of the attributes are considered very important by the users and which of them are considered as relatively less important. TOPSIS result indicates *Connectivity of the metro* (C_j^*=0.667), *Metro fare* (C_j^*=0.664), *Cleanliness of station* (C_j^*=0.659) are top-most important attributes for better quality of metro travel. On the other hand, attributes such as, *Availability of seats and its condition* (C_j^*=0.338), *Information on ticket machine* (C_j^*=0.471) and *Facility for buying tickets* (C_j^*=0.489) were observed as least important attributes from user perception. In this section, the TOPSIS analysis is conducted for the total sample, in the following section, separate TOPSIS analysis is conducted for six different subgroups and the ranks of all groups are reported in Table 5.

Based on the rankings reported in Table 5, it could be clearly observed that the derived rankings across different groups do not vary significantly with respect to either satisfaction or importance based TOPSIS analysis. In general, attributes such as *facility for buying tickets* or *cleanliness inside trains* were observed to be satisfactory for all group users with minor variations in ranking. All groups of users were observed to be least satisfied with attributes such as *Fare* or *Condition of the lift, elevators and other amenities in station or Availability of seats and its condition*, indicating user's common concern. However, some interesting observations could be seen for some of the attributes. For example, frequent trip makers were observed to be significantly dissatisfied with the attribute *Security* compared to other groups, this could be attributed to their relative more exposure to the security arrangements compared to other users. Similarly, elder users were found to be most satisfied by the *Cleanliness inside train*. Hence, for most of the attributes, no significant difference could be observed among rankings derived from total dataset and

six subsets. Thus, a clear understanding of user perception towards these attributes could be obtained through TOPSIS analysis; however, a simultaneous application of both degrees of importance and satisfaction is required for better policy implications and focused intervention from authorities. In order to address this issue, the collected degree of importance and satisfaction associated with all attributes were further analyzed based on the ISA in the following section.

IMPORTANCE SATISFACTION ANALYSIS (ISA)

Using the data collected via the questionnaire survey, the ISA was conducted to cluster the attributes into four quadrants based on their associated importance and degree of satisfaction as perceived by the metro commuters in the ISA, the input data, both degree of satisfaction and degree of importance of each attribute, was collected based on the dataset with 414 samples. Subsequently, the values are normalized to a single measuring scale. Equations (1) and (2) provide the initial degree of satisfaction (IDS_K) and standardized satisfaction value (SS_K) for attribute K:

$$IDS_k = \frac{Sum\ DS_K}{N} \quad (1)$$

$$SS_K = \frac{IDS_K - Average\ IDS\ in\ all\ Attributes}{Standard\ Deviation\ of\ IDS\ in\ all\ attributes} \quad (2)$$

Where, N is the number of respondents; and $SumDS_K$ is the sum of degrees of satisfaction from all respondents for attribute K *(31)*. Equations (3) and (4) provide the initial degree of importance (IDI_K) and standardized importance value (SI_K) for Attribute K:

$$IDI_K = \frac{Sum\ DI_K}{N} \quad (3)$$

$$SI_K = \frac{IDI_K - Average\ IDI\ in\ all\ attributes}{Standard\ Deviation\ of\ IDI\ in\ all\ attributes} \quad (4)$$

Where, N is the number of respondents; and $SumDI_K$ is the sum of degrees of importance from all respondents for attribute K *(31)*. The (SS_K, SI_K) value for all attributes can be classified into four categories by plotting them in a two-dimensional matrix *(34)* such as

- (SS_K Positive and SI_K Positive): Attribute K with high satisfaction and high importance
- (SS_K Positive and SI_K Negative): Attribute K with high satisfaction and low importance
- (SS_K Negative and SI_K Positive): Attribute K with low satisfaction and high importance
- (SS_K Positive and SI_K Negative): Attribute K with low satisfaction and low importance

Based on the degree of satisfaction and importance with each attribute, specific improvement-measures could be adopted with special emphasis on fourth type of attributes. Table 6 presents the SumDS, IDS, SS, SumDI, IDI and SI for each attribute.

Based on the respective SS and SI values (Table 4), a two dimensional matrix is plotted (Figure-1) with SI along x and SS along y-axis and interpreted.

Based on the importance satisfaction matrix, the attributes could be clearly clustered into four quadrants/segments. The attributes belonging to first quadrant (SS Positive and SI Positive) are very important as well as satisfactory as per commuter perception. The attributes such as *Cleanliness of stations* and *Cleanliness inside train*, *Security and Frequency* were observed to belong to the **first quadrant**, indicating that metro commuters are satisfied with them and it is required to keep up the good work by maintaining the services related to those attributes.

