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OPTIMIZING SERVICE QUALITY MANAGEMENT OF THE BUS RAPID TRANSPORT SYSTEM IN LAGOS USING THE MULTI-CRITERIA DECISION ANALYSIS

Summary. Evaluation of Bus Rapid Transportation (BRT) based on service quality criteria and customer satisfaction can never be overemphasized due to its derivative, such as optimizing the performance of the transportation industry. Thus, this study employs the multi-criteria decision-making (MCDM) method for the evaluation of service quality and customer satisfaction of the BRT system in Nigeria using the fuzzy analytical hierarchy process (FAHP) and visekriterijumska optimizacija i kompromisno resenje (VIKOR), which are components of multi-criteria optimization and compromise solution to evaluate notable factors responsible for the user's perspective. Research design is quantitative and analytical in nature through a survey of experts who are users of BRT services. Samples were drawn through a multi-stage sampling procedure and a total of 402 copies of questionnaires were administered to BRT users based on their experience with the system. Hence, VIKOR and FAHP methods are applied to analyse data retrieved from the field on services quality and performance level. The service

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quality (SERVQUAL) model (a multi-dimensional research instrument designed to capture consumer expectations and perceptions of service) was modified thereby generating six dimensions and thirty-six service criteria for this research. The FAHP method was employed to determine the weights of the decision criteria because there is a need to measure commuters' perceptions and expectations based on numerical linguistic variables due to the vague, imprecise and complexity related to the nature of services. The criteria weights and responses of the survey analysis (data) related with the BRT are input for the VIKOR method for ranking. As measuring the perception of service quality based on crispy value can often be misleading, hence, the use of the fuzzy MCDM method can give a more realistic measurement. The result of the multi-criteria decision analysis revealed that pricing quality is the most relevant service quality dimension to users' satisfaction, followed by the empathy quality dimension. The summary of strength and weakness areas of service quality discovered through the research and its managerial implications with recommendations were related to the appropriate authority in charge of the BRT system for improved performance.

Keywords: MCDM, FAHP, VIKOR, SERVQUAL, BRT

1. INTRODUCTION

The key to the sustainable productivity of the service industry is to ensure customer satisfaction; this can be achieved in almost no other better way than to continually deliver excellent service quality to customers at all times. Practically, everyone has in one way or other experienced public transportation services, either at home or abroad. Thus, public transportation is indispensable to the well-being of any country, its essentiality can never be overstressed, in fact, if well planned and efficiently governed, the value derived from the public transportation system would span across many industries, as it enhances mobility, reduces air pollution and traffic congestion, etc. [8, 9]. However, the present state of public transportation in Nigeria calls for a service quality appraisal. Hence, this research is centred on the evaluation of commuters' perception of service quality of the Bus Rapid Transport (BRT) in Lagos, Nigeria, using the modified SERVQUAL as an instrument, while AHP and VIKOR explore measurement strategies for solving problems relating to service quality and commuters` satisfaction. The need for the evaluation of service quality delivered by the BRT system can never be overemphasized due to the continuous and increased demand for a better service experience by commuters.

The factor responsible for the dissatisfaction/satisfaction of commuters varies across individuals and environmental settings, thus, a study is needed to evaluate some notable factors from the account and experience of BRT users/commuters in the Lagos metropolis. These could be retrospective or prospective evaluations; the appraisal may be economic, social, technological, environmental, or political. Moreover, the focus on a means of public transport such as BRT in a highly populated mega city like Lagos is essential as it serves the provision of basic service in the society thereby ameliorating reoccurring traffic and capturing some of the complaints by the users of the facilities. Since the public forms the fulcrum for providing or investing in BRT, it is essential to measure their perception [3], to ensure their satisfaction and continuous patronage. Thus, the dynamic nature of service quality in Nigeria's transportation industry calls for robust research similar to the one in this framework (multi-criteria decision analysis). In BRT services, most especially where there are cheaper alternatives, customers' satisfaction is regarded as the apex assessment for efficiency, and it is a significant determinant of patronage, which subsequently affects the revenue and sustainability of this model of transportation in one of Africa's highly populated city.

2. LITERATURE REVIEW

2.1. Fuzzy analytical hierarchy process (FAHP)

The analytical hierarchy process (AHP) is a multi-criterion decision-making (MCDM) method invented by [18]. AHP is known to be a structured technique used for analyzing complex decisions or issues that involves subjective judgements. In other words, AHP is a traditional powerful decision-making technique for determining priorities among different criteria, comparing the decision alternatives for each criterion, and determining an overall ranking of the decision alternatives [10]. The main advantages of AHP are to handle multiple criteria, easy to understand, and effectively deal with both qualitative and quantitative data. In reality, most data gotten from respondents include uncertainty and vagueness owing to the lack of complete information, impreciseness of human judgements, and vagueness of the decision environment. The combined effect of the fuzzy set theory and analytical hierarchy process makes the fuzzy analytical hierarchy process (Fuzzy AHP) a more powerful method for multi-criteria decision-making (MCDM). Furthermore, many researchers who have studied the fuzzy AHP, which is the extension of Saaty's theory, have shown evidence that it shows a relatively more sufficient description of this kind of decision-making process compared to the traditional AHP methods.

