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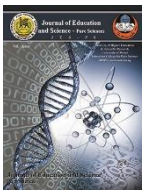

A Multiobjective Genetic Algorithm for Assessing Service Quality Factors in Banking Environment

F. E. Ayo[(1*)], T. J. Odule[(2)], L. A. Ogundele[(3)], S. O. Folorunso[(4)], E. F. Ologunleko[(5)]

[(1,2,3,4)] Department of Computer Sciences, Faculty of Science, Olabisi Onabanjo University, Ago-Iwoye, Ogun State, Nigeria
[(5)] Department of Statistics, Faculty of Science, Olabisi Onabanjo University, Ago-Iwoye, Ogun State, Nigeria

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Correspondence:
AYO Femi Emmanuel
ayo.femi@oouagoiwoye.edu.ng

Abstract

This study proposes a multiobjective genetic algorithm-based framework to optimize key determinants of service quality in banking environments, addressing the limitations of conventional SERVQUAL and BSQ model. This study uses Nigerian banks as a case study to provide a trustworthy scale of measurement for service quality in banks. The BSQ model served as the foundation for the adopted SERVQUAL model. A 5-point Likert scale was used in a standardized questionnaire, and 136 valid answers were gathered. Based on the BSQ model, a total of 22 items were taken into consideration, and the importance of these factors to customer satisfaction was examined. The most important parameters for assessing service quality were extracted using factor analysis. According to principal factor analysis, eight (8) items were chosen to measure how well services were perceived in banks. Genetic algorithm in MATLAB was used to formulate the objective function for multiple regression analysis on the selected items. Goodness of fit of the developed service quality model was evaluated using the F-Test. To determine whether the chosen individual item for service quality were significant, the t-test was also employed. The results showed statistical significance and were perfectly suited to the advanced service quality model. Finding the most accurate variables to assess the perceived level of service quality in banks was done using a genetic algorithm. The results demonstrated that the best items for service quality in banks are "they deliver when promised", "accuracy in account records", "services offered align with the most recent advancements in financial services", and "you can be certain that you will receive value for the money you paid". The results suggest that tangibles, service portfolio, and effectiveness and assurance are the best ways to assess the quality of bank services.

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1. Introduction

In the past, provision of good service quality is not one of the strong points organizations used in ensuring sustainable competitive advantage over their counterparts. In order to stay relevant in the cutthroat business world of today and to guarantee customer pleasure, organizations have recently been delivering high-quality services to their clients [1]. Technology has brought new and valued innovations in the way the banking industry performs its operations (Chauhan, Yadav, & Choudhary, 2022) [3].

Although service quality in banking has always been seen as significant, it has only lately drawn the attention of academics [4]. Because of advances in the way financial services can be rendered for better competitiveness, there may be a renewed interest for financial institutions in studying service quality in banking. Contemporary financial institutions worldwide continuously reevaluate their business practices and create fresh approaches to draw in new clients and keep hold of current ones. In order to help financial institutions match their operations with the expectations of their clients and maintain their

competitiveness and profitability at all times, the concept of assessing service quality in banks is required. Banks that consistently monitor the quality of their services can gain a distinct competitive edge in terms of increased earnings, client retention, and consumer acquisition [5].

Banks can obtain a competitive edge by measuring service quality and using best practices to collect information about market demands, process that information, and use the resulting knowledge to improve service quality [6]. Managers and researchers learn the details about factors of service quality in their organization to enhance customer satisfaction and increase profits. There are various problems that businesses are faced with time after time due to lack of accurate information on market demands. Proper management of information on market demands is a major challenge for modern industries to improve service quality in the face of high market competitions. In order to address the issues of keeping current clients and attracting new ones for increased profitability, banks must create a measurement model for service quality. Poor management of information on market demands and lack of models to measure service quality in banks could lead to customer loss, decline in profits and eventual closure of business.

Previous SERVQUAL studies do not optimize variable selection. According to the majority of research on perceived service quality in banks, some or most of the items that make up the concept of perceived service quality are not a valid way to measure customer satisfaction [7]. In a similar vein, a number of studies on how bank customers perceive service quality are limited to factor analysis on the items of the service quality model and its variations, resulting in a measurement scale that may not be entirely trustworthy for evaluating customer satisfaction [8]. In this study, perceived quality of service was measured based on some of these constructs and in addition with some customers' perceptions for services offered based on a well-designed questionnaire. The multiple regression method was used to generate an objective function. The generated objective function was then used as input into a genetic algorithm to get the optimal decision variables most suitable for the assessment of quality service in banks.

The contribution of this study include: (1) The design of a new construct to assess quality of service quality in banks; (2) The use of multiple regression analysis to generate regression equation as the objective function; (3) The use of genetic algorithm based on the generated objective function to get the optimal decision variables most suitable for the assessment of quality service in banks.

The remainder of this research is structured as follows: Related work is included in Section 2. Section 3 provides the materials and method. Section 4 presents the findings. The study is concluded in Section 5.

2. Literature review

2.1. Motivation

Since its initial publication in Parasuraman et al., 1985 [9], the SERVQUAL model has undergone numerous revisions, either by the same pioneers or by other scholars. The most well-known of these was the component analysis study by [7], which identified five dimension-constructs from their earlier work in 1985 to evaluate the gap between perceived and expected customer satisfaction. Many scholars have made various changes to SERVQUAL, which are reflected in the majority of contemporary papers [10] [11] [12]. One of the objections made by Parasuraman et al. (1988) [7] that the five-dimension constructs are not a standard way to quantify customer happiness and service quality is addressed by these changes.

2.2. Related work

Abdullah et al. (2011) [13] suggested a service quality index for the purpose of evaluating service performance in banks. A total of 3,380 clients of 21 commercial and Islamic banks were given questionnaires and 44.9% of them responded. To test the suggested service quality index, both exploratory and confirmatory factor analysis were used. The factor analysis findings demonstrated that systemization, dependable communication, and responsiveness are the three components of service quality. Additionally, the study employed multiple regression analysis to propose that systemization is the most crucial aspect of service quality in the banking industry. The study is exclusive to one field of study and is not general.

