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Article

A Six Sigma and DEA Framework for Quality Assessment in Banking Services

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Abstract: This study proposes a methodology that combines Six Sigma and Data Envelopment Analysis (DEA) to measure the quality of banking services. The proposed framework emphasizes seven essential quality dimensions: prompt response, efficient channels, fraudulence, processes, dependable service, credibility, customer satisfaction, and risk management. Integrating both techniques enables a holistic approach to quality evaluation and provides valuable information for the banking industry's continual improvement. To validate the properties of the methodology, we developed a case study involving 25 Colombian banks. Using Six Sigma metrics, DEA models, and slacks analysis, the results provide a comprehensive study of the quality performance, identifying each bank's relative strengths and weaknesses in several quality dimensions. The data indicate that some banks perform better on quality characteristics such as customer happiness, dependable service, and procedures. However, this study also reveals a promising finding: banks still have the potential for development, particularly in their response time, channel efficiency, fraud, and credibility, offering hope for the future of banking services.

Keywords: six sigma; DEA; efficiency; quality dimensions; banking service

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1. Introduction

The banking industry has long been at the forefront of implementing creative strategies to enhance the quality and effectiveness of its services (Gonzalez-Ruiz et al. 2024). As the financial sector faces increased competition and regulatory scrutiny, the need for dependable and efficient quality assessment methodologies has grown in recent years. In this context, two well-known approaches known as Six Sigma and Data Envelopment Analysis (DEA) have emerged as essential instruments for analyzing and improving the performance of financial services. This study seeks to investigate the implementation of these approaches in evaluating the quality of banking services, shedding light on their effectiveness in promoting service enhancements and customer satisfaction.

Six Sigma, a systematic and data-driven approach to process improvement, originated in the manufacturing sector and has since been adopted by various industries, including banking (Sreedharan et al. 2020). Six Sigma has been implemented in financial services to improve process efficiency, minimize errors, and increase customer satisfaction (Laureani and Antony 2018). By employing statistical tools to reduce process variability, Six Sigma enhances the quality of products and services (Sunder M. et al. 2019).

Conversely, Data Envelopment Analysis (DEA) is a non-parametric technique that compares the input–output ratios of decision-making units (DMUs) to determine their relative efficiency (Charnes et al. 1978). DEA has been utilized across various industries,

including banking, to assess and compare the performance of different units, branches, or services (Fukuyama and Matousek 2017). Previous research has highlighted the potential of DEA in identifying best practices, allocating resources, and setting performance improvement goals in the banking industry (Ouenniche and Carrales 2018).

Although Six Sigma and DEA have been independently implemented to evaluate and enhance financial services, a detailed analysis of their combined use to measure service quality is still lacking. This research aims to fill this gap by exploring the integration of Six Sigma and DEA within the banking assessment framework, establishing a comprehensive framework for assessing and enhancing service quality.

To achieve this, the study sets out to develop a framework incorporating both Six Sigma and DEA methodologies. This framework will provide a holistic approach to boosting service performance, fostering customer satisfaction, and ultimately contributing to the success of financial institutions. This framework will be tested using empirical data from a selection of banks, demonstrating its applicability and usefulness for evaluating service quality and identifying areas for improvement.

Consequently, the research hypothesis is guided by the following statement: The integration of Six Sigma and DEA approaches significantly improves service quality in the banking sector by providing a more robust framework for measurement and continuous improvement. This is guided by several key questions: How have the Six Sigma and DEA approaches been applied separately to assess the quality of financial services? What are the potential synergies and obstacles associated with the integration of Six Sigma and DEA to measure service quality in the banking sector? How can a comprehensive framework incorporating the Six Sigma and DEA approaches be developed to analyze and improve the service quality in financial services?

2. Theoretical Framework

Examining the integration of Six Sigma and DEA approaches within the banking industry requires a comprehensive investigation of relevant theoretical frameworks.