2.2. VIKOR method

The VIKOR method (Visekriterijumska Optimizacija i Kompromisno Resenje in Serbian) was developed by Opricovic in 1990 as a multi-criteria optimization method to solve complex decision problems that have several possible solutions. VIKOR aims to rank the set of alternatives to a set of conflicting evaluation criteria and suggest the solution that is "closest" to the "ideal" solution [22].

VIKOR is known for its computational simplicity and solution accuracy [7, 19]. The focus of this method is to select and rank a set of alternatives based on the compromised solutions for a problem with conflicting criteria to assist a decision-maker in taking an optimized decision in their final course of action. VIKOR defines the compromised ranking list based on a particular measure of nearness to the ideal solution [7].

2.3. SERVQUAL model

Parasuraman et al. [17] developed the service quality model or SERVQUAL model, also known as the Gap model. It is a multi-dimensional research instrument designed to acquire users' desires and perceptions of a service along the 5 dimensions of service quality. SERVQUAL is made on the expectancy-disconfirmation paradigm, which in simple terms means service quality. This is the extent to which consumers' pre-consumption expectations of quality are confirmed or disconfirmed by their definite observations of the service quality experience. The potential application of the SERVQUAL scale cannot be overemphasized, it can help a good range of service organizations in assessing perceptions of service quality [6].

The managerial implication given by Kang et al. [11] reveals that SERVQUAL will allow managers to scrutinize the interior service quality and external service quality and subsequently update employees to acknowledge their role in delivering quality to customers.

3. RESEARCH METHODS

Ontologically, this research work engaged a pragmatist view and employed a positivist epistemology. Thus, it implemented the quantitative method and a descriptive and explanatory survey designed in a non-controlled setting. This empirical study makes use of MCDM tools to examine the research objectives and their respective implications. The questionnaire layout is constructed in sections, such that there is part A - the bio-data section, which captures the personal details such as the age, sex, qualifications, etc. of respondents. Parts B and C of the questionnaire fielded questions relating to the research and are structured in FAHP and VIKOR formats, respectively; it evaluates the dimensions of modified SERVQUAL models. These dimensions are evaluated by considering the dissimilar criteria. The FAHP format used allows pairwise comparison of these alternatives to measure their weight while the modified VIKOR explores the SERVQUAL model designed questionnaire. The operations research models (FAHP and VIKOR) were used for the analysis of data to draw a scientific conclusion. In line with this, the analysis was based on fuzzification, defuzzification, normalization, synthesis, priorities, uni-criterion flows and global flows. The population of this study comprises Lagos BRT commuters with at least a year's experience of patronage at BRT terminals across Lagos. The study is limited to the following BRT terminals in Lagos: Oshodi Bus terminal, Ikorodu BRT terminal, Mile 12 Station, Fadeyi Station, Tollgate terminus, TBS Bus Terminal and Lagos Island terminal. The BRT users of the above terminals with at least a year's service experience are a very large number considering the aforementioned areas as the largest corridors in Lagos state.

Sampling is compulsory, as it is practically impossible for a researcher to use the whole population for the research study. Thus, random sampling was adopted and explored to collect the data. The research was limited to a sample of 402 respondents due to time constraints and financial resources. The sample was chosen from BRT users within the population and study area described above.

The random sampling technique was adopted for this research study to sample BRT users' opinions, achieve the objectives of the research and find answers to the research questions posed in the study. We relied on the position of Mugenda and Mugenda [12], who maintain that the random sampling technique is the method that creates equal chances for the elements within a study population to be sampled.

Primary data were gathered through a self-completion questionnaire, and a multi-stage sampling procedure was employed to select the participant for the research with the permission and approval of the relevant authorities. This involves the use of carefully structured questionnaires containing structured questions and closed-ended responses suitable for modelling FAHP and VIKOR. A sample of "402" passengers of the Lagos BRT was used for the research.

The questionnaire used for the collection of data was designed in line with the modified SERVQUAL model and expert literature reviews. It contains six dimensions and twenty-nine criteria. The passenger's service quality perception is gauged using the linguistic variable scale which was labelled as 'Extremely low important (EL)', 'Very low important (VL)', 'Low important (L)', 'Moderately Important (M)', 'High importantly (H)', 'Very high important

(VH)' and 'Extremely high important (EH)' and their respective triangular fuzzy scale are shown in Table 1 and Figure 1.

Tab. 1

Linguistic variable and scale

Linguistic Scale for Criteria and Alternative	Triangular Fuzzy Number
Extremely Low Important (EL)	(1,1,2)
Low Important (VL)	(1,2,3)
Low Important (L)	(2,3,4)
Moderately Important (M)	(3,4,5)
High Important (H)	(4,5,6)
Very High Important (VH)	(5,6,7)
Extremely High Important (EH)	(6,7,7)

