Exploring Improvement Priorities For Urban Bus Service: A Network And Routes Perspectives

Karim Zehmed, Fouad Jawab

Abstract: The purpose of this paper is to develop a three-stage methodology approach that assesses the quality of bus service from the user’s point of view and identifies service attributes and routes that should be prioritized for improvement actions. The first stage consists of an evaluation of the satisfaction and importance levels of various service attributes using linguistic terms. This stage incorporates the features of the Fuzzy Set Theory so as to handle the possible uncertainty and vagueness of the user’s point of view in the evaluating process. The second stage involves detecting the service attributes that should primarily be acted on using an Importance-Performance analysis (IPA). In the third stage, data envelopment analysis (DEA) was conducted to identify routes in which the urgent intervention is needed. The bus transport service in Fez city (Morocco) was the empirical context of the proposed methodology. The results showed that five service aspects over 15 bus routes need to be prioritized for improvement actions.

Index Terms: M Public bus transport, service quality, Satisfaction, Fuzzy Set Theory (FST), Importance-Performance Analysis (IPA), Data Envelopment Analysis (DEA).

1 INTRODUCTION

Various methodologies have been developed in the last decades to analyze the service quality of urban public transport from the passenger’s point of view. These methods belong to two distinct methodological approaches namely aggregated analysis and disaggregated analysis [1]. In an aggregated analysis, an index of the overall quality or overall satisfaction is measured to analyze service over time or to compare different services. On the contrary, the disaggregated analysis consists of analyzing the service attributes individually in order to help managers to set priorities for service improvement and allow them to choose from a long list of attributes to determine where to best invest their time and resources available to their organization [2]. The most commonly used disaggregate analysis method for evaluating quality urban public transport is the importance-performance analysis (IPA) in which performance has quite often been substituted by quality perception or satisfaction concepts [2]. Based on the customer satisfaction surveys, several authors have applied IPA to analyze service quality and identify improvement priorities for urban public transport service in different geographical context such as the United States (e.g. [3], [4], [5], [6], [7]), United of Kingdom (e.g. [8]), Korea and Taiwan (e.g. [9]), Serbia (e.g. [10]), China (e.g. [11]) and Algeria (e.g. [12]). In the above studies, two major approaches have been used to estimate the relative importance of service attributes. The first is called the “stated importance” which consists of, simply, asking users to express explicitly their perception of the importance of each attribute (e.g. [3], [4], [6], [10]). The second is called the “derived importance” which consists in statistical evaluation of the strength of the relationship of individual attributes with overall satisfaction, using different statistical techniques such as bi-variate correlation (e.g.[5], [7]), structural equation modelling (e.g., [9]) and regression analysis (e.g. [11]). Recently, some authors have adopted innovative approaches such as combining the stated and derived importance (e.g. [11]) or new methods such as Classification and Regression Trees (CART) (e.g. [12]).

Further, all previous studies identified service attributes that need improvement priorities for the whole transport network. However, it is important to identify not only service attributes but also routes that need urgent intervention to improve service level. In addition, the perception of importance and satisfaction have been measured based on numeric scales (e.g. Likert scales are the most used) whereas this measurement tool is criticized as its obtained scores do not reflect the user preference [13]. In Morocco, some academic studies have focused on analyzing the transport sector in Fez City such as problems of public transport (e.g. [14]), the performance of freight transport (e.g. [15]) and the location of loading/unloading spaces for urban freight (e.g. [16]). However, no empirical study has been performed to analyze the service quality of bus transport service, except for an analysis carried out by [17] which lays the theoretical foundations for the present study. The purpose of this paper is to assess the quality of bus service from the user’s point of view in Fez City and identifies service attributes and routes that should be prioritized for improvement actions. To this end, a three-stage methodology approach is proposed. The first stage consists of an evaluation of the satisfaction and importance levels of various service attributes using linguistic terms while incorporating the features of the Fuzzy Set Theory so as to handle the possible uncertainty and vagueness of the user’s point of view in the evaluating process. The second stage involves detecting the service attributes that should primarily be acted on using an Importance-Performance analysis (IPA). In the third stage, data envelopment analysis (DEA) was conducted to identify routes in which the urgent intervention is needed. The rest of this paper is divided into five sections. The second section presents in detail the proposed methodology. In the third section, data collection and some descriptive statistics about the sample are described. The fourth section discusses the results and finally, the last section presents the main conclusions of the study.