2.1. Six Sigma in Banking Services

The banking industry has been extensively researched in terms of implementing Six Sigma methodologies which are known for increasing process efficiency, reducing errors, and improving customer satisfaction (Sunder M. et al. 2019). Another study (Zuluaga-Ortiz et al. 2022) examined the preparedness variables for implementing Lean Six Sigma in higher education institutions, emphasizing the importance of creating a DMAIC method (DMAIC: Define, Measure, Analyze, Improve, and Control) for assessing academic efficiency. Recognizing the critical success criteria for adopting Six Sigma allows banks to overcome obstacles and reap the benefits. A further study (Sunder M. and Ganesh 2020) identified senior management commitment, organizational culture, and training as critical variables for implementing Six Sigma in the banking industry. Similarly, (Vashishth et al. 2019) conducted a systematic literature study and provided a comprehensive framework of crucial success factors for applying Six Sigma in the financial services industries, including banking.

2.2. Data Envelopment Analysis (DEA) in Banking Services

Data Envelopment Analysis (DEA) has been widely used in the banking industry to assess the performance of banks and their branches (Paradi and Zhu 2013). In a 1978 research study by Charnes, Cooper, and Rhodes, the authors introduced the DEA approach to evaluate the performance of decision-making units. Since then, numerous academics, including those studying commercial banks, have utilized DEA to assess the efficiency of banks (Zha et al. 2016; Avkiran 2015). DEA allows for benchmarking and identifying best practices, which can lead to improved performance and resource allocation (Visbal-Cadavid et al. 2017).

DEA has been employed to evaluate efficiency in various banking subsectors, such as commercial banks (Xu and Zhou 2020), credit unions (Dia et al. 2022), and microfinance institutions (Fall et al. 2018). These research studies have evaluated the effectiveness of banks, identified performance indicators, and supplied valuable insights for decision makers in the banking industry.

2.3. Integration of Six Sigma and DEA

The combined application of Six Sigma and DEA (Data Envelopment Analysis) has been studied in various industries, including the financial services, manufacturing, healthcare, and education. While these two methodologies have been used individually, there has been minimal research on their combined application. One study (Ouenniche and Carrales 2018) used Six Sigma and DEA to assess the effectiveness of UK commercial banks, leading to insights into bank performance and improvement opportunities.

In the Indian automobile sector, (Swarnakar et al. 2021) demonstrated that the combined application of Six Sigma and DEA increased productivity and customer satisfaction. Similarly, (Delahoz-Dominguez et al. 2022) assessed the efficiency of academic processes in universities using the integrated method, highlighting the potential for process improvement and resource optimization.

Integrating Six Sigma and DEA can be challenging due to the differences in their fundamental ideas and procedures. It is essential to understand the advantages and disadvantages of each method and how they might complement one another for effectively implementing an integrated strategy (Zuluaga-Ortiz et al. 2023).

After reviewing the relevant literature, it is evident that there is a growing interest in implementing Six Sigma and DEA in the banking industry. However, there has been limited research on the combined use of these two techniques in assessing the quality of financial services. This study addresses this gap by investigating how Six Sigma and DEA can be used to assess and improve banking service quality. This research intends to develop a comprehensive framework for enhancing service performance, promoting customer satisfaction, and contributing to financial institutions' success by leveraging the strengths of both techniques.

3. Results

Table 1 provides an analysis of the Six Sigma metrics—specifically Yield and Sigma Level (Z)—across various quality dimensions in the banking services, offering critical insights into the effectiveness of these services. The yield reflects the percentage of services that are delivered correctly without defects, serving as a direct measure of service quality. Higher yield values indicate a greater proportion of error-free services, which is closely associated with higher customer satisfaction and service efficiency. For instance, the dimensions "Fast Answer" and "Procedures" exhibited the highest yield, exceeding 99%, suggesting that these areas are managed with exceptional precision, leading to superior service delivery.

Sigma Level (Z) quantifies the frequency of defects within a process, with higher sigma levels indicating fewer defects and, consequently, better process performance. In the context of banking services, a high sigma level signifies that the bank consistently delivers high-quality services with minimal errors. "Fast Answer" and "Procedures" not only showed the highest yields but also boasted sigma levels above 4.5, indicating that these processes are nearly defect-free and highly reliable.