Kumar and Dash (2013) [14] used the Structural Equation Modeling (SEM) approach to present a model for evaluating the quality of services provided by Indian banks. The goal of the study is to investigate the importance of quality service elements that affect client happiness. Based on the SERVQUAL model, the study used data from 200 bank clients. The findings demonstrated the favorable relationship between service quality variables and customer retention and satisfaction. The presented model is specific to banks in India.

Supriyanto et al. 2021 [10] looked at how customer satisfaction and service quality affected bank customers' loyalty. The questionnaire of the study was created with Indonesian bank organizations as its target audience. Path analysis and one-way analysis of variance were used to examine the answers to the questionnaire that was given out. The findings showed that customer satisfaction was directly impacted by service quality, and that customer satisfaction in turn had an indirect impact on customer loyalty. The findings addressed earlier studies that found that customer loyalty was impacted by service quality, but they were unable to quantify the key factors that determine service quality.

Zhou et al. 2021 [11] suggested additional variables that influence loyalty intention and service quality in mobile banking. A total of 224 users of mobile banking provided data for the designed survey. The data gathered was analyzed using

structural equation modeling (SEM). SEM showed that service quality and loyalty retention in mobile banking are influenced either directly or indirectly by interface design, system quality, security assurance, and service quality. The elements influencing the service quality and loyalty intention of mobile banking added to the body of knowledge on mobile banking but the design of the study is specific to Chinese bank settings.

Ayinaddis et al. (2023) [12] proposed a model to investigate how customer satisfaction in Ethiopia is impacted by the quality of e-banking services. A total of 385 individuals chosen using a convenience sampling technique provided data for the study with closed-ended survey questions. Multinomial logistic regression and chi-square correlations were used to analyze the gathered data. The findings demonstrated a substantial relationship between consumer satisfaction and the following variables: responsiveness, reliability, security and privacy, speed, and convenience. Through high-quality e-banking services, the data further confirm that customer pleasure significantly influences customer loyalty. The findings showed that there is no statistically significant relationship between customer satisfaction and the factors of system availability, usability, and service charge. The study identified variables that have an indirect effect on customer loyalty and a direct impact on customer satisfaction. However, the analysis did not indicate if the chosen variables were optimal for customer satisfaction.

Sudirjo et al. (2024) [15] used structural equation modeling to offer a measure for the service quality of online banking customer care. The research assessed the level of customer care services that clients may get to ensure their happiness and continued usage of the e-banking system. A questionnaire with 100 samples was created for the investigation. The samples were analyzed using structural equation modeling, and the findings indicated that e-banking system customers were happy with the services provided by the online customer support. Based on the quality of online bank customer service, the results also indicated a significant likelihood of decreased client loyalty.

Dangaiso et al (2024) [16] suggested a strategy to assess Zimbabwean e-customer bank retention rates during the COVID-19 epidemic. Both quantitative and explanatory research methodologies were used in the investigation. A total of 261 genuine answers were obtained from the questionnaires that were distributed. Covariance-based structural equation modeling was used to analyze the gathered data. The findings demonstrated that e-banking service quality had a considerable impact on e-customer satisfaction and e-word-of-mouth. Additionally, the results showed that e-customer retention and e-word-of-mouth are favorably correlated with e-customer satisfaction. The research is restricted to a certain field of study.

Khan et al. (2024) [17] used structural equation modeling to create a technology service quality model to assess the happiness of bank customers. A total of 355 data were collected for the study, and the analysis was done using the structural equation modeling approach. The findings demonstrated that certainty, tangibles, and dependability all had statistically significant relationships with bank customers' happiness with technology and the quality of their technological services. The study also showed that, when it comes to the quality of technology services and the level of pleasure that bank clients have with technology during a pandemic, responsiveness and empathy variables are not statistically relevant. The research is not general and is restricted to a certain field of study.

Kim et al. (2024) [18] suggested an integrative approach to investigate the relationship between perceived service quality and perceived service value. With the e-banking experience as a factor, the suggested approach includes perceived risk, convenience, and perceived quality. In order to analyze the 700 e-banking user data that was collected, the study employed the path analysis approach. The findings demonstrated that perceived quality was not statistically significant for financial risk, but it was statistically significant for transaction convenience, access convenience, and performance risk. The analysis showed that financial risk, transaction convenience, performance risk, perceived quality, and access convenience were all statistically significantly correlated with perceived value. The association between perceived quality and perceived value was shown to be considerably influenced by e-banking experience. The study did not include factors relating to trust, security, and customer loyalty to gauge the value of e-banking services.

Minhaj and Khan (2025) [19] used a structural equation model technique to identify e-banking parameters that affect consumer satisfaction. Using purposive sampling approaches, the study created and distributed a questionnaire that received 187 valid replies and structural equation modeling for analysis. The findings shown that customer satisfaction and retention are directly positively impacted by elements like effectiveness, dependability, and service quality. The investigation excluded the optimality of the elements influencing e-banking client retention and satisfaction.

Ezechi et al. (2025) [20] introduced a data-analytic method for enhancing banking service quality. In order to improve service quality in the banking industry, the study examines and reviews the application of data analytics based on machine learning. The study identified three main areas where data analytics may enhance banking service quality: customer relationship management, operational effectiveness, and risk management. The research also discussed sophisticated analytics methods that may be applied to identify potential financial fraud and detect invasive trends. Predictive model was used to forecast credit frauds for decision-making. Instead of presenting real implementations, the research just reviewed data-analytic methodologies for improving service quality.

Table 1 shows a comparative summary of previous studies methodologies, models used, sample sizes, and main limitations.