2 METHODOLOGY

2.1 Preliminaries

2.1.1 Identification of service quality attributes

A large number of service attributes have been proposed in the literature on the evaluation of urban public transport quality. Attributes are normally grouped into dimensions/aspects on which there is no consensus as to their nature. However, there
is a general recognition that service quality is a multidimensional construct [18] and multilevel or hierarchical [19]. As an example, the Transit Cooperative Research Program [20] in the United States proposes a list of 48 attributes grouped in nine dimensions. In Europe, the standard EN 13816 [21] has defined the quality of service according to 8 dimensions and 30 attributes. Eboli and Mazulla [22] used 11 dimensions and 25 attributes whereas [23] defined 6 dimensions and 20 attributes. Based on a literature review as well as for practical consideration, we have used in this study a list of 12 attributes describing the main characteristics of service including service availability, information availability, comfort, service reliability, security and safety, fares, buses accessibility, physical state of buses, route connectivity, driver’s quality, professionalism of administrative staff, and behavior of field staff.

2.1.2 Fuzzy sets and fuzzy numbers
Definition 1: Let \( X \) be the universe of discourse \( X = \{x_1, x_2, \ldots, x_n\} \). A fuzzy set \( \tilde{A} \) of \( X \) is characterized by a membership function \( u_{\tilde{A}}(x) \), which associates with each element in \( X \) in \( X \) a real number in the interval \([0, 1]\). The function value \( u_{\tilde{A}}(x) \), is termed the grade of membership of \( x \) in \( \tilde{A} \) [24].

Definition 2: A triangular fuzzy number (Fig.1) is represented as a triplet \( \tilde{A} = (l_A, m_A, u_A) \). The membership function is defined as:

\[
u_{\tilde{A}}(x) = \begin{cases} \frac{x-l_A}{u_A-m_A} & \text{for } l_A \leq x \leq m_A \\ \frac{x-u_A}{u_A-m_A} & \text{for } m_A \leq x \leq u_A \\ 0 & \text{otherwise} \end{cases}(1)
\]

Where \( l_A, m_A, u_A \) are real numbers and \( l_A \leq m_A \leq u_A \). The parameter \( m_A \) corresponds to the maximum value of \( u_{\tilde{A}}(x) \) (i.e. 1 for normalized TFNs), whereas \( l_A \) and \( u_A \) are the lower and upper bounds of the definition interval respectively.

2.2 Fuzzy Evaluation

2.2.1 Conversion of Linguistic terms to fuzzy numbers
The users were asked to rate the importance level and the perceived level of various service attributes using two sets of linguistic terms respectively ([Not important, slightly important, moderately important, Important, very important]; [Very dissatisfied, dissatisfied, neutral, satisfied, very satisfied]). In the fuzzy set theory, each linguistic term is transformed into a fuzzy number. The triangular numbers used in this paper, distributed between zero and ten as shown in table 1.