In contrast, dimensions such as "Reliable Service" and "Efficient Channels" showed the lowest sigma levels which fell below 3, and yields below 90%. These figures suggest that these areas are more prone to errors and inconsistencies, which could detract from the overall customer experience. A sigma level below 3 typically indicates a need for significant improvement to meet the desired quality standards.

The Six Sigma metrics presented in Table 1 underscore the varying degrees of service quality across different dimensions of the banking services. Banks that achieve higher sigma

levels and yields are better positioned to provide consistent, high-quality services that meet or exceed customer expectations. Conversely, dimensions with lower metrics indicate those areas requiring focused improvement to enhance service quality, reduce the incidence of errors, and ultimately increase customer satisfaction and trust in the bank's services.

Table 1. Six Sigma metrics by quality dimension.

Yield	Sigma Level Z	DPMO	Quality Dimensions
0.99	4.65	793.62	Timely response
0.93	2.98	69,030.34	Efficient channels
0.98	3.67	14,723.81	Fraudulence
0.99	4.85	399.38	Procedures
0.86	2.59	137,155.79	Reliable service
0.91	2.84	89,747.15	Credibility
0.96	3.34	32,800.90	Customer satisfaction

Table 2 comprehensively compares the Six Sigma metrics and DEA efficiency scores for 25 banks, offering valuable insights into their operational quality and efficiency. The Six Sigma metrics, including Yield and Sigma Level (Z), measure the quality of service delivery by quantifying the proportion of services correctly performed and the capability of the process to operate without defects. Banks with higher sigma levels, such as Bank_23 (3.84) and Bank_19 (3.62), demonstrated their superior quality with high yields of 95%. Conversely, banks like Bank_24 (2.71) and Bank_25 (2.81) exhibited lower sigma levels and yields, indicating a higher frequency of service errors and overall their lower quality.

The DEA analysis further evaluates the banks' operational efficiency using three key scores: Constant Returns to Scale (CRS), Variable Returns to Scale (VRS), and Scale Efficiency. CRS measures the efficiency of a bank assuming that the output increases proportionally with an increase in inputs. VRS, on the other hand, accounts for variations in efficiency when the proportionality between inputs and outputs is not maintained, making it a more flexible and realistic measure of efficiency for banks of different sizes. Scale Efficiency compares the efficiency under CRS with that under VRS, indicating whether the bank is operating at its most productive scale size.

Banks such as Bank_2, Bank_3, Bank_4, and Bank_19 exhibited perfect efficiency under both CRS and VRS, with scores of 1 across all categories. This indicates that these banks are efficient in their operations and operate at an optimal scale, maximizing their resource utilization and service delivery capabilities. In contrast, banks like Bank_5 and Bank_7, which had slightly lower scores under both CRS and VRS, face minor inefficiencies, suggesting room for improvement in operational practices to enhance efficiency.

The Scale Efficiency score further reveals whether a bank operates at its ideal scale. While most banks maintain high scale efficiency, indicating that they effectively utilize their scale of operations, some, such as Bank_13 (0.85) and Bank_17 (0.9), showed lower scale efficiency. This suggests that these banks may not operate at the optimal scale, potentially leading to inefficiencies that could impact their overall service quality.

The combined analysis of Six Sigma metrics and DEA scores underscores the relationship between operational efficiency and service quality in the banking sector. Banks that maintain high-efficiency levels under both CRS and VRS, along with strong sigma metrics, are better positioned to deliver high-quality services with minimal errors. Conversely, banks with lower efficiency and sigma levels may struggle to meet service quality expectations, highlighting the importance of optimizing operational processes and scale to enhance overall performance.

Table 2. Six Sigma metrics and Efficiency Scores.