Table 1: Comparative summary of previous studies

Author(s)	Model used	Sample size	Strength	Limitation
Abdullah et al. (2011) [13]	Exploratory and confirmatory factor analysis	1, 517	Evaluating service performance in banks	The study is exclusive to one field of study and is not general. Did not optimize variable selection
Kumar and Dash (2013) [14]	Structural Equation Modeling	200	Established relationship between service quality variables and customer retention and satisfaction	Did not optimize variable selection for SERVQUAL in banking
Supriyanto et al. 2021 [10]	Path analysis and one-way analysis	1190	The findings addressed earlier studies that found that customer loyalty was impacted by service quality	The study is unable to quantify the key factors that determine service quality
Zhou et al. 2021 [11]	Structural Equation Modeling	224	The study identified the elements influencing the service quality and loyalty intention of mobile banking	Did not optimize variable selection for SERVQUAL in banking
Ayinaddis et al. (2023) [12]	Multinomial Logistic Regression & Chi-square Correlations	385	The study identified variables that have an indirect effect on customer loyalty and a direct impact on customer satisfaction	The analysis did not indicate if the chosen variables were optimal for customer satisfaction
Sudirjo et al. (2024) [15]	Structural Equation Modeling	100	Provided a measure for the service quality of online banking customer care	Did not optimize variable selection for SERVQUAL in banking
Dangaiso et al. (2024) [16]	Covariance-based Structural Equation Modeling	261	Developed a model to assess e-customer bank retention rates during the COVID-19 epidemic	Did not optimize variable selection for SERVQUAL in banking
Khan et al. (2024) [17]	Structural Equation Modeling	355	Created a model for service quality to assess the happiness of bank customers	Did not optimize variable selection for SERVQUAL in banking
Kim et al. (2024) [18]	Path Analysis Approach	700	Investigated the relationship between perceived service quality and perceived service value	The study did not include factors relating to trust, security, and customer loyalty to gauge the value of e-banking services
Minhaj and Khan (2025) [19]	Structural Equation Modeling	187	Developed a model to identify e-banking parameters that affect consumer satisfaction	The investigation excluded the optimality of the elements influencing e-banking client retention and satisfaction
Ezechi et al. (2025) [20]	Data Analytics based on Machine Learning	N/A	Presented a review study on data-analytic method for enhancing banking service quality	The study did not present real implementations for improving service quality

2.3 Customer satisfaction

According to Parasuraman et al. (1988) [7], customer satisfaction is the difference between perceived and expected services. Parasuraman et al. (1988) [7] defined customer satisfaction as "Customer Satisfaction = Perception of Performance – Expectations". In other words, the gap between the performance and the expectations of the customers in an organization is a function of customer satisfaction. The financial benefit of a company may be significantly increased by customer happiness, and consumers are more likely to remain loyal to a company that provides high-quality services if they are satisfied with the services they get [21] [22].

Businesses sometimes spend enormous sums of money on advertisements for their products or services, but in reality, the perceived quality of the services feedback provided by consumers may greatly increase the popularity of the business with no extra cost. Customers who are happy with a business are more likely to tell friends and family about it, which indirectly recommends the business to potential clients [23]. In contrast, a dissatisfied consumer will inherently not present a favorable picture of a company [24]. Individually satisfied consumers are the catalyst that promote the business of an organization.

3. Service quality

Due to the large number of researchers, there are several definitions of service quality. According to the definitions of several researchers, service quality is generally understood to be the comparison of an organization's performance with the expectations of its consumers. Service quality, as described by Haksever et al. (2015) [25], is the discrepancy between an organization's perception of what its consumers anticipate and the actual level of service quality. Reliability, responsiveness, competence, accessibility, courtesy, communication, credibility, security, understanding, and tangibles are the 10 essential elements that Parasuraman et al. (1985) [9] initially identified in their study of service quality.

4. Service quality model

Over the years, scholars have presented opposing views on how to quantify perceived service quality, particularly in the banking industry. The SERVQUAL is a well-known model that was created by Parasuraman et al. (1985) [9] to gauge service quality. Out of ten elements identified in earlier exploratory research, five factors related to perceived service quality were chosen via factor analysis in the subsequent work of Parasuraman et al. (1988) [7]. By extending the SERVQUAL model or other comparable models, later researchers have contended that there is no single appropriate scale for assessing perceived service quality [26] [27]. According to the majority of research on perceived service quality in banks, some or most of the elements that make up the concept of perceived service quality are not a valid way to assess customer satisfaction. This study suggested a multiobjective evolutionary algorithm for assessing bank service quality in light of this issue. The SERVQUAL model and its variations are the exclusive focus of the majority of studies on perceived service quality in banks, which results in a measuring scale that may not be a valid indicator of customer satisfaction.

Parasuraman et al. (1988) [7] conducted an exploratory study on the 10 elements that were found and concluded that five factors, which they called the SERVQUAL model, dominate the explanation of perceived service quality. Among these elements are:

- Tangibles: The cleanliness of the workspace and the aesthetic appeal of the surroundings.
- Reliability: The absence of mistakes in service delivery.
- Responsiveness: Being prepared to help clients and providing timely service.
- Assurance: It is the capacity of the staff in an organization to instill a positive reputation and a sense of security in clients.
- Empathy: Giving each consumer individualized attention.

5. Materials and method

The Parasuraman et al. (1988) [7] approach proposed five dimensions of perceived service quality: assurance, responsiveness, empathy, tangible, and dependability. The expectation-perceived service gap serves as the foundation for the service quality (SERVQUAL) paradigm. Perceived service quality is assessed in this study utilizing a well-designed questionnaire that incorporates some of these dimensions as well as customers' perceptions of the services provided. The simple random sampling method was used to reduce bias in population selection. A total of 136 respondents most of whom were between the ages of 46 and 56, were surveyed using a questionnaire method. The decision variables that are most important for assessing the quality of bank services were tested using factor analysis. The factor analysis was used to produce a total of eight (8) components which were then fed into the multiple regression analysis to produce the regression equation. The regression equation was used as objective function into the genetic algorithm optimization (gamultiobj) in MATLAB to select the optimal factors for service quality in banks.