<table>
<thead>
<tr>
<th>Linguistic terms of importance</th>
<th>Membership function</th>
<th>Linguistic terms of perception</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not important (NI)</td>
<td>(0,1,3)</td>
<td>Very dissatisfied (VD)</td>
</tr>
<tr>
<td>Slightly important (SI)</td>
<td>(1,3,5)</td>
<td>Dissatisfied (D)</td>
</tr>
<tr>
<td>Moderately important (MI)</td>
<td>(3,5,7)</td>
<td>Neutral (N)</td>
</tr>
<tr>
<td>Important (I)</td>
<td>(5,7,9)</td>
<td>Satisfied (S)</td>
</tr>
<tr>
<td>Very important (VI)</td>
<td>(7,9,10)</td>
<td>Very satisfied (VS)</td>
</tr>
</tbody>
</table>

2.2.2 Calculation of the perception and importance scores for each service attribute
Considering the \( k \) service attribute to be rated by \( J \) users. Let \( (S_{k,j}) = (l_{k,j}, m_{k,j}, u_{k,j}) \) and \( (I_{k,j}) = (l_{k,j}, m_{k,j}, u_{k,j}) \) be the TFN representing the quality perception and importance level expressed by the \( j \)th customer with reference to \( k \) Service attribute. \( (S_{k,j}) \) and \( (I_{k,j}) \) are expressed according to the linguistic term of the fuzzy evaluation scale represented in table 1. Considering the \( k \)th service attribute, Let the TFN \( (S_k) = (l_k, m_k, u_k) \) and \( (I_k) = (l_k, m_k, u_k) \) denote the average perceived quality and the average importance level respectively. The \( (S_k) \) and \( (I_k) \) are obtained via the arithmetic mean to aggregate group evaluations as follows:

\[
\bar{S}_k = \left( \frac{\sum_{j=1}^{J} l_{k,j}}{J}, \frac{\sum_{j=1}^{J} m_{k,j}}{J}, \frac{\sum_{j=1}^{J} u_{k,j}}{J} \right)
\]

\[
\bar{I}_k = \left( \frac{\sum_{j=1}^{J} l_{k,j}}{J}, \frac{\sum_{j=1}^{J} m_{k,j}}{J}, \frac{\sum_{j=1}^{J} u_{k,j}}{J} \right)
\]

2.2.2 Calculation of the perception scores for each service attribute per bus route
Let \( r \) be the considered bus route (with \( r = 1, 2, \ldots, R \) to be rated by \( J \) users with respect to \( k \) service attribute (with \( k = 1,2,3, \ldots, K \)). Let \( (S_{k,j,r}) = (l_{k,j,r}, m_{k,j,r}, u_{k,j,r}) \) be
the TFN representing the quality perception of the bus route \( r \) expressed by the \( j \)th customer with reference to \( k \) Service attribute. \( \hat{S}_{k,j}^{(r)} \) is expressed according to the linguistic term of the fuzzy evaluation scale represented in table 1. Considering the \( r \)th bus route, let the TFN \( \hat{S}_{k}^{(r)} = (l_{S_k}, m_{S_k}, u_{S_k}) \) denote the average perceived quality on the \( k \)th service attribute. The \( \hat{S}_{k}^{(r)} \) is obtained via the arithmetic mean to aggregate group evaluations as follows:

### 2.2.4 Calculation of the crisp scores

The fuzzy numbers could be transformed into crisp numbers. Among the various methods to carry out this transformation process, we use, in this paper, the graded mean integration representation method [25] to transform the fuzzy perception and importance scores. According to this method, the fuzzy scores of perception \( (\hat{S}_{k}) = (l_{S_k}, m_{S_k}, u_{S_k}) \) and importance \( (l_{i_k}, m_{i_k}, u_{i_k}) \) becomes:

\[
P_S(\hat{S}_k) = \frac{(l_{S_k}) + (4 \times m_{S_k}) + (u_{S_k})}{6},
\]

\[
P_I(l_{i_k}, m_{i_k}, u_{i_k}) = \frac{(l_{i_k}) + (4 \times m_{i_k}) + (u_{i_k})}{6}.
\]

### 2.3 Importance-Performance analysis (IPA)

The IPA has been developed for the first time by [26]. This technique is based on the ratings of customers regarding two fundamental aspects of service attributes, namely their importance and performance. These ratings are plotted on a matrix of four quadrants (fig.3), and strategies for improvement can be described according to the position of the ratings. In particular:

- **Quadrant I:** Service attributes placed in this quadrant have relatively high scores of performance and importance respectively. Thus, managers should keep up the good work.
- **Quadrant II:** Service attributes located in this quadrant have a higher score of performances but a lower score of importance. Consequently, improvements efforts should be concentrated here.
- **Quadrant III:** Service attributes placed in this quadrant have relatively low scores of performance and importance respectively. In this case, managers should not be worried as the service attributes are not considered to be very important. Therefore, limited resources should be invested in this low priority area.
- **Quadrant IV:** Service attributes placed in this quadrant have low scores of importance but relatively high scores of performances. In this case, the current efforts on these service attributes should be considered by managers as excessive.

In this study, performance has been substituted by quality perception.

### 2.4 Data Envelopment Analysis (DEA)

Data Envelopment Analysis is a technique for the assessment of the relative efficiency of a set of decision-making units (DMUs) that use several inputs to produce several outputs. The definition of a DMU is generic and flexible and includes different consumable or non-consumable inputs and outputs. The relative efficiency of a DMU is measured by estimating the ratio of weighted outputs to weighted inputs and comparing it with those of other DMUs. DEA allows each DMU to choose automatically the input and output weights that maximize its efficiency. DMUs that achieve 100% efficiency are considered efficient, while DMUs with efficiency scores below 100% are inefficient. The first DEA model, proposed by [27], is the CCR model, which assumes that production exhibits, constant returns to scale. In addition, a DEA model (CRS or VRS) can be oriented towards inputs or outputs. In an inputs-oriented approach, the DEA model minimizes inputs for a given level of output. In an outputs-oriented approach, the DEA model maximizes outputs for a given level of inputs. However, it would be meaningless in MCDM to consider both inputs and outputs as evaluation criteria when only outputs (or inputs) are necessary to consider. To address this circumstance, Lovell and Pastor [30] suggest the pure output (or input) model without inputs (or outputs). They proved that an output-oriented CCR model with a single constant input and an input-oriented CCR model with a single constant output coincide with the corresponding BCC models, but a CCR model without inputs (or outputs) is meaningless. On the other note, the Conventional DEA models don’t give a ranking those DMUs deemed efficient (all of which have a score of 100%). To this end, Andersen and Peterson [31] propose the super efficiency DEA Model which involves executing the standard DEA models (CRS or VRS), but under the assumption that the DMU being evaluated is excluded from the reference set so that efficient DMUs may have efficiency scores larger than or equal to 100%. The objective of this stage is to identify bus routes that need more attention in terms of the service priority attributes. To have a valid comparison, the bus routes should be compared on the basis of a single indicator instead of separate measures of each service attribute. To this end, the super-efficiency DEA model has been applied in light of the pure output model of Lovell and Pastor [30]. More precisely, let...
consider a set of DMUs to be evaluated and ranked (DMU), each DMU has a set of inputs and outputs. The DMUs represent bus routes. For each bus route, a single constant (1) is considered as input and the crisp perception scores of each service priority attribute are considered as outputs. Based upon the CRS DEA model [27], the output-oriented CRS super-efficiency model can be expressed as:

\[ \text{Min } \theta \]

Subject to

\[ \sum_{j=0}^{n} \lambda_{ij} x_{ij} \leq \theta x_{io} \quad i = 1, 2, \ldots, m \]

\[ \sum_{j=0}^{n} \lambda_{rj} y_{rj} \leq y_{ro} \quad r = 1, 2, \ldots, s \]

\[ \theta \geq 0 \]

\[ \lambda_{ij} \geq 0 \quad j \neq o \]

Where the DMU under evaluation is excluded from the reference set. When DMU is efficient and model (11) is feasible, \( \theta^* > 1 \), indicating that DMU’s inputs are increased to reach the frontier formed by the rest of the DMUs. That is, super-efficiency is expressed in terms of input increases. We can use \( \theta^* \) as the super-efficiency score for DMU.