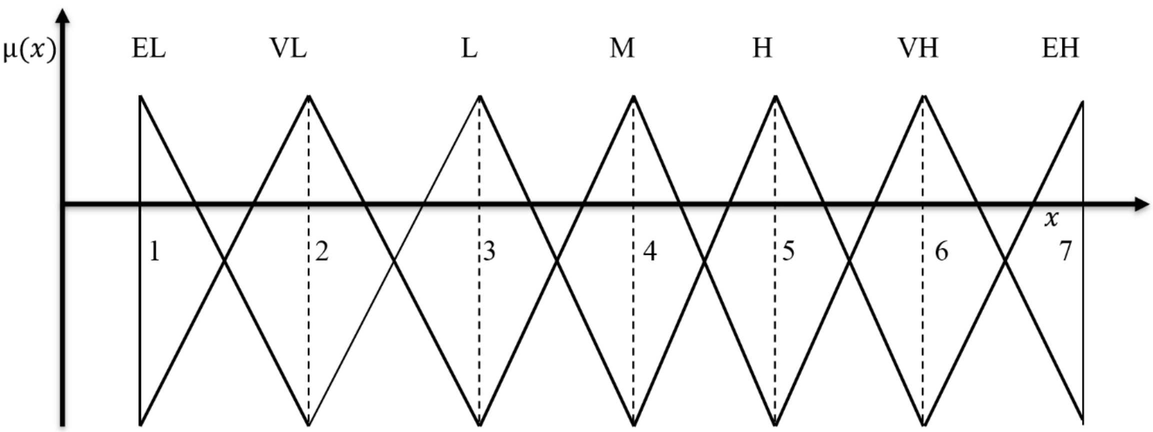

Fig. 1. Linguistic scale

The following integrated steps coupled with the support of data analysis software such as MS Excel and SPSS were employed for the data analysis: fuzzification and defuzzification of scores for service criteria, and their respective weighting using the FAHP model, ranking and selection of alternatives from best to the worst criteria by the VIKOR method. Fuzzy AHP was used for fuzzification and defuzzification of service quality criteria measures and their respective weighting. The procedure is more rigorous and significantly different from the normal/conventional weighting system of AHP used to assess service quality in other sectors like banking, health, telecommunication, and others [1, 14, 15].

The FAHP method is an unconventional analytical technique advanced from the conventional AHP, for the convenience of AHP in handling both the quantitative and qualitative criteria of the MCDM problem based on managers or decision-makers verdicts. However, the conventional AHP cannot fully reflect the human thinking style, as fuzziness and vagueness still exist and may result in imprecise decision-making judgement [14, 16]. Thus, this study embraces the fuzzy AHP method for service quality performance because, in complex systems, the experiences and judgements of humans are represented mostly by linguistic and vague patterns. For this research, we explored the noble geometric mean method, which can be easily extended to fuzzy pairwise comparison matrices.

Consider the triangular fuzzy comparison matrix shown below:

$$\tilde{C} = \left(\widetilde{c_{ij}}\right)_{n\times n} = \begin{bmatrix} (1,1,1) & (l_{12}, m_{12}, u_{12}) & \dots & (l_{1n}, m_{1n}, u_{1n}) \\ (l_{21}, m_{21}, u_{21}) & (1,1,1) & \dots & (l_{2n}, m_{2n}, u_{2n}) \\ \vdots & & & \vdots \\ (l_{n1}, m_{n1}, \quad _{n1}) & (l_{2n}, m_{2n}, u_{2n}) & \dots & (1,1,1) \end{bmatrix} \quad (1)$$

Where $\widetilde{c_{ij}} = (l_{ij}, m_{ij}, u_{ij})$ and $\widetilde{c_{ij}}^{-1} = \left(\frac{1}{u_{ij}}, \frac{1}{m_{ij}}, \frac{1}{l_{ij}}\right)$ $for\ i, j = 1, \dots, n\ and\ i \neq j.$

Hence, to compute the final weights based on the fuzzy pairwise comparison matrix, as explained by Buckley (1985), the geometric mean of each row of the matrix is computed thus:

$$\tilde{r}_i = \left(\prod_{j=1}^{n} \tilde{P}_{ij}\right)^{1/n} \quad (2)$$

and

$$\widetilde{w}_i = \tilde{r}_i \otimes \left(\sum_{i=1}^{n} \tilde{r}_i\right)^{-1}, i = 1,2,3, \dots, n \quad (3)$$

Thus, for defuzzification of the computed result of $\widetilde{w}_i$, the simple centroid method of Opricovic and Tzeng [13] was applied. To get crisp numeric values, we defuzzified fuzzy number $\widetilde{w}_i$ and then normalize the resulting values. The defuzzification is carried out using the defuzzification method called centre of area (COA):

$$\widetilde{w}_i = \frac{l + m + u}{3} \quad (4)$$

The modified VIKOR method

The major difference between the modified VIKOR and the original VIKOR is the replacement of a fixed common number of criteria for all alternatives with a set of criteria for each alternative, and providing a method for ranking the unimproved gaps of alternatives [13]. The application of any VIKOR method starts with the development of the corresponding evaluation or decision matrix, which shows the performance of the alternatives regarding various criteria [4]. Let, fij represent the performance measure of ith alternative regarding the jth criterion. The multi-criteria measure for compromise ranking is then developed from the $Linear\ programming - metric$ used as an aggregating function in a compromise programming method [23]. The alternatives are denoted as $A_1,\ A_2,\ A_3,\ \dots,\ A_m$, while the criteria are denoted by $c_1,\ c_2,\ c_3,\ \dots, c_n$, where w_{ij} is the weight of each of the j criterion and f_{ij} being the performance ratings of the j criterion that belong to A_i alternative. The application of the modified VIKOR involves the following five procedural steps.