5.1 Materials

A questionnaire approach using random sampling was adopted with well-structured questions based on the modified version of the dimension constructs of Parasuraman et al. (1988) [7]. To evaluate the perceived level of service quality at banks primarily in Lagos State, Nigeria, a five-point Likert scale was used. Six factors consisting of 22 items were utilized to assess customer satisfaction: effectiveness and assurance, access, price, tangibles, service portfolio, and reliability. These factors were derived from the Banking Service Quality (BSQ) [28]. A total of 236 surveys were distributed with 136 valid responses. Male

respondents within 46-56 age range make up the majority of the study sample (61.8%). The collected data was analyzed using MATLAB and SPSS.

5.2. Method

The most significant aspects that can affect customer happiness were identified using factor analysis, multiple regression analysis, and multiobjective optimization in order to provide some degree of confidence to the scale of measurement on service quality in banks. Principle Component Analysis (PCA) was used for factors reduction. The PCA first performed data normalization and calculate eigenvalues for the selection of factors for service quality. Multiple regression analysis in SPSS was used to generate the regression equation that will serve as the objective function for the Genetic Algorithm (GA). The selected factors were prepared and imported into the SPSS for regression analysis. The assumption on the suitability of the data for multiple regression analysis was checked. The dependent and independent variables was defined and the multiple regression was run to generate the regression equation. The GA in MATLAB was then used to get the better factors for assessing service quality in banks. The generated regression equation was written into a MATLAB function and stored in a folder along the MATLAB path. The GA solver in MATLAB was selected and the MATLAB function was invoked into the solver through a function handle. Eight (8) variables were specified as the number of variables and other GA parameter settings in the solver was chosen before running the GA solver. Genetic algorithm was used over other optimization methods because of its superior ability to handle discrete, complex and multiple objective problems. Genetic algorithm was used in this study to effectively handle multiple objective problems simultaneously and returned a set of optimal factors. Figure 1 shows the workflow of the Principal Component Analysis (PCA), Multiple Regression (MR) analysis and Genetic Algorithm (GA).

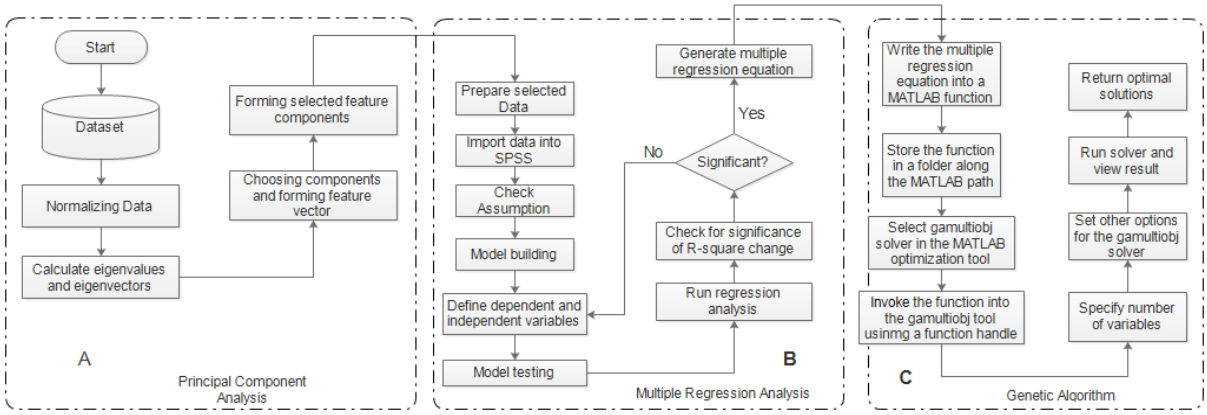

Figure 1: Methodology workflow of the proposed PCA-MR-GA for service quality

5.2.1 Questionnaire

The questionnaire was organized into six (6) major constructs: price, tangibles, service portfolio, reliability, effectiveness and assurance, and accessibility. According to the questionnaire, there are 22 items altogether among these six constructs. Table 2 provides an explanation of these six constructs and their 22 items.

Table 2: Description of decision criteria (six factors, 22 items)

Factors	Items
a. Effectiveness and Assurance	1. The staff at the bank is highly skilled. 2. Their employee show good reputation. 3. No hold-ups because of bureaucratic process and issues. 4. The banks offers a feeling of security. 5. They deliver when promised. 6. No service outages while interacting with customers. 7. The bank has demonstrated an excellent degree of confidentiality.
b. Access	8. An adequate quantity of ATMs in each branch. 9. The bank offers up-to-date equipment. 10. There are enough open tellers. 11. The waiting period is short. 12. Rapidly moving lines.

Factors	Items
c. Price	13. I get contacted by the bank whenever it is helpful. 14.The bank consistently offers thorough justifications for service charges. 15. Fair charges for account management. 16. Notifying clients if a better way to solve an issue arises.
d. Tangibles	17. Accuracy in account records. 18. Facilities at the bank are consistently spotless. 19. The interior of the bank is always adorned.
e. Service portfolio	20. The services offered align with the most recent advancements in financial services. 21. You can be certain that you will receive value for the money you paid.
f. Reliability	22. Lack of mistakes in the provision of services.

