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EVALUATION OF FINANCIAL EFFICIENCY AND OPERATIONAL RISK MANAGEMENT IN CONSTRUCTION COMPANIES IN ARMENIA, QUINDÍO

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ABSTRACT

The construction sector is fundamental to regional economic development. However, the municipality of Armenia in Quindío faces structural limitations in control and management processes that negatively impact profitability and business efficiency. Evidence of these weaknesses includes the sustained reduction in housing launches and sales despite moderate growth in gross value added (GVA), suggesting failures in the sector's planning, financial management, and operational efficiency. This study analyzed the financial efficiency and operational risks of housing construction companies in Armenia from 2019 to 2023 using the Data Envelopment Analysis (DEA) model with the output-oriented CCR approach. This methodology estimates the efficient frontier by comparing homogeneous decision units and identifying opportunities to optimize financial results without allocating more resources. Additionally, operational risk analysis was conducted using the COSO ERM framework to evaluate risk management in financial performance. The results show that the companies analyzed are below the financial efficiency frontier and have significant exposure to operational risks mainly associated with administrative and financial management.

KEYWORDS: Financial Efficiency; Envelopment Analysis; Construction Sector; Business Sustainability; Risk.

1. INTRODUCTION

The construction sector plays a strategic role in economic growth, job creation, and urban development. However, due to the complexity of executing a housing project, the concentrated use of resources, and sensitivity to economic and regulatory changes, the sector is exposed to operational and financial risks. In regional contexts such as Armenia, Quindío, Colombia, these conditions result in persistent limitations in control and management systems that affect the sector's profitability, financial efficiency, and business sustainability.

Despite this sector's economic relevance, empirical evidence shows that construction companies have difficulty effectively articulating risk management with financial performance measurement, which limits strategic decision-making based on objective information. While the literature acknowledges the usefulness of quantitative tools, such as data envelopment analysis (DEA), to evaluate organizational efficiency and the Committee of Sponsoring Organizations of the Treadway Commission (COSO) enterprise risk management (ERM) framework to identify and comprehensively manage business risks, their combined use is limited, particularly in studies with a territorial and sectoral approach.

This paper analyzes the financial efficiency and operational risks of construction companies in Armenia, Quindío, from 2019 to 2023 using an integrated DEA-COSO ERM approach. The research uses an output-oriented DEA CCR model developed in two stages. In the first stage, financial efficiency is determined. In the second stage, operational risks associated with administrative management, processes, human capital, and marketing are analyzed as performance explanatory variables. This approach provides relevant empirical evidence to optimize financial performance and support strategic decision-making in a sector vital to economic development.

2. THEORETICAL FRAMEWORK

2.1. Envelopment Analysis (DEA)

Charnes et al. (1981) introduced Data Envelopment Analysis (DEA), a methodology that builds on the previous work of Farrell (1957). DEA is a mathematical tool used to evaluate organizational efficiency (Canale & Furlani, 2022). Otley (1999, as cited in Salgado & Calderón, 2020) pointed out that the primary objective of management control is to facilitate strategic implementation within organizations by motivating and directing employees to achieve the proposed results.

Fontalvo et al. (2019) confirmed the usefulness of DEA in Colombian business contexts by facilitating accurate measurements of technical and financial efficiency and allowing for strategic financial projections. Pérez (2020) proposed an integrative approach relating traditional management control perspectives with business excellence criteria, highlighting elements such as retrospective analysis and proactive organizational performance evaluation. Pérez and Quintero (2020) demonstrated that DEA not only facilitates the accurate measurement of technical and financial efficiency but also the preparation of strategic projections for Colombian construction companies.

Data envelopment analysis (DEA) is a tool used to evaluate relative efficiency in business contexts. Likewise, it addresses the main theories that support business management, providing a theoretical basis that allows one to contextualize the investigated phenomenon and identify existing gaps. This justifies the proposal of a model applicable to construction companies in Armenia, where objective efficiency measurement is key to improving strategic decision-making and promoting permanence.