Efficiency Scores (DEA)			Six Sigma Metrics		
Scale Efficiency	**VRS**	**CRS**	**Sigma Level (Z)**	**Yield**	**Banks**
1	0.98	0.98	3.56	0.95	Bank_1
1	1	1	3.3	0.94	Bank_2
1	1	1	3.22	0.92	Bank_3
1	1	1	3.53	0.95	Bank_4
0.99	0.97	0.96	3.55	0.95	Bank_5
1	0.99	0.99	3.34	0.94	Bank_6
0.99	0.94	0.94	3.6	0.95	Bank_7
1	1	1	3.52	0.94	Bank_8
1	1	0.99	3.35	0.93	Bank_9
0.95	0.96	0.91	3.35	0.93	Bank_10
0.99	0.98	0.97	3.53	0.94	Bank_11
0.96	0.92	0.88	3.61	0.94	Bank_12
0.85	0.95	0.81	2.67	0.86	Bank_13
0.94	0.93	0.87	3.3	0.91	Bank_14
1	1	1	3.47	0.94	Bank_15
1	1	1	3.54	0.95	Bank_16
0.9	0.97	0.87	3.55	0.93	Bank_17
1	0.99	0.98	3.31	0.92	Bank_18
1	1	1	3.62	0.94	Bank_19
1	1	1	3.32	0.91	Bank_20
1	1	1	2.84	0.9	Bank_21
0.91	0.94	0.86	3.31	0.92	Bank_22
1	1	1	3.84	0.95	Bank_23
1	1	1	2.71	0.83	Bank_24
0.91	1	0.91	2.81	0.88	Bank_25

4. Materials and Methods

4.1. Data

The study database, published by the Colombian government, includes 948,673 requests, complaints, and claims submitted to Colombian banks between 2019 and 2022 (Datos.gov.co 2022). Table 3 shows the characterization of the Colombian banks. Thus, in terms of ownership, 80% of the banks are privately owned, while only 4% are public (Banagrario being the sole public institution). Additionally, 32% of the banks are international, such as BBVA and Citibank, while the majority, 68%, are domestically owned. Regarding size, 32% of the banks are classified as large, 28% as medium sized, and 40% as small, indicating a significant presence of both large, established institutions and smaller, specialized banks.

In terms of their geographical focus, 64% of the banks operate primarily in urban areas, while 36% extend their services to both urban and rural regions, reflecting an effort by certain banks to reach underserved populations outside of the major cities. Service offerings also vary, with approximately 52% of the banks focusing on general personal and corporate banking services, 28% specializing in microfinance and microcredit, and the remaining 20% providing specialized services such as cooperative banking or consumer credit.

The public vs. private distribution is heavily skewed towards private ownership, with 96% of the banks being privately owned, emphasizing the dominance of private institutions in Colombia's banking sector. In terms of their client focus, 52% of the banks cater to a general customer base, while 32% are dedicated to microenterprises, and 8% focus on cooperatives. Additionally, 8% of the banks primarily target high-profile clients, offering more exclusive services. Finally, asset distribution shows that 40% of the banks have assets of $10 billion or more, highlighting their large-scale operations, while the remaining 60% of banks are smaller, with assets under $10 billion.

Table 3. Characterization of the sample of 25 Colombian banks.

Approximate Assets (USD)	Client Focus	Public/Private	Type of Services	Size	Ownership	Bank
$7 billion	General	Private	Savings and consumer banking	Medium	National	Bank_1
$15 billion	Agricultural sector	Public	Agricultural loans, savings	Large	National	Bank_2
$1 billion	Microenterprises	Private	Microfinance	Small	National	Bank_3
$5 billion	Low-income sectors	Private	Social banking	Medium	National	Bank_4
$30 billion	General	Private	Mortgage, personal, business banking	Large	National	Bank_5
$50 billion	General	Private	Personal, business banking	Large	National	Bank_6
$15 billion	General	Private	Commercial and personal banking	Large	National	Bank_7
$2 billion	General	Private	Consumer credit	Small	International	Bank_8
$4 billion	General	Private	Corporate and personal banking	Medium	International	Bank_9
$1 billion	Microenterprises	Private	Microfinance	Small	National	Bank_10
$3 billion	General	Private	Personal banking, microenterprises	Medium	International	Bank_11
$10 billion	General	Private	Loans, savings, investments	Medium	National	Bank_12
$20 billion	General	Private	Personal, business banking	Large	International	Bank_13
$500 million	General	Private	Consumer banking	Small	National	Bank_14
$1 billion	Microenterprises	Private	Microcredit	Small	National	Bank_15
$60 billion	General	Private	Personal, business banking	Large	National	Bank_16
$1 billion	Microenterprises	Private	Microfinance	Small	National	Bank_17
$500 million	Cooperatives	Private	Cooperative banking	Small	National	Bank_18
$18 billion	General	Private	Personal, business banking, insurance	Large	International	Bank_19
$25 billion	High-profile clients	Private	Personal and corporate banking	Large	International	Bank_20