5.2.2 Factor analysis

One effective intermediary approach for data reduction is Principal Component Analysis (PCA) [29]. PCA was utilized in this study to extract significant features from the 22 BSQ-based item constructs. Eight (8) elements in total were retrieved, and the regression equation was then generated by using these factors as inputs into multiple regression analysis. Equation (1) shows a linear equation that the PCA uses to produce component score coefficients for evaluating the influence of each decision variable on the assessment of service quality.

$$C_{i,j}=\sum_{k=1}^{\infty} b_{k,j}\, S_{i,k}, \quad i = 1, 2, 3, \dots n \text{ and } j = 1 \tag{1}$$

where n is the number of selected assessors, $S_{i,k}$ is the standard score of the i^{th} assessor for the k^{th} decision variable, $b_{k,j}$ is the component score coefficient of the k^{th} decision variable for the j^{th} factor, and $C_{i,j}$ is the contribution of the i^{th} assessor to the j^{th} factor. $S_{i,k}$ is estimated as fin (2):

$$S_{i,k} = A + \frac{(x_i + y_i)}{d_i} \tag{2}$$

where A stands for the minimum raw score that can be assigned to a decision variable, which in this instance is 1; x_i is the raw score of the i^{th} decision variable; y_i is the mean of the raw scores of the i^{th} decision variable; and d_i is the standard deviation of the raw scores of the i^{th} decision variable. As shown in (3), the system of linear equations for the single extracted factor can be represented for each selected assessor.

$$b_{1,1}S_{i,1} + b_{2,1}S_{i,2} + \dots . + b_{4,1}S_{i,4} = C_{i,1} \tag{3}$$

In order to assess the proportional contribution of each component to the effectiveness of service quality measurement, the eigenvalue of each component is produced. The equation (4) determines the eigenvalue of the j^{th} factor, represented as E_j.

$$E_j=\sum_{k=i}^{\infty} x_{i,j}^2, \quad i = 1, 2, 3; j = 1 \tag{4}$$

where i, j stands for the j^{th} factor loading on the i^{th} decision variable. The degree to which each element matches the experimental data is indicated by the eigenvalue. The equation (5) represents the percentage.

$$P = 100 \left(\frac{E_j}{n}\right) \tag{5}$$

where n is the number of components taken into account in this investigation. The regression equation will be produced by using the collected component factors as input to the multiple regression analysis.

5.2.3 Multiple regression analysis

A regression equation involving the selected factors was produced using multiple regression [30]. The aim of multiple regression in this study is to generate a regression equation showing the linear relationship between the dependent variable and independent variable. This multiple regression equation (6) forms the objective function for the genetic algorithm used for the optimization of the decision variables. A simple regression model uses one independent variable for prediction. In this study, the multiple regression equation is a simple regression modified into two or more independent variables for more complex prediction.

$$Y = a + b_1x_1 + b_2x_2 + \cdots + b_nx_n \tag{6}$$

where Y represents customer satisfaction as the dependent variable, x_i is the independent variable that predicts Y, a denote the intercept of the regression line on the Y-axis, and b_i is the constant coefficient of x and n is the number of factors.

5.2.4 Genetic algorithm

For the genetic method in MATLAB, the fitness function is represented by the regression equation from the multiple regression step. The genetic method was carried out to optimize the factors selected for assessing service quality (See Figure 1C for the flow diagram of the genetic algorithm).

6. Results and Discussion

6.1 Demographic analysis

According to the demographic data analysis (Table 3), 52 respondents (38.2%) of the sample size were female, and 84 respondents (61.8%) of the sample size were male. Additionally, it was noted that 59 (43.4%) of the respondents were in the 46–56 age range which account for most of the respondents, 36-45 years were observed to represent 37 (27.2%) respondents, 26-35 years were observed to represent the least of the total observations with 8(5.9%) and respondent 56- above represent 23(16.9%). The occupation of the respondents also revealed that a larger proportion of the respondents are traders (52 respondents) accounting for a total percentage of 38.2%, 28 (20.6%) are retirees, 34(25.0%) works in private sectors, 9(6.6%) are civil servants, and 13(9.6%) represent a portion of the respondents that do other work. These statistics indicate that larger portions of the study population are traders and business persons.

Table 3: Frequency distribution for Respondents' Demographics

	No of respondent	**Percentage (%)**
Sex		
Male	84	61.8
Female	52	38.2
Age		
56 Above	23	16.9
46- 56yrs	59	43.4
36- 45yrs	37	27.2
26- 35yrs	8	5.9
18- 25yrs	9	6.6
Occupation		
Retiree	28	20.6
Private sector	34	25.0
Civil servant	9	6.6
Trading	52	38.2
Others	13	9.6
TOTAL	**136**	**100**

6.2 Principal component analysis

The decision variables that can be used to assess the perceived level of service quality in banks were extracted using PCA. The Kaiser-Meyer-Olkin (KMO) is a measure of sampling adequacy (MSA) (Table 4) that was used to assess the suitability of the data. Although the MSA does not yield a p-value, any value more than 0.5 is deemed sufficient to proceed with the PCA analysis. With a KMO score of 0.564, which is higher than 0.5, the PCA test can be carried out. Additionally, the significance level of 0.000 indicates that the test can be conducted.

Table 4: KMO and Bartlett's Test

Bartlett's Test of Sphericity	Kaiser-Meyer-Olkin Measure of Sampling Adequacy	.564
	Approx. Chi-Square	1435.171
	Df	231
	Sig.	.000

Table 5 shows the Total Variance Explained which determine how many factors to be extracted by the PCA. A value close to 1 is better for the extracted variables. In this study, eight (8) factors and their eigenvalues were extracted, the percentage of variance attributed to each factor and their respective cumulative.