Stage 1: Organized the decision matrix and determine the best f_i^* and the worst f_j^- values of all criterion functions, $i = 1,2,\dots,n$ because each alternative is ranked according to its own criteria. Thus, we have:

$f_i^* = \max(f_{ij}, j = 1,\dots,J)$, $f_j^- = \min(f_{ij}, j = 1,\dots,J)$, $if\ the\ i-th\ function\ is\ benefit$ $f_i^* = \min(f_{ij}, j = 1,\dots,J)$, $f_j^- = \max(f_{ij}, j = 1,\dots,J)$, $if\ the\ i-th\ function\ is\ cost$

If we assume that the jth function represent benefit, then; $f_i^* = \max i(f_{ij})$ (setting as aspired level or the greatest level) and $f_i^- = \min i(f_{ij})$. Setting as tolerable level or the acceptable (at least) level.

Tab. 2

Decision Matrix

Alternatives	Criteria				
	C_1	...	C_j	...	C_n
A_1	f_{11}	⋯	f_{1j}	⋯	f_{1n}
.	.		.		.
.	.		.		.
.	.		.		.
A_i	f_{i1}	⋯	f_{ij}	⋯	f_{in}
.	.		.		.
.	.		.		.
.	.		.		.
A_m	f_{m1}	⋯	f_{mj}	⋯	f_{mn}

Alternatively, if we assume the jth function represent a cost/risk, then $f_i^* = \min i(f_{ij})$ (setting as aspired level) and $f_i^- = \max i(f_{ij})$ (setting as tolerable level).

Stage 2: Normalize. The normalize weight rating matrix (determined by using the relationship weight ratings) can be expressed as:
where w_j^i is the weight $i\,(1,2,\dots,m)$ alternative and $j,(1,2,\dots\ ,n)$ criteria, and the performance scores as normalized ratings (r_{ij}) are indicated as:

$$r_{ij} = {(f_i^* - f_{ij})}\Big/{(f_i^* - f_j^-)}, i = 1,2,\dots,m; j = 1,2,\dots\ ,n \quad (5)$$

Where f_i^* is the best score of each criterion of each alternative and f_j^- is the worst score of each criterion of each alternative.

Stage 3: Compute the values S_i and R_i $i = 1,2,\ldots,m$, which are the utility measures and regret measures, respectively, using:

$$S_i = \sum_{j=1}^{M} w_j r_{ij} \ , S_i = \sum_{j=1}^{M} w_j \left[{(f_i^* - f_{ij})}\Big/{(f_i^* - f_j^-)} \right] \tag{6}$$

$$R_i = \max\{w_j r_{ij}\} \ , R_i = \max\left\{ w_j \left[{(f_i^* - f_{ij})}\Big/{(f_i^* - f_j^-)} \right] \right\} \tag{7}$$

Where:
$i = 1,2,\ldots,m; j = 1, 2, \ldots \ , n$ where w_j is the weight of the j criterion.

Stage 4: Compute the index valueQ_i, $i = 1,2,\ldots,m$ using the equation;

$$Q_i = \frac{v(S_i - S^-)}{(S^* - S^-)} + \frac{(1-v)(R^- - R^*)}{(R^* - R^-)} \tag{8}$$

Where: Q_i represents the ith alternative VIKOR value, $i = 1,2,3,\ldots m$;

$$S^* = \max_i S_i \ , \ S^- = \min_i S_i \tag{9}$$

$$R^* = \max_i R_i \ , \ R^- = \min_i R_i \tag{10}$$

The term "v" is introduced as the weight of the maximum group utility. It ranges between 0 and 1, and is based on the level of compromise among decision-makers. The higher the v value, the greater the compromise. In most cases, it is set to 0.5 ($v = 0.5$).

Stage 5: The last step in VIKOR is to rank the alternatives. The ranking is done by sorting or arranging the $S, R \ and \ Q$, from the minimum value to the maximum. The outcomes are three ranking lists. The alternative A' and $A''$are, respectively, the alternative with first (minimum) and second positions in the ranking list by the measure Q (minimum) provided these two conditions are satisfied:

C1: A' Is the best ranked by $\boldsymbol{S}$ **or/and** $\boldsymbol{R}$.
C2: Acceptable advantages: $Q(A'')$ - $Q(A') \geq \ DQ$; where $DQ = \frac{1}{N-1}$; where m is the number of alternatives. If one of the conditions is not satisfied, then a set of compromise solutions are proposed as follows:

- Alternatives A' and A'' if **condition C1** only is not satisfied or
- If condition C2 is not satisfied ($Q(A'')$ - $Q(A') \geq \ DQ$), then the alternatives A', A''…, A^m are considered as a compromise solution; hence, A^m is determined by the relation $Q(A^m)$ - $Q(A') \geq \ DQ$ for the maximum M (the b position of these alternatives is in closeness).