Table 3. *Cont.*

Approximate Assets (USD)	Client Focus	Public/Private	Type of Services	Size	Ownership	Bank
$500 million	Cooperatives	Private	Cooperative banking, microcredit	Small	National	Bank_21
$800 million	General	Private	Auto financing	Small	National	Bank_22
$20 billion	High-profile clients	Private	Personal and corporate banking	Large	International	Bank_23
$1 billion	General	Private	Personal and corporate banking	Small	International	Bank_24
$500 million	Microenterprises	Private	Microcredit	Small	International	Bank_25

Table 4 presents the number of complaints reported for the banks in this study. The data reveals a significant range in the volume of complaints, suggesting varying levels of customer dissatisfaction or service issues among the banks.

Table 4. Complaints by DMUs.

Complaints	Bank	Complaints	Bank
11.929	Bank_20	149.944	Bank_16
9.837	Bank_9	126.656	Bank_6
9.018	Bank_18	98.033	Bank_19
6.060	Bank_14	92.592	Bank_5
5.041	Bank_3	55.914	Bank_1
2.826	Bank_10	48.376	Bank_12
2.612	Bank_15	47.358	Bank_8
2.215	Bank_17	36.374	Bank_7
576	Bank_13	33.158	Bank_23
421	Bank_21	24.028	Bank_4
394	Bank_24	20.616	Bank_11
146	Bank_25	17.471	Bank_2
		16.816	Bank_22

4.2. Six Sigma Implementation

In this study, the Six Sigma methodology was implemented to analyze complaints and evaluate the performance of the banks studied. Thus, all the values that the variable can take were analyzed and grouped according to how they were related in quality dimensions; within the quality dimensions, each value is called an error opportunity (see Table 5).

Consequently, the bank's performance was assessed by calculating the Sigma Z level, the Defects Per Million Opportunities (DPMO) and the performance of each dimension.

The same evaluation was carried out this time for each of the banks individually, considering only the complaints filed with them and the quality dimensions that arose from those complaints based on those already defined in the first step.

Table 5. Six Sigma metrics conceptualization.

Formula	Description	Concept
Not applicable	When evaluated, quality components provide a helpful framework that helps define, analyze and measure the extent to which quality standards and procedures are met.	Quality dimensions
Not applicable	Number of opportunities a unit has to present defects	Opportunities for error
$\sum Numberofcomplaintsbelonging\ aQualityDimension.$	Number of complaints belonging to a Quality Dimension	Unsatisfactory services
$\sum Complaints$	Total number of complaints	Number of services evaluated
$\frac{Unsatisfactoryservices}{Evaluatedservices \times Opportunitiesforerror} \times 1.000.000$	Defects Per Million Opportunities. It is an index that expresses how a process behaves based on the number of defects detected. The DPMO standardizes the number of defects at the opportunity level, which is helpful because it allows for comparing processes with different complexities.	DPMO
$\text{DISTR. NORM. STAND. INV}\left(1 - \frac{Unsatisfactoryservices}{Evaluatedservices \times Opportunitiesforerror} + 1.5\right)$	Measure the variation that the data has around the average. It tells us how well a process performs; the larger it is, the better the process will perform and the less chance of errors occurring.	Sigma Z level
$1 - \frac{Unsatisfactoryservices}{Numberofservicesevaluated \times Opportunitiesforerror}$	It is the probability that an item is free of failures or defects	Yield