Table 5: Total Variance Explained

Compo-nent	Initial Eigen value			Extraction Sums of Squared Loading			Rotation Sums of Squared Loading		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.146	23.389	23.389	5.146	23.389	23.389	2.936	13.345	13.345
2	2.460	11.182	34.571	2.460	11.182	34.571	2.670	12.137	25.482
3	2.075	9.432	44.004	2.075	9.432	44.004	2.020	9.183	34.665
4	1.707	7.757	51.761	1.707	7.757	51.761	1.956	8.893	43.558
5	1.429	6.494	58.255	1.429	6.494	58.255	1.900	8.636	52.194
6	1.259	5.723	63.978	1.259	5.723	63.978	1.899	8.630	60.823
7	1.181	5.367	69.345	1.181	5.367	69.345	1.597	7.260	68.083
8	1.131	5.141	74.486	1.131	5.141	74.486	1.409	6.403	74.486
9	.911	4.141	78.627						
10	.729	3.316	81.943						
11	.715	3.249	85.192						
12	.576	2.618	87.810						
13	.522	2.373	90.183						
14	.465	2.115	92.298						
15	.376	1.708	94.005						
16	.305	1.389	95.394						
17	.243	1.106	96.500						
18	.212	.963	97.462						
19	.198	.898	98.361						
20	.169	.769	99.129						
21	.119	.543	99.672						
22	.072	.328	100.000						

Extraction Method: Principal Component Analysis

The scree plot to confirm the number of variables that the PCA will extract is also displayed in Figure 2. The number of components that correspond to the 22 questions in the questionnaire is displayed on the x-axis of the plot, while the y-axis displays the eigenvalues of each component. The scree plot shows points with maximum curves where the line suddenly bends and then levels out at 9 components above. The components to the left of these points with maximum curves determines the numbers of factors to be extracted.

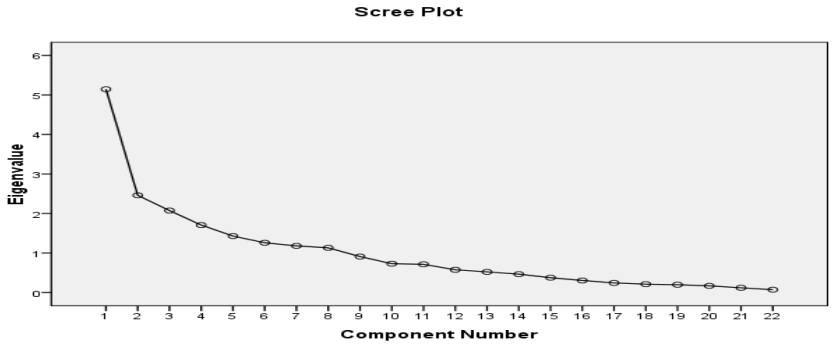

Figure 2: Scree Plot for eigenvalue of the components for PCA

Table 6 shows the principal component extraction of the number of factor solution explained. Factors between 0.7 and above were chosen because their loading on the first and second components suggests their significance to the assessment of service quality. Similarly, the factors within 0.7 and above was selected from other components. Hence, the factors selected in Table 2 based on the rotated component matrix are: Q21, Q8, Q14, Q15, Q5, Q4, Q20, and Q17 representing "You can be certain that you will receive value for the money you paid", "An adequate quantity of ATMs in each branch", "The bank consistently offers thorough justifications for service charges", "Fair charges for account management", "They deliver when promised", "The

banks offers a feeling of security", "The services offered align with the most recent advancements in financial services" and "Accuracy in account records" respectively. The generated component score coefficients in Table 5 are used to estimate the impact of the decision variables on the assessment the value of service in banks.

6.3 Multiple regression

At a significance level of 5%, the suggested perceived service quality model's goodness of fit was evaluated using the F-Test. Additionally, the t-test was utilized to determine the significance of the chosen individual elements, namely Q21, Q8, Q14, Q20, Q5, Q15, Q4, and Q17, from the 136 responses gathered for service quality. In order to manage the problem of overfitting and strengthen the regression results, k-fold (k = 5) cross-validation was used. The training data was randomly divided into 5 equal sized subsets of the dataset. A single subset was used to test the multiple regression model and the remaining 4 subsets were used as training data.

Table 7 shows the coefficient result that provided the general multiple regression equation (7) to predict service quality in banks from Q21, Q8, Q14, Q20, Q5, Q15, Q4, and Q17. The generated multiple regression equation was used as the objective function inside the genetic algorithm of MATLAB to determine the optimal decision variables for the assessment of the quality of service in banks. Unstandardized coefficients column shows the degree of variance of dependent variable with an independent variable when all other independent variables remain constant. The "**Sig.**" column is used to test the significance of the independent variables for service quality. The "**Sig.**" column indicate that not all independent variable coefficients are statistically significant for the assessment of service quality in banks.

Table 6: Rotated Component Matrix[a]

	Components							
	1	2	3	4	5	6	7	8
An adequate quantity of ATMs in each branch	.795							
Accuracy in account records	.735				.451			
Rapidly moving waiting lines	.674					.340	-.332	
I get contacted by the bank whenever it is helpful	.625							
They deliver when promised		.833						
No service outages while interacting with customers		.669						
There are enough open tellers		.609		.390		.361		
Facilities at the bank are consistently spotless		.590			.390			
The interior of the bank is always adorned		.532		-.495				-.326
The banks offers a feeling of security			.798					
The bank consistently offers thorough justifications for service charges			.722					
No hold-ups because of bureaucratic process and issues			.597					-.505
Fair charges for account management				.818	.347			
Notifying clients if a better way to solve an issue arises	.393			.650				
The services offered align with the most recent advancements in financial services					.750			
You can be certain that you will receive value for the money you paid					.708			
The bank offers up-to-date equipment.						.851		
Their employees show good reputation			.468			.601	.369	
The waiting period is short		.351		.438		.508		
The staff at the bank is highly skilled							.814	
The bank has demonstrated an excellent degree of confidentiality	.428						.581	
Lack of mistakes in the provision of services								.801

$$Y = -34.159 + 2.853x(1) + 1.018x(2) + 0.001x(3) + 0.075x(4) + 0.014x(5) + 0.614x(6) + 0.480x(7) + 0.194x(8) \quad (7)$$

where

Y = service quality, $x(1)$ = Q4, $x(2)$ = Q5, $x(3)$ = Q8, $x(4)$ = Q14, $x(5)$ = Q15, $x(6)$ = Q17, $x(7)$ = Q20 and $x(8)$ = Q21.