3 DATA AND SAMPLE CHARACTERISTICS
To apply our methodology, an ad-hoc customer satisfaction survey was conducted at Fez City (Morocco). Based on a structured questionnaire, 784 users were interviewed giving 1217 responses about 44 bus routes. Excluding per urban routes and routes for which the number of responses is less than 20 responses yielded a final set of data including 25 routes with 750 users giving 1090 responses. The survey was realized between May and June 2019, and data collection took place in the bus stops/stations of the main avenues of the city where the majority of the routes intersect. Each user is asked to rate the degree of importance of each attribute of service quality and to rate the degree of satisfaction with at least two routes (each route independently). The questionnaire gathered also information about demographic profile of users and their travel behavior as showed in table 2.

<table>
<thead>
<tr>
<th>TABLE 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHARACTERISTICS OF SAMPLE USERS</td>
</tr>
</tbody>
</table>

| Gender | Female (57%); Male (43%) |
| Age | Less than 24 years (73%); Between 25-44 years (25%); More than 45 years (2%) |
| Principal Activity | Students (81%); Employee (13%); Self-employed (3%); Unemployed (3%) |
| Aim of use | Work (14%); Study (80%); Healthcare (1%); Shopping (1%); Entertainment (2%); Something else (1%) |
| Frequency of use | At least once a Day (63%); At least once a Weak (23%); At least once a month (14%) |

4 RESULTS AND DISCUSSION

4.1 Importance and perception scores of each service attributes
Using the formulas (6) and (7), the average fuzzy scores of importance and perception of each service attribute are calculated respectively. Then, the crisp scores are obtained using the formulas (9) and (10) respectively. The majority of service attributes obtained low perception scores except for tariffs and drivers’ driving quality which obtained medium ones. On the contrary, most of the service attributes showed the highest levels of importance perception.

<table>
<thead>
<tr>
<th>TABLE 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMPORTANCE AND PERCEPTION SCORES OF SERVICE ATTRIBUTES</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Service attributes</th>
<th>Fuzzy scores</th>
<th>Crisp scores</th>
<th>Fuzzy scores</th>
<th>Crisp scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service availability</td>
<td>(1.36, 2.84, 4.81)</td>
<td>2.93</td>
<td>(4.82, 6.70, 8.20)</td>
<td>6.64</td>
</tr>
<tr>
<td>Comfort</td>
<td>(0.75, 2.10, 4.08)</td>
<td>2.20</td>
<td>(4.75, 6.62, 8.15)</td>
<td>6.56</td>
</tr>
<tr>
<td>Information availability</td>
<td>(1.55, 3.09, 5.04)</td>
<td>3.16</td>
<td>(4.11, 5.98, 7.76)</td>
<td>5.92</td>
</tr>
<tr>
<td>Security and safety</td>
<td>(1.21, 6.64, 4.60)</td>
<td>2.73</td>
<td>(5.14, 7.01, 8.37)</td>
<td>6.92</td>
</tr>
<tr>
<td>Service reliability</td>
<td>(1.16, 2.59, 4.56)</td>
<td>2.68</td>
<td>(5.13, 6.98, 8.37)</td>
<td>6.91</td>
</tr>
<tr>
<td>Tariffs</td>
<td>(3.17, 4.99, 6.89)</td>
<td>5.00</td>
<td>(4.73, 6.63, 8.22)</td>
<td>6.58</td>
</tr>
<tr>
<td>Bus accessibility</td>
<td>(0.96, 2.29, 4.26)</td>
<td>2.40</td>
<td>(4.34, 6.22, 7.85)</td>
<td>6.18</td>
</tr>
<tr>
<td>Physical condition of buses</td>
<td>(1.30, 2.79, 4.77)</td>
<td>2.87</td>
<td>(4.36, 6.19, 7.77)</td>
<td>6.15</td>
</tr>
<tr>
<td>Professionalism of administrative team</td>
<td>(1.62, 3.21, 5.18)</td>
<td>3.27</td>
<td>(4.57, 6.43, 7.99)</td>
<td>6.38</td>
</tr>
<tr>
<td>Driver’s driving quality</td>
<td>(3.98, 5.88, 7.67)</td>
<td>5.86</td>
<td>(5.20, 7.12, 8.58)</td>
<td>7.04</td>
</tr>
<tr>
<td>Route connectivity</td>
<td>(3.03, 4.86, 6.80)</td>
<td>4.88</td>
<td>(4.56, 6.44, 8.05)</td>
<td>6.39</td>
</tr>
<tr>
<td>Behaviour of field workers</td>
<td>(2.04, 3.67, 5.61)</td>
<td>3.72</td>
<td>(4.75, 6.63, 8.15)</td>
<td>6.57</td>
</tr>
</tbody>
</table>