In Colombia, Moreno et al. (2022) note that the absence of rigorous financial control has limited the sustained growth of SMEs in the housing sector. To overcome these limitations, intelligent decision-making models are proposed, such as the one suggested by Ortiz (2023). These models integrate financial analysis, strategic planning, and performance evaluation. These approaches strengthen the capacity for evidence-based decision-making, enabling managers to anticipate budgetary and operational deviations. Implementing efficient control models is thus a key strategic resource for achieving sustainable organizational development.

Additionally, data envelopment analysis (DEA) is a nonparametric quantitative technique that evaluates the relative efficiency of decision-making units (DMUs) with multiple inputs and outputs. DEA's theoretical foundation lies in linear programming, specifically in constructing an efficient boundary that identifies units making optimal use of available resources. DEA's nonparametric nature and ability to handle multiple inputs and outputs make it an ideal instrument for analyzing relative efficiency (Solana, 2017).

Unlike other statistical models, DEA does not require a specific production function, providing greater flexibility. DEA has been adopted in numerous sectors, including health, education, banking, and construction, due to its ability to

identify efficient units and determine the necessary improvements for inefficient ones. In an organizational context, DEA allows us to observe how an entity uses inputs, such as human resources, materials, and time, to generate expected outputs or results.

According to Ortiz (2023), the DEA facilitates the design of intelligent systems for strategic decision-making in small and medium-sized enterprises by providing objective and detailed evaluations, which contribute to optimizing performance. This technique has emerged as a robust methodological tool for evaluating organizational efficiency, especially in sectors with multiple operating units. By analyzing multiple performance dimensions, DEA can detect entities operating on the efficient frontier and those with significant deviations. This facilitates formulating specific strategies to improve performance in critical areas. Similarly, it allows for the integration of quantitative and qualitative aspects of the production process, enabling a comprehensive approach to performance measurement (Fontalvo et al., 2020).

Evaluating financial efficiency requires a set of complementary indicators that connect operating performance and economic results. These indicators include operating margin, which synthesizes cost control; return on assets (ROA) and return on equity (ROE), which assess capital productivity; budget compliance, which signals spending discipline; working capital turnover, which manages liquidity; and operating cash flow, which demonstrates project self-sufficiency. Integrating these indicators makes it possible to distinguish quality profits from fragile accounting gains, prioritize corrective actions, and facilitate intra- and inter-company benchmarking in the volatile construction market (CAMACOL, 2022; Rivera-Godoy et al., 2023). Table 1 presents typical financial efficiency indicators in construction.

Table 1: Typical Indicators of Financial Efficiency in Construction.

Dimension	Indicator	Interpretation	Main Use
Cost-effectiveness	Operating margin	Efficiency of operating expenditure	Compare works and periods
Cost-effectiveness	ROA / SWR	Productivity over assets and wealth	Evaluate value creation
Spending discipline	Budget compliance	Deviation vs. Baseline	Preventive control
Liquidity	Rotations and cash cycle	Working Capital Efficiency	Payment and collection management
Case	Operating cash flow	Operational self-sufficiency	Sustainability of the project

This tool not only facilitates the alignment of operational actions with the institutional vision but also promotes comprehensive measurement of performance. In the construction sector, its adaptation has been useful to integrate quality management, environmental management and customer satisfaction into control models, strengthening business management (Macedo et al., 2023).

2.2. Operational Risks

As Belacazar (2020) points out, operational risks in companies are difficult to mitigate since there will always be factors that generate them, no matter how organized an organization is. Sustainable financial strategies are applied to establish a vision based on the prevention and application of practical solutions to problems such as coping with internal or external business risks (p. 20). Therefore, prevention and the application of practical solutions are essential. Insider risks include financial, operational, and personnel-related issues, which can be mitigated through efficient control and process automation (Figueroa, 2004).

Figueroa (2004) emphasizes the importance of analyzing company risks, which change constantly due to operational or structural modifications in response to market needs or changes. (p. 3). Therefore, risk analysis enables companies to identify, evaluate, and mitigate potential events that could impact their strategic and financial objectives. It allows them to anticipate adverse scenarios, make informed decisions, protect their resources, and ensure long-term sustainability.