Table 7: Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
1 (constant)	-34.159	.141		-242.515	.000	-34.435	-33.883
Q4	2.853	.008	.384	362.325	.000	2.837	2.868
Q5	1.018	.001	.919	866.371	.000	1.016	1.021
Q8	.001	.001	.001	1.124	.261	.000	.002
Q14	.075	.070	.001	1.069	.285	-.063	.213
Q15	.014	.070	.000	.199	.843	-.123	.151
Q17	.614	.041	.016	15.043	.000	.534	.693
Q20	.480	.012	.042	39.960	.000	.457	.504
Q21	.194	.007	.029	27.248	.000	.180	.208

a. Dependent Variable: SERVQUAL

Table 8 show the model summary of the developed multiple regression model. The "R" column represents the multiple correlation coefficient that measure the quality of service in banks. A value of 0.994 indicates a good level of prediction for quality of service in banks. Table 8 also demonstrated that the p-values of the independent variables are significant at 0.000 and well-suited to the suggested service quality model. This suggests that every variable is making a substantial contribution to the suggested service quality model. The R^2 column indicate that the independent variables Q21, Q8, Q14, Q20, Q5, Q15, Q4, and Q17 together account for 98.9% of the information regarding the service quality model. Similarly, the adjusted $R^2 = 0.989$ shows that the independent variables of the regression model explain 98.9% variation of the dependent variable and that just 1.1% remains unexplained.

Table 8 also show the Durbin-Watson test to verify that the observations in the multiple regression are independent. The purpose of the test is to validate that successive observations are not related or autocorrelated. The normal result for the Durbin-Watson test should be between 1.5 and 2.5. The model summary showed that the Durbin-Watson test is 2.001 which is between 1.5 and 2.5 and therefore the data is not autocorrelated.

Table 8: Model Summary

Model					Change Statistics					Durbin-Watson
	R	R^2	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	
1	0.994[a]	0.989	0.989	2.038	0.989	109812.494	8	127	0.000	2.001

a. Predictors: (Constant), Q21, Q8, Q14, Q20, Q5, Q15, Q4, Q17

6.4 Genetic algorithm

The genetic algorithm optimization (gamultiobj) in MATLAB was used to arrive at the final optimal factors for service quality in banks. The multiple regression equation in (7) was written into a M-file definition in MATLAB for the solution of the optimization problem for service quality in banks. The M-file for the script code written from the multiple regression equation is shown in (8). It is to be noted that minus sign was added to the original generated regression equation to denote maximization problem. This is because the optimization problem is to maximize the decision variables to make a final selection of the most important variables for the assessment of quality of service in banks. Fitness function y was stored in a folder along the MATLAB path after the M-file was written in the M-code format. The function was then invoked using a function handle in the gamultiobj optimization tool.

```
function y = quality(x)
y = -(-34.159 + 2.853*x(1)+ 1.018*x(2)+ 0.001*x(3)+
0.075*x(4)+ 0.014*x(5)+ 0.614*x(6)+ 0.480*x(7)+ 0.194*x(8));
```

(8)

Figure 3 shows the problem setup and results of the genetic algorithm optimization with the final function values of all the eight (8) decision variables. The generated regression equation was written into a MATLAB function and stored in a folder along the MATLAB path. The GA solver in MATLAB was selected and the MATLAB function was invoked into the solver through a function handle. Eight (8) variables were specified as the number of variables and other GA parameter settings in the solver was chosen before running the GA solver. The GA parameter settings include: population size (100), crossover rate (0.35), mutation rate (0.01), and generations (1000).

The optimization outputs produce four (4) optimal solutions of the individual decision variables (Table 9). The items Q5, Q17, Q20 and Q21 were selected based on their optimal fitness values. These items are: "they deliver when promised", "accuracy in account records", "services offered align with the most recent advancements in financial services", and "you can be certain that you will receive value for the money you paid" represents the optimal factors to assess service quality in banks. In other word, factors effectiveness & assurance, tangibles, and service portfolio are the most optimal factors to assess the quality of service in banks.