The research instrument was subjected to face and content validity by experts in decision science and experienced agents of transportation regulators in the study area. While to ensure internal consistency, the Cronbach's Alpha (α) test was applied in which values greater than 0.70 but less than 0.9 was obtained for each of the service quality dimension, which is acceptable. Thus, operations research models (FAHP and VIKOR) were adopted in the analysis of this research. FAHP model was adopted for the calculation of dimensional weight, while the VIKOR model was used for the complete ranking of actions (alternatives). Figure 2 summarizes the evaluation dimensions/perspective and criteria used in the assessment and evaluation of the Lagos BRT system.

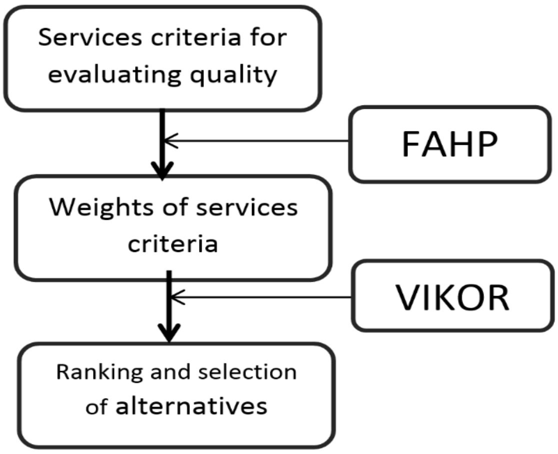

Fig. 2. Research Model for the assessment of Lagos BRT (LBRT) service quality system

4. DATA ANALYSIS

This section presents the results of the analyzed data obtained from the fieldwork using questionnaires specifically designed for this study, administered to 353 randomly selected respondents (Commuters) drawn from the Lagos BRT corridor across Lagos, Nigeria, the research area. Specifically, the BRT terminals located at Ikorodu, Oshodi, Fadeyi, Mile 12, TBS, and Surulere. Of 380 questionnaires administered to commuters, only 310 copies of the questionnaire representing 81.5% rate of return were found valid for analysis.

4.1. Demographic data

Table 3 presents the demographic data of the respondents used in the study. It was observed that of the 310 respondents, male and female were well represented, 42 were male while 33 were female, representing 44 and 56%, respectively. Age distribution of respondents show that majority of the respondents, that is, 50.9% are 25 years old and below, 96 of the respondents representing 30.9% have age ranges between 30 – 36 years, 47 of the respondents representing 15.1% are between the age of 36 and 45 years, while 3.2% representing just 10 respondents are 45 years old and above. It is further detailed in the table that the larger part of the respondent, 72%, are unmarried, while 87 respondents representing 28%, are married. As for educational qualifications, 47.6% of the respondents indicated education below graduate level, 30.2% responded to being graduates, 15.1% have postgraduate degrees, while the other 7.1% indicated other qualifications. Professional designation of the BRT respondents indicated that most of them are students with 149 respondents, representing 47.9% of the sample size, it is followed by those who are self-employed, which as well covered 20% of the sample size. This is followed by civil servants and professionals with 18.1 and 14.1%, respectively.

Frequency distribution of the respondents according to how long they have been using BRT saw that 94 respondents representing 30.2%, have been using BRT for more than 4 years, 84 respondents representing 27% have been patronizing the BRT system for about 3-4 years, while 25.1% have been with the system between 1 and 2 years and 17.6% for less than a year.

Tab. 3

Frequency distribution of respondents by demographic status

Variables	Frequency	Percentage (%)
Gender		
Male	132	44.0
Female	178	56.0
Total	310	100.0
Age		
Less than 25	158	50.8
26 – 30	96	30.9
36 – 45	47	15.1
Above 45	10	3.2
Total	310	100.0
Marital status		
Married	87	28
Unmarried	223	72
Total	310	100
Qualifications		
Undergraduate	148	47.6
Graduate	94	30.2
Postgraduate	47	15.1
Others	22	7.1
Total	310	100
Employment status		
Self-Employment	62	20.0
Civil Servant	56	18.0
Professional	44	14.1
Students	148	47.9
Total	310	100.0
Total		
Year of experience with BRT		
Below a year	55	17.6
1-2 years	78	25.1
3-4 years	84	27.0
4 years and above	94	30.2
Total	310	100.0
Distance Travelled using BRT		
1 – 3 km	65	20.85
Greater than 5-8	98	31.55
Greater than 8 – 11 km	92	29.55
Greater than 12 km	56	18.05
Total	310	100

4.2.1. FAHP model for assigning weight to BRT service quality dimensions

Since most human problems are multi-criteria in nature, MCDA methods were used to ascertain an alternative, optimizing all the criteria. These SERVQUAL service quality dimensions based on BRT users and expert opinions were evaluated using the noble geometric mean method by Buckley [5] of analyzing fuzzy AHP for final weighing. The process is shown thus; the first step is to generate the fuzzy pairwise comparison matrix, the aggregated triangular fuzzy pairwise comparisons matrix (l_{ij}, m_{ij}, u_{ij}) generated from the responses provided by the respondents in the AHP questionnaire is shown in Table 4, from which the r_i values were computed and presented in Table 5.