The most important attributes belong to **the second quadrant**, (SS Negative and SI Positive), which although being important, require immediate attention from the concerned authorities due to low degree of commuter satisfaction associated with them. Attributes such as, *Connectivity or feeder system*, *Condition of the lift, Elevators and other amenities inside station* and *Fares* are not found satisfactory by the users and require improvement for improved quality of metro travel.

The attributes, which belong to third quadrant (SS Positive and SI *Negative*) are not very important but are satisfactory as per commuter's perception. Attributes such as *Facility for buying tickets, Amount of standing room at stations* and *Information on ticket machine* fall into **this third quadrant**. These attributes do not need further improvement, probably they have been taken more care compared to requirement, possible a case of overkill could be observed for them. However, in this regard, it should be mentioned that these attributes need to be taken necessary care such that they could be maintained in adequate satisfactory level for a comfortable level of service, without necessary measures, these attributes may become critical deterrents towards using metro and might eventually go to quadrant 2 of the ISA matrix.

The attributes belonging to **the fourth quadrant** are the fourth quadrant are neither important nor satisfactory; hence emphasis could be given on these attributes (*Amount of standing room inside train, Availability of seats and its condition*), but with a lower priority than attributes belonging to second quadrant.

In this section, the ISA is conducted for the total sample, in the following section, separate ISA is carried out for six different subgroups and the respective SS and SI of all groups are reported in Table 7. Based on the reported findings, a number of observations can be made. Firstly, although the respective SS and SI scores associated with different attributes vary across user groups; their relative position in a particular quadrant remains for the most part the same across different sub-groups compared to the total sample. Secondly, based on the comparison of relative location of the attributes on the ISA matrix, it could be inferred that attributes such as *Connectivity to metro, Fare and Condition of the lift, elevators and other amenities in station* are consistently perceived as attributes with low satisfaction and high importance, indicating common concern for users irrespective of socio-demographic characteristics. Hence, based on the results, it could be inferred that socio-demographic characteristics do not play a significant role in user perception. Thus ISA is here successfully applied to cluster the set of attributes based on their priority. The following section presents a combination and comparison of the prioritization and ISA findings for better policy implications.

COMPARISON OF TOPSIS AND ISA METHODS

In this section, the results of both TOPSIS and ISA derived for the complete dataset are compared and the derived results are combined for selection of final set of attributes on the basis of prioritization and ISA. Table 5 presents the combined results of both TOPSIS and ISA for further comparison.

Results clearly indicate the relative strength and weakness of each metro service/infrastructure specific attribute and present the probable role of metro authorities for each of them. For example, the attribute *Cleanliness of station* is found to be the third most important attribute, as well as the second most satisfying attribute from user perception. Furthermore, the attribute was observed to belong to the first quadrant of ISA-matrix, indicating continued emphasis on *Cleanliness of station* will improve the travel quality of metro commuters. On the other hand, *Metro frequency*, which also belonged to the same quadrant of ISA matrix, was observed to be ranked seventh based on satisfaction rating, indicating prioritized intervention measures needs to be taken place for this particular attribute for improved quality of satisfaction for the commuters Similarly, it could be observed that the attribute *Cleanliness inside train* was observed to be attribute performing moderately satisfactorily as per user perception (satisfaction rank-3), however was not perceived as important (importance rank-6) by the commuters. This observation directs metro authorities to provide relatively lower emphasis on this attribute belonging to quadrant-1. *Security*, the last attribute belonging to quadrant 1 is found to be quite important (importance rank-4), but performing rather poorly (satisfaction rank-5), indicating that arrangement of improved security through more number of CCTV cameras, increased number of enforcement-personnel would actually satisfy the user needs.

Hence, among all attributes belonging to quadrant-1, *Frequency*, followed by *Security*, *Cleanliness of station* and *Cleanliness within train* should be improved upon by the metro-authority.

The most important group of attributes requiring immediate and prioritized importance belong to quadrant-2 of the ISA-matrix. *Fare*, *Condition of the lift, elevators and other amenities in station* and *Connectivity of the metro* were observed to be the key attributes, which were perceived with high importance and lower satisfaction. Among these *Connectivity of the metro* was perceived as the most important attribute related to metro service/infrastructure, however the existing status of the feeder mode system was observed to be not performing up to the satisfaction level of commuters. In general, the feeder modes or access or egress modes of Hyderabad metro needs to be significantly upgraded for increased modal share of metro users. The TOPSIS results also indicated *fare* to be one of the unsatisfactory attributes as perceived by the commuters. This finding indicates that in depth investigation needs to be carried out to examine the existing fare-level and revise them, if necessary; otherwise it may deter commuters towards using metro in near-future. *Condition of the lift, elevators and other amenities in station* is also perceived with relatively lower degree of satisfaction, requiring further attention from metro authorities. An interesting finding could be seen in this particular quadrant of attributes, that fare is been grouped with all other attributes such as station amenities and connectivity, improvement of which require higher revenue to be generated. In this regard, it is necessary to mention that generation of higher revenue does not only mean increasing fare to the passengers, which may deter them to use metro as their main mode of transport, rather such findings should encourage the transport agencies to identify the possible sources of non-fare-box revenue such as advertisements at metro rail , rental shops at the metro-stations such that the extra revenue could be generated and could be used for improvement of all key attributes in general, attributes belonging to quadrant-2 in particular.