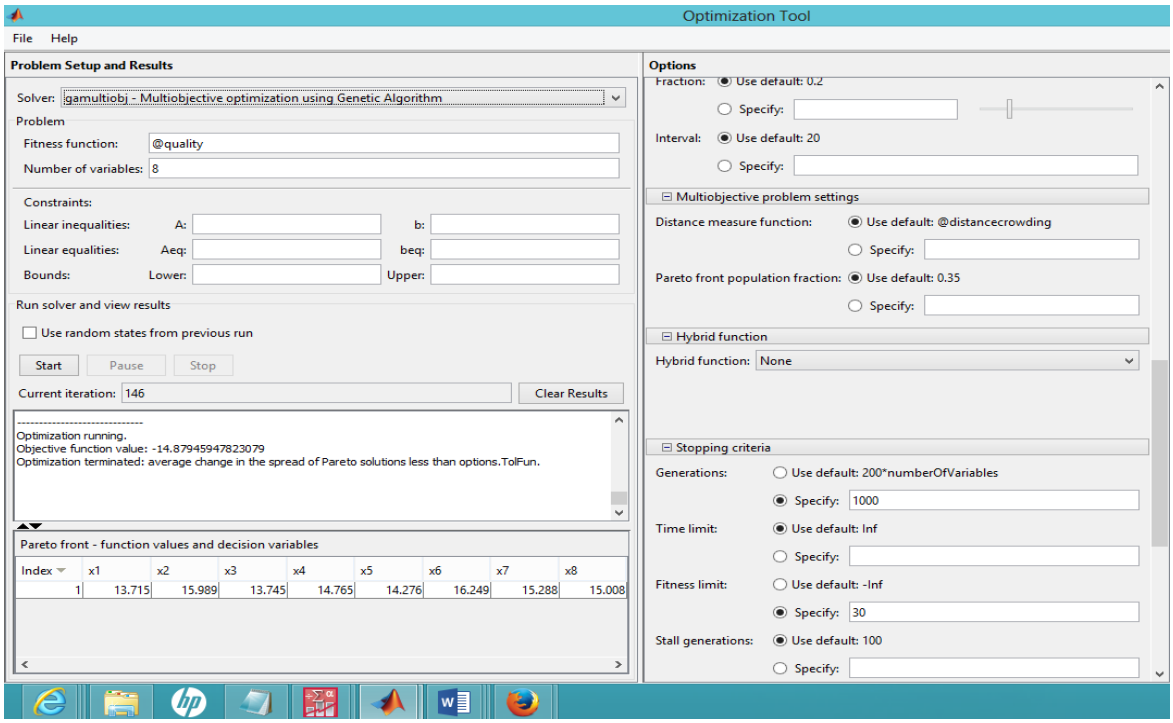

Figure 3: GA results of the optimization tool in MATLAB for measuring service quality in banks

Table 9: Fitness values and decision variables

Individual (x)	Fitness value	*f(x)*
1	13.715	1.7143750000000009
2	15.989	1.998625000000001
3	13.745	1.7181250000000008
4	14.765	1.845625000000001
5	14.276	1.7845000000000009
6	16.249	2.0311250000000007
7	15.288	1.911000000000001
8	15.008	1.8760000000000008

7. Conclusion

In this study, 22 factors were taken into consideration to assess the quality of bank services. The difference between expected and perceived bank service was determined using the SERVQUAL, which is based on the BSQ model. Data was gathered using the questionnaire method. To determine which of the decision variables are the primary determinants of service quality in banks, the study employed factor analysis. At the 5% level of significance, the goodness of fit of the suggested perceived service quality model was evaluated using the F-Test. Additionally, the significance of the chosen individual variables was examined using the t-test. In order to create the regression equation, the factor analysis retrieved a total of eight (8) elements, which were then fed into the multiple regression analysis in SPSS. In order to determine the best factors for bank service quality, the created regression equation was then utilized as the objective function in the MATLAB genetic algorithm optimization. Each of the criteria that were chosen had a significant p-value in the results. The analysis showed a significant p-value for each of the selected factors. The findings also show that tangibles, service portfolio, and efficacy and assurance are the best factors to assess the quality of bank services. Although several frameworks for assessing service quality have been proposed in earlier work, none of them have been able to apply the concept of optimization to the choice of decision variables for service quality. This study has been able to come up with new construct that produces optimal decision variables for service quality in banks. In the future, the study will validate the proposed model using larger and cross-country samples, and assess whether other optimization algorithms can further enhance the selection of service quality indicators.

8. Acknowledgements

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9. Declarations

9.1 Ethics approval and consent to participate

Not applicable.

9.2 Consent for publication

Not applicable.

9.3 Availability of Data and Materials

Data will be provided upon receiving a valid request.

9.4 Conflicts of interest

The authors declare that there is no conflict of interest.

9.5 Funding

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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خوارزمية جينية متعددة الأهداف لتقييم عوامل جودة الخدمة في البيئة المصرفية

فيمي إيمانويل أيو [1*] ، تولا جون أودولي [2]، لقمان أديبايو أوجونديلي [3]، ساكينات أولوابوكونلا فولورونسو [4]، إيمانويل فيمي أولوغونليكو [5]

قسم علوم الحاسوب، كلية العلوم، جامعة أولابيسي أونابانجو، آجو إيوي، ولاية أوجون، نيجيريا [1،2،3،4]

قسم الإحصاء، كلية العلوم، جامعة أولابيسي أونابانجو، آغو إيوي، ولاية أوجون، نيجيريا [5]

تقترح هذه الدراسة إطار عمل متعدد الأهداف قائم على الخوارزمية الجينية لتحسين المحددات الرئيسية لجودة الخدمة في البيئات المصرفية، متجاوزةً بذلك قصور نموذجي SERVQUAL و BSQالتقليديين. تستخدم الدراسة البنوك النيجيرية كدراسة حالة لتوفير مقياس موثوق لجودة الخدمة في البنوك. وقد شكّل نموذج BSQ الأساس لنموذج SERVQUAL المُعتمد. استُخدم مقياس ليكرت خماسي النقاط في استبيان موحد، وجُمعت 136 إجابة صالحة. بناءً على نموذجBSQ ، أُخذ 22 بندًا في الاعتبار، وجرى فحص أهمية هذه العوامل لرضا العملاء. استُخرجت أهم المعايير لتقييم جودة الخدمة باستخدام تحليل العوامل. وفقًا لتحليل العوامل الرئيسية، اختيرت ثمانية (8) بنود لقياس مدى جودة الخدمات المُدركة في البنوك. استُخدمت الخوارزمية الجينية في برنامج MATLAB لصياغة دالة الهدف لتحليل الانحدار المتعدد على البنود المختارة. جرى تقييم مدى ملاءمة نموذج جودة الخدمة المُطور باستخدام اختبار .F لتحديد مدى أهمية كل عنصر من عناصر جودة الخدمة المختارة، تم استخدام اختبار .t وأظهرت النتائج دلالة إحصائية، وكانت متوافقة تمامًا مع نموذج جودة الخدمة المتقدم. وتم استخدام خوارزمية جينية لإيجاد المتغيرات الأكثر دقة لتقييم مستوى جودة الخدمة المُدرك في البنوك. وأظهرت النتائج أن أفضل عناصر جودة الخدمة في البنوك هي: "الوفاء بالوعود"، و"دقة سجلات الحسابات"، و"مواكبة الخدمات المقدمة لأحدث التطورات في الخدمات المالية"، و"ضمان الحصول على قيمة مقابل المال المدفوع". وتشير النتائج إلى أن الملموسات، ومجموعة الخدمات، والفعالية والضمان هي أفضل الطرق لتقييم جودة الخدمات المصرفية.