Tab. 4

Fuzzy Pairwise comparison matrix

	T	***R***	***RP***	***A***	***E***	***P***
T	(1,1,1)	(2.47,4.47,6.47)	(2.31,4.31,6.31)	(1.90, 3.90, 5.90)	(2.41,4.41,6.41)	(2.20,4.20.6.20)
R	(0.15,0.22,0.40)	(1,1,1)	(1.43,3.43,5.43)	(2.01,4.01,6.01)	(1.82,3.82,5.82)	(2.84,4.84,5.84)
RP	(0.16,0.23,0.43)	(0.18,0.29,0.67)	(1,1,1)	(1.79,3.79,5.79)	(2.01,4.01,5.01)	(2.06, 4.06, 6.06)
A	(0.17,0.26,0.52)	(0.17, 0.25, 0.50)	(0.17, 0.26, 0.56)	(1,1,1)	(2.02,4.02,6.02)	(2.12,4.12,6.12)
E	(0.16,0.23,0.41)	(0.15,0.21,0.35)	(0.17, 0.25, 0.50)	(0.17,0.25,0.50)	(1,1,1)	(2.47,4.47,6.47)
P	(0.16,0.24,0.45)	(0.15,0.21,0.35)	(0.17,0.25,0.49)	(0.16,0.24,0.47)	(0.15,0.22,0.40)	(1,1,1)

Step 2: Compute $\tilde{r}_i$ using

$$\tilde{r}_i = \left(\prod_{j=1}^{n} \tilde{P}_{ij}\right)^{1/n}$$

Tab. 5

Computed $\tilde{r}_i$ values

	$\tilde{\boldsymbol{r}}_{\boldsymbol{i}} = \left(\prod_{j=1}^{n} \tilde{\boldsymbol{P}}_{\boldsymbol{ij}}\right)^{1/n}$
T	(1.99,3.42,4.75)
R	(0.15, 1.98,2.90)
RP	(0.79, 1.27, 2.01)
A	(0.15, 0.81, 1.33)
E	(0.35, 0.50, 0.87)
P	(0.20, 0.29, 0.47)
	(4.99, 8.27, 12.30)

Step 3: we calculate the fuzzy weight $\widetilde{w}_i$ using;

$$\widetilde{w}_i = \tilde{r}_i * \left(\sum_{i=1}^{n} \tilde{r}_i\right)^{-1}, i = 1,2,3, \ldots, n$$

Thus, we have the fuzzy weights for each service quality dimension used in this study as presented in Table 6.

Tab. 6

Fuzzy weight $\widetilde{w}_i$ values for the service quality dimensions

	Fuzzy weight $\widetilde{\boldsymbol{w}}_i$
T	$(1.99,3.42,4.75) * (\frac{1}{12.8}, \frac{1}{8.27}, \frac{1}{4.99}) = (0.155, 0.414, 0.952)$
R	$(0.15,1.98,2.90) * (\frac{1}{12.8}, \frac{1}{8.27}, \frac{1}{4.99}) = (0.093, 0.239, 0.581)$
RP	$(0.79,1.79,2.01) * (\frac{1}{12.8}, \frac{1}{8.27}, \frac{1}{4.99}) = (0,064, 0.154, 0.403)$
A	$(0.15,0.81,1.33) * (\frac{1}{12.8}, \frac{1}{8.27}, \frac{1}{4.99}) = (0.041, 0.098, 0.267)$
E	$(0.35,0.50,0.87) * (\frac{1}{12.8}, \frac{1}{8.27}, \frac{1}{4.99}) = (0.028, 0.060, 0.168)$
P	$(0.20, 0.29, 0.47) * (\frac{1}{12.8}, \frac{1}{8.27}, \frac{1}{4.99}) = (0.016, 0.035, 0.094)$

Finally, to get crisp numeric values, we defuzzified fuzzy number $\widetilde{w}_i$ and then normalized the resulting values. The defuzzification is carried out using the defuzzification method called ***centre of area (COA)***;

Centre of Area (COA) $\widetilde{W}_i = \frac{l + m + u}{3}$

Thus, we have Table 7 showing the weights and the normalized weighs of each dimension side by side.

Hence, the weights of the BRT service quality dimension as computed using the geometric mean method of fuzzy AHP are *0.390, 0.238, 0.162, 0.105, 0.067 and 0.038* for Tangibility (T), Reliability (R), Responsiveness (RP), Assurance (A), Empathy (E) and Pricing, respectively.

4.2.2. Assessing the use of the modified VIKOR model to prioritize the best service quality dimensions in the BRT system for competitive advantage and sustainability

As explained under this method, the application of modified VIKOR involves the following procedural steps:

Step 1: Organize the decision matrix and determine the best f_i^* and the worst f_j^- values of all criterion functions.