Information on ticket machine, *Facility for buying tickets* and *Amount of standing room at the station* belong to third quadrant of attributes, which are perceived as less important but are performing satisfactorily. Among these attributes, *Facility for buying ticket* was observed to be perceived as less important (importance rank-10) but is performing exceedingly well (satisfaction rank-1); hence it can be inferred that facility for buying ticket at Hyderabad metro does not require further improvement at present. Similarly, *Information on ticket machine* was observed to be less important but well-performing. On the other hand, *Amount of standing room at the station*, was perceived to be less important as well as poorly performing, indicating that metro-authorities may plan for more amount of space for passengers waiting inside-station.

Amount of standing room inside train and *Availability of seats and its condition* are the two attributes which belong to quadrant-4 of ISA matrix and were also observed to be ranked significantly lower in terms of both user-perceived importance (ranked 10^{th} and 12^{th} respectively) and satisfaction (both attributes ranked 12^{th}). Hence, it could be observed that these attributes need further improvement, but are not priority compared to other attributes.

Thus, a comparison and combination of TOPSIS and ISA results provide planners with a clear understanding on various facility/infrastructure related attributes specific to metro rail in Indian context. These findings could be instrumental for long term planning of metro rail system in the context of cities with metro rail.

CONCLUSIONS

In this study, a detailed investigation was carried out to identify and prioritize the attributes influencing metro rail service, facility and infrastructure based on user-perception. TOPSIS, an extensively adopted MADM technique, was used to prioritize the attributes with respect to degree of importance and satisfaction associated. Subsequently, ISA was used to classify the attributes into four groups and then both results were combined and compared for better understanding and policy level implications. Based on the research results and observations, the following concluding remarks can be made:

Firstly, it can be concluded that attributes such as *Metro fare*, *Connection to metro* and *Metro-frequency* are the most important attributes but are not performing well as perceived by commuters. Metro authority should prioritize and provide more emphasis on these attributes for improving the overall quality

of travel by metro rail in Indian context. A rational fare increment strategy, better feeder systems and reduced headway could be key strategies for addressing the aforementioned concern and subsequently increasing user satisfaction associated with these attributes.

Secondly, it can be inferred that socio-demographic characteristics such as Gender, Age and Trip-frequency do not have a significant influence on user perception towards metro rail service quality attributes. Minor differences in ranking could be observed for a few attributes, but in general, results were observed to be consistent across six socio-demographic sub-groups in terms of perceived importance and satisfaction associated with the key attributes influencing metro service quality.

Thirdly, it can also be observed that the results derived from the TOPSIS and the ISA, two methods with different theoretical basis conform to similar results in terms of user perception towards the identified attributes. The TOPSIS provides a user-perception based ranking of the attributes, whereas the ISA helps to classify the attributes into four clusters based on their associated degree of importance and satisfaction. Simultaneous uses of results derived from both these methods were helpful for a micro-level analysis of an attribute. Based on the expected results and observations, simultaneous use of both these methods could be recommended to researchers interested in exploring user satisfaction towards key attributes pertaining to a specific product.

Fourthly, the results could be important tools for informed decision making with respect to long-term development of metro infrastructure. Due to budgetary constraints, agencies often need to prioritize their needs based on the level of improvement required in a particular sector and allocate the budget accordingly. The study results could be adopted by a particular metro rail agency to prioritize the attributes for improvement and allocate budget accordingly. Such planning decisions would help in developing cost-efficient infrastructure improvement strategies by improving the quality of travel by metro rail not only in India, but across the world.

Finally, the authors would like to state that importance or satisfaction levels associated to a particular attribute might vary due to differences across respondents. Hence, the results obtained for Hyderabad Metro may not be representative for all other cities across the globe. Therefore, authors would like to extend this existing research across different cities across India and other countries and would also like to compare the attitudes and perceptions of respondents at metro stations and on-board surveys separately for a better and informed decision making; nonetheless the methodology developed could be used with findings serving as basis for comparison across other cities with similar size and characteristics. Furthermore, the methodology and the survey instrument are generic, which could even be used in cities of other developed and developing countries planning for improving metro infrastructure. It is especially true for cities trying to focus on metro as one of the primary mode of transportation to improve the overall air quality and livability.