4.2 IPA results
The IPA results (Fig.4) show that security and safety, service reliability, service availability, comfort and behavior of field workers required high-priority improvement actions from the bus operator in Fez city. Concerning security and safety, the bus operator should make more efforts to increase the level of preventive measures against crime, aggression, and harassment on the one hand, and the level of protective measures against the dangers of accidents, fires, and collisions on the other hand. Besides, the bus operator should make more efforts to improve the level of adherence of buses to schedules. In terms of service availability, the bus operator should increase the bus frequency, the hours of service and extend the bus network to more geographic areas. In addition, the bus company should reduce the level of congestion and nuisance onboard buses and make in operation buses with more seats and functional air conditioners. It should also invest more in equipping bus stops and stations with benches and shelters. Last, the bus operator should sensitize their field workers to behave well towards users (welcome, respect, courtesy, and assistance) and ensure that they have a
uniform clothing appearance and holding badges.

5.3 DEA Results

As stated in the methodology section, the aim of this stage is to identify bus routes that need more attention in terms of the five service attributes identified in the quadrant II of the IPA analysis. Using the formulas (8), the fuzzy score of each service attributes per route has been calculated. Then, the crisp scores are obtained using formula (9). The results depicted in Fig.4, represent substantial feedback of the users’ perception of bus service quality. However, they vary in a different sense, which will not allow us to quickly pinpoint any route whose overall perceived quality was high or low. For this reason, the DEA method was employed to get a single composite indicator of perceived quality for each bus route to make a valid comparison. The values of the quality perception of the five service attributes per bus route were considered as output data of the DEA model. Applying the model (11) using the MaxDEA ultra software, the final scores the 25 bus routes in terms of overall perceived quality are given in Fig.5.

The results show that the average score is 87, 99% and only 10 routes are above this mean. The 15 remaining routes (#13, #14, #17, #2, #20, #25, #29, #30, #31, #41, #42, #5, #51, #52 and #53) obtained a score below the average, and thus require urgent improvement in terms of security and safety, service reliability, service availability, comfort and behavior of field workers.

6 CONCLUSION

In order to achieve a more balanced and efficient modal share of transport in Fez city, the proportion of bus transport should be increased as recommended by the Master plan of mobility. To do this, efforts provided by policy-makers and transport managers should be focused on improving the service quality as this later is an incentive of a large part of the population to use buses instead of walking or using individual motorized means. In this point, this paper purpose a methodology approach that evaluates the perceived quality by customers and identifies service attributes and routes that should be prioritized for improvement actions. The proposed methodology is based on three stages. The results of the first stage showed that the majority of service attributes obtained low perception scores except for tariffs and Driver's driving quality which obtained medium ones. On the contrary, most of the service attributes showed the highest levels of importance perception. Then, an IPA has been performed which results showed that five service aspects including security and safety, service reliability, service availability, comfort and behavior of field workers required high-priority improvement actions. The result of the third stage showed that the average quality score is 87, 99% and only 10 routes are above this mean. The 15 remaining routes obtained a score below the average, and thus require urgent intervention.

7 REFERENCES


[9] J.-S. Chou, C. Kim, Y.-C. Kuo, and N.-C. Ou,