4.3. Quality Dimensions

Table 6 displays the quality dimensions used to evaluate the quality of financial services together with the accompanying error for opportunities. This table groups 185 unique causes into seven quality aspects, accounting for 20 error opportunities. Each error opportunity in Table 6 reflects the critical aspects of banking operations that, if not managed properly, can lead to significant risks and consequences. Starting with timely response, delays in payments and procedures are essential to address, as they directly impact customer satisfaction and trust. When customers experience delays in payments, they may face financial penalties or miss out on opportunities, which can result in frustration and a loss of confidence in the bank. Similarly, delays in procedures such as loan approvals or account openings can cause customers to seek out more efficient competitors, leading to lost business.

Efficient channels—both physical (branches, ATMs) and magnetic (online banking, card transactions)—are vital for seamless customer interactions. Failures in these channels can lead to long wait times, transaction delays, and a diminished customer experience. Moreover, with increasing reliance on digital banking, failures in magnetic channels can raise security concerns and disrupt access to funds, impacting the bank's reputation and leading to customer attrition.

Fraudulence, particularly in the form of impersonation and counterfeit bills or checks, poses a major threat to both the bank and its customers. Impersonation can lead to unauthorized transactions and significant financial losses, while counterfeit currency undermines trust and exposes the bank to legal liabilities. Implementing robust fraud prevention mechanisms is crucial for safeguarding customer assets and maintaining operational integrity.

Procedures—including clarity in processes and requirements—are essential for legal compliance and operational consistency. Errors or ambiguities in procedures can create inefficiencies, leading to rejected applications or delayed approvals. These lapses not only

cause frustration among customers but also expose the bank to regulatory penalties and reputational harm.

Reliable service, characterized by providing accurate information and proper attention, is foundational to maintaining customer trust. Incorrect information can lead to poor financial decisions for customers, while improper attention can leave issues unresolved, leading to dissatisfaction and customer loss. A reliable service model is critical to maintaining long-term relationships with clients and avoiding potential legal repercussions.

Credibility is another vital dimension, as errors related to contractual breaches, payment application, and product management can severely damage a bank's standing. Issues like denial in payment applications, errors in discounts, or non-cancellation of products can lead to customer dissatisfaction, loss of loyalty, and even legal disputes. Maintaining credibility ensures not only customer retention but also compliance with industry standards and regulations.

Finally, customer satisfaction, encompassing areas such as reliefs, investments, social benefits, and commerce-related transactions, is a comprehensive measure of a bank's success in meeting customer needs. Errors in these areas can cause financial loss or legal complications for customers, directly affecting their loyalty and trust in the bank. Ensuring accuracy and responsiveness in these services is essential for fostering strong customer relationships and enhancing the bank's reputation.

Table 6. Quality dimensions and opportunities for error.

Error Opportunity	Quality Dimensions
Delay in payments	Timely response
Delay in procedures	
Physical channel failures	Efficient channels
Magnetic channel failures	
Impersonation	Fraudulence
Counterfeit bills and checks	
Procedures	Procedures
Requirements	
Incorrect information	Reliable service
Improper attention	
Contractual breaches	Credibility
Denial in the application of payments and opening of products	
Payment and discount errors	
Non-cancellation of products or unjustified cancellation	
Reliefs and supports	Customer satisfaction
Investments	
Social benefits	
Liens, titles, and orders	
Commerce	
Settlement	

4.4. Method

This study's methodology included the phases outlined below: A. Apply the DMAIC framework to examine the observed inefficiencies, including identifying problem areas, measuring key performance indicators (KPIs), analyzing root causes, implementing improvement measures, and installing control mechanisms. B. Calculate the relative efficiency

of the sample banks based on their input–output ratios by doing a DEA analysis utilizing the Constant Return to Scale (CRS) and Variable Return to Scale (VRS) models. C. Identify ineffectiveness: Based on the DEA analysis results and the slacks, identify inefficiencies in the banks with the lowest efficiency ratings.

This research intends to illustrate the combined use of the Six Sigma and DEA techniques in assessing and enhancing the quality of banking services. The outcomes will give a solid framework for improving service performance, encouraging customer happiness, and contributing to the success of financial institutions.