Tab. 7

Weights $\widetilde{w}_i$ and *Normalized weighted* values

	Weights $\widetilde{\boldsymbol{w}}_{\boldsymbol{i}}$	***Normalized weight***
T	0.498	$\frac{0.498}{\mathbf{1.277}} = 0.390$
R	0.304	$\frac{0.304}{\mathbf{1.277}} = 0.238$
RP	0.207	$\frac{0.207}{\mathbf{1.277}} = 0.162$
A	0.135	$\frac{0.135}{\mathbf{1.277}} = 0.105$
E	0.085	$\frac{0.085}{\mathbf{1.277}} = 0.067$
P	0.048	$\frac{0.304}{\mathbf{1.277}} = 0.038$
Total	$\mathbf{1.277}$	$\mathbf{1.000}$

Step 2: The next step is to compute the normalized ratings (r_{ij}) as indicated below:

$$r_{ij} = {(f_i^* - f_{ij})}\Big/{(f_i^* - f_j^-)}, i = 1,2, \dots, m; j = 1, 2, \dots \ , n$$

The computation is shown in Table 9 for each $i = 1,2, \dots, m; j = 1, 2, \dots \ , n$

Stage 3: Compute the values S_i and R_i $i = 1,2, \dots, m$, which are the utility measures and regret measures, respectively, using:

$$S_i = \sum_{j=1}^{M} w_j \, r_{ij} \ , S_i = \sum_{j=1}^{M} w_j \left[{(f_i^* - f_{ij})}\Big/{(f_i^* - f_j^-)} \right]$$

$$R_i = \max\{w_j \, r_{ij}\} \ , R_i = \max\left\{ w_j \left[{(f_i^* - f_{ij})}\Big/{(f_i^* - f_j^-)} \right] \right\}$$

$i = 1,2, \dots, m; j = 1, 2, \dots \ , n$ where w_j is the weight of the j criterion. The computation is shown in Table 9:

Tab. 8

VIKOR decision and normalized ratings

	T	R	E	RP	A	P	f_j^-	f_i^*	r_{ij}
T1	3.63						1	5	0.3425
T2	3.29						1	5	0.4274
T3	2.67						1	5	0.5815
T4	3.45						1	5	0.3883
T5	3.42						1	5	0.3956
R1		3.15					1	5	0.4615
R2		3.21					1	5	0.4485
R3		2.97					1	5	0.5082
R4		2.24					1	5	0.6896
R5		3.53					1	5	0.3672
E1			3.44				1	5	0.3901
E2			2.86				1	5	0.5348
E3			3.08				1	5	0.4789
E4			3.19				1	5	0.4515
E5			2.90				1	5	0.5247
RP1				2.76			1	5	0.5595
RP2				2.89			1	5	0.5284
RP3				2.95			1	5	0.5129
RP4				2.83			1	5	0.5421
RP5				2.84			1	5	0.5394
A1					2.79		1	5	0.5322
A2					3.51		1	5	0.3727
A3					3.78		1	5	0.3049
A4					3.75		1	5	0.3123
A5					3.43		1	5	0.3919
P1						3.18	1	5	0.4542
P2						3.22	1	5	0.4451
P3						2.99	1	5	0.5053
P4						3.13	1	5	0.4679
P5						3.11	1	5	0.4734

Tab. 9

Utility measure and regret measure values

	Utility Measure $(\boldsymbol{S_i})$	***Regret Measure*** $(\boldsymbol{R_i})$
Tangibility	0.8328	0.2268
Reliability	0.5891	0.1641
Empathy	0.1595	0.0358
Responsiveness	0.4346	0.0358
Assurance	0.2031	0.0580
Pricing	0.0891	0.0191

Step 4: Next is to compute the index value $Q_i, i = 1,2, \dots, m$ using the equation:

$$Q_i = \frac{v(S_i - S^-)}{(S^* - S^-)} + \frac{(1-v)(R^- - R^*)}{(R^* - R^-)}$$

Where; Q_i represent the ith alternative VIKOR value, $i = 1,2,3, \dots m$; where $v = 0.5$.

Tab. 10

Ranking Qi

	S_i	R_i	Q_i	Ranking
Tangibility	0.8328	0.2268	0.5104	6th
Reliability	0.5891	0.1641	0.3437	5th
Empathy	0.1595	0.0358	0.0490	2nd
Responsiveness	0.4346	0.0358	0.2364	4th
Assurance	0.2031	0.0580	0.0793	3rd
Pricing	0.0891	0.0191	0.0009	1st

Step 5: The last step in VIKOR is to rank the alternatives. The ranking is done by sorting or arranging the S, R *and* Q, from the minimum value to the maximum. The outcomes are the ranking lists. Thus, from the result of the analysis above through the VIKOR model, the best service quality dimension significant to the Lagos BRT system for competitive advantages is the pricing dimension.

4.2.3 Order of importance of the service quality dimensions related to the LBRT system

To achieve this, we refer to Table 9, where the final ranking of the service quality dimensions is carried out based on the FAHP and VIKOR models. Hence, re-arranging the ranking in Table 9 gives us the required order of importance as shown in Table 10, the order of importance is thus, $P > E > A > RP > R > T$ where P, E, A, RP, R and T represent pricing, empathy, assurance, responsiveness, reliability and tangibility, respectively.