3. COSO ERM METHODOLOGY (2017)

COSO ERM 2017 provides senior management, managers, and responsible personnel with a structured tool to mitigate risk in its various forms and strengthen the internal control system. This tool generates a culture of fraud prevention and mitigates the potential impact on the organization.

This framework includes a governance culture, a review and control system, clear and achievable objectives, ways to address problems, solid communication channels, basic and clear information, report generation, and constant and periodic review systems to evaluate the entity's performance, among others. In other words, it is a complex process that takes various aspects into account. However, because it is complex, risk management requires execution. In other words, managers must establish an execution plan driven by an organizational culture that delegates tasks to each person within the company to achieve the planned objectives.

The tasks of monitoring business risk for managers can include reviewing strategies for

achieving performance in the modern business context. This supervision involves monitoring and controlling the proposals made. The company must remain alert because risk situations require active participation and intervention with proposals for possible solutions. Likewise, risk monitoring must consider all factors that can contribute to the company's growth or failure.

This framework promotes these practices and enhances the company's strengths. However, COSO recommends taking it a step further. In other words, taking a more ambitious approach to intelligent risk management will strengthen the company. In this sense, the updated framework, COSO ERM 2017, meets the following expectations: it more clearly connects risk management with stakeholder expectations, positions business risk in a real context, allows companies to better anticipate risk, and helps understand that change creates opportunities, not just crisis situations. Finally, one of the most important aspects is that this publication encourages entrepreneurs to take risks and seize opportunities, no matter how intimidating they may be. With the publication of this COSO ERM 2017 update, the evolving nature of risks is emphasized. There are new forms of risk that can greatly affect a company.

3.1. Classification and Characteristics of Operational Risks

Classifying operational risk is a fundamental tool for understanding and managing the various sources of loss that can affect an organization. It enables us to identify patterns, assign responsibilities, and design more effective mitigation strategies, particularly in complex environments where multicausality is common (Crouhy et al., 2014; Hopkin, 2018). Thus, it becomes a vital component of a comprehensive risk management framework (Table 2).

Table 2: Classification of Operational Risks.

Classification	Risks	Quotes
People / Human Resources	**- Careless errors- Insufficient training- Poor staff management**	**Henao, 2013; Orihuela & Orihuela, 2016**
Processes	**- Failures in execution- Weak internal controls- Inadequate procedures - Deficiencies in project management**	**Martínez Martínez, 2015; Camacol, 2023**
Technology	**- Hardware or software failures- Cyberattacks- Technological obsolescence**	**Appiah, 2020; Orihuela & Orihuela, 2016**
External factors	**- Climate changes- Social phenomena- Economic situation- Government regulations**	**Camacol, 2023; Henao, 2013**
Legal Events	**- Litigation and sanctions- Regulatory changes**	**Martínez Martínez, 2015; Camacol, 2023**

Source: Own elaboration (2025).

Similarly, characterizing operational risks helps us understand their behavior, scope, and impact within an organization. This is an essential element for strengthening risk management systems. Several authors agree that this type of risk is characterized by its cross-cutting nature, multi-causal origin, and difficulty in anticipation due to the simultaneous interaction between people, processes, technology, and external factors (Crouhy et al., 2014; Hopkin, 2018). Likewise, the impact of operational risk can vary from minor losses to critical events that compromise business continuity. This requires constant monitoring and a preventive approach (Basel Committee on Banking Supervision, 2004). These characteristics justify the need for comprehensive, systematic management to reduce the probability of occurrence and mitigate associated adverse effects (Table 3).

Table 3: Characteristics of operational risks.

Feature	Description	Quote
Multicausality	- Interaction between people, processes, technology and external factors- Simultaneous causes that contribute to risk	Henao, 2013; Orihuela & Orihuela, 2016
Transversality	- It affects all areas of the organization- It does not depend on a single factor	Martínez