5. Discussion

Previous research has demonstrated the significance of quality management in the banking industry and its effect on customer satisfaction, loyalty, and financial success (Supriyanto et al. 2021; Raza et al. 2020). The findings of this study give a complete evaluation of the quality performance of 25 banks in Colombia. Utilizing Six Sigma measurements, DEA models, and slacks analysis, it was feasible to determine each bank's relative quality strengths and weaknesses. The data indicate that certain banks perform better regarding quality characteristics such as satisfaction, dependable service, and processes. However, most banks still have the potential for development, notably in response time, channel efficiency, fraud, and credibility.

Using the Six Sigma metrics, such as DPMO and sigma level, allowed us to benchmark the quality performance of each bank against a global standard and set ambitious improvement targets. However, the results showed that most banks are far from achieving Six Sigma levels, indicating their processes are not as efficient and effective as possible. Therefore, there is a need for continuous quality improvement initiatives that involve all employees and stakeholders, such as Lean Six Sigma, Total Quality Management, or ISO standards (Grima et al. 2014; Antony et al. 2016).

The DEA models and slacks analysis provided a different perspective on quality performance, as they measured the relative efficiency of each bank in using their re-sources to deliver quality services. The results showed that some banks are more efficient in using their inputs to generate outputs that satisfy their customers' needs and expectations. However, the slacks analysis also revealed that most banks could improve their efficiency by reducing input usage or increasing output levels. Therefore, there is a need for resource optimization initiatives that focus on reducing waste, redundancy, and variability while improving productivity, innovation, and agility (Barroso Del Toro et al. 2022; Da Silva Gomes et al. 2022; Macias-Aguayo et al. 2022).

This study contributes to the literature on quality management in the banking industry by providing empirical facts on Colombian banks' quality performance and suggesting areas for improvement. The suggested framework provides a significant addition to the knowledge of performance assessment and process improvement in the banking industry despite the study's limitations, such as the use of secondary data and the focus on a single region and period. Thus, future studies might solve these shortcomings using primary data, diverse techniques, and a comparative viewpoint across nations and historical periods. In addition, future research could examine the implementation and outcomes of quality improvement initiatives based on the findings of this study in order to better understand the factors that influence the success of such initiatives and their influence on customer satisfaction, loyalty, and financial performance.

6. Conclusions

This research is based on the hypothesis that the integration of the Six Sigma and DEA approaches significantly improves service quality in the banking sector by providing a more robust framework for measurement and continuous improvement. In this sense, the research proposes a methodology that integrates Six Sigma and DEA to evaluate the quality of banking services in Colombia. To this end, the research identifies seven key dimensions

for quality (prompt response, efficient channels, fraudulence, processes, dependable service, credibility, customer satisfaction, and risk management).

For the development of the methodology, a sample of 25 Colombian banks were chosen. The results show that, although some banks excel in areas such as customer satisfaction and service reliability, most have significant opportunities for improvement, especially in critical aspects such as response time and channel efficiency.

In addition, the use of metrics calculated through Six Sigma allows for the establishment of general standards, which show that many banks are still far from reaching optimal levels of efficiency. On the one hand, the DEA analysis generates a review based on the use of resources and provides insight into how banks can optimize the use of their resources to maximize service quality.

On the other hand, within the limitations of the study, the exclusive use of secondary data and its regional scope due to the nature of the sample are identified. However, the findings contribute significantly to the body of knowledge on quality management in the banking sector. In this sense, it is suggested that future research address these limitations by using primary data and comparative approaches between different geographical contexts.

In summary, this study is not limited to a comprehensive assessment of the current performance of Colombian banks in terms of service quality, but also establishes a benchmark analysis that is useful as a path forward towards continuous improvement and optimization in a vital sector for the economy. The effective implementation of the proposed framework could be a catalyst to transform banking services in Colombia, ensuring that they align with changing customer expectations and global market demands.

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Conflicts of Interest: The authors declare no conflicts of interest.

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