Tab. 11

Ranking of service quality dimension of BRT in the VIKOR method

	S_i	R_i	Q_i	Ranking
Pricing	0.0891	0.0191	0.0009	1th
Empathy	0.1595	0.0358	0.0490	2nd
Assurance	0.2031	0.0580	0.0793	3rd
Responsiveness	0.4346	0.0358	0.2364	4th
Reliability	0.5891	0.1641	0.3437	5th
Tangibility	0.8328	0.2268	0.5104	6th

In assessing the most influential service quality criteria for Lagos BRT users, Table 10 has the most influential service quality dimension obtained from the VIKOR and FAHP analysis of the services quality data acquired from Lagos BRT users; it is the **pricing** dimension with the lowest VIKOR index value ($Q_i = 0.0009$), among others.
To optimize the service quality of the BRT system using MCDM, the result established that the combination of FAHP and VIKOR models proved to be a rational framework that can support the management of BRT systems to optimize their service delivery and rank the alternatives to solve problems related to service quality delivery. The ranking and the stability interval helped to relate the best alternatives to the most sensitive criterion, thus bringing new insights to decision-makers.

The first ranking of the alternatives that established new insights for the decision-maker is the pricing dimension. This study revealed the measurement of service quality in public transport services in Nigeria, using the multi-criteria decision-making model of FAHP and VIKOR. Thus, the framework is an important contribution to the current theory-building effort, improving the ongoing body of research in service quality and MCDM.

4.4. Discussion of findings

This study was conducted in Lagos, Nigeria, the most populous city in Africa. The data used for the analysis was obtained from Lagos BRT users in selected corridors of the BRT in Lagos. The *Weights* $\widetilde{w}_i$ and *Normalized weighted* values, reveal the normalized weights of the BRT service quality dimensions, using the fuzzy AHP model, it was observed that *Tangibility (T)*, *Reliability (R)*, *Responsiveness (RP)*, *Assurance(A)*, *Empathy (E)* and *Pricing (P)*, weighted to be $0.390, 0.238, 0.162, 0.105, 0.067, and\ 0.038$, respectively. To assess the modified VIKOR model to prioritize the best service quality dimension significant to the Lagos BRT system, appropriate weights computed using the FAHP model were assigned to each of the dimensions correspondently, and then the modified VIKOR model was exploited to compute and prioritize the rank service quality dimension from the user's perspective relative to the Lagos BRT system. In Table 7, where organized decision matrix was normalized for weight rating (r_{ij}), it was observed that the best f_i^* and the worst f_j^- values of all criterion functions are 5 and 1, respectively. Therefore, Table 11 displays the computational results of the utility measure, regret measure, and the VIKOR index. Thus, ***pricing quality*** has the minimum VIKOR index value of 0.0009, minimum utility measure and regret measure, and thus, meets the VIKOR final ranking conditions as the most influential criteria on service quality according to Lagos BRT users' experiences. It was then followed by ***Empathy***, then ***Assurance***, ***Responsiveness***, ***Reliability*** and ***Tangibility*** in ranking order. Based on this priority ranking, the best service quality dimension to focus on to satisfy LBRT users is pricing, this implies that the Lagos BRT management and policymakers need to continually optimize their service pricing strategy to increase commuters' satisfaction and ultimately increase competitive advantage. The finding aligns with similar studies conducted to measure commuters` uptake of the BRT system using the SERVQUAL model in Cape Town, South Africa. Similarly, Ugo [20] discovered that passengers were not satisfied with the bus fare charges and the frequent unavailability of bus ticket sales outlets. Furthermore, the study suggested that the Cape Town BRT management and policymakers should focus on responsiveness and affordability dimensions of service quality to ensure commuters' satisfaction. There is a similar related trend in the work of Adeola and Adebiyi [2], carried out on the Nigerian transportation sector (aviation), where airline companies were also advised to increase their service quality and ensure correspondence between passengers fares and service delivered. VIKOR used in this study assisted in ranking the set of alternatives (service quality dimension) regarding a set of conflicting evaluation criteria and suggested the solution "closest" to the "ideal" solution [21]. This represents the priority of the commuters in the study area and will assist in road transportation policy formulation and implementation.

5. CONCLUSION AND RECOMMENDATIONS

This study assessed the management of service quality optimization of a bus rapid transport system using the multi-criteria decision analysis. It was established that the combination of FAHP and VIKOR models proved to be a rational framework that can support the management of the BRT system to optimize their service delivery, by ranking the alternatives to solve the problem related to service quality delivery. The ranking and the stability interval helped to relate the best alternatives to the most sensitive criterion, thus providing new insights to decision-makers.

The first ranking of the alternatives that established new insights for decision-makers is the pricing dimension.

Based on the conclusion, the following recommendations were made,

i. The BRT system requires ultimate attention to price as commuters are very sensitive to this service quality dimension, thus, optimal pricing strategy should evolve by ensuring that price and quality meet the needs of commuters per distance travelled and comfort to be enjoyed.
ii. Management of the BRT system should improve their employee training on empathy quality as the result of the research shows that Lagos BRT users are treated with low empathy. Thus, it is suggested that loud music should be well regulated in transit, more attention should be given to people with disabilities and pregnant women, and the system should be optimized to reduce commuters' delay time at the terminals.
iii. The research analysis shows that users are satisfied to some extent with the tangibility quality; hence, it is recommended that the BRT system should leverage it to continually ensure users' satisfaction.
iv. The management of the Lagos BRT system should frequently conduct service quality reviews from the user's perspective to optimize their services to continually meet customer satisfaction from time to time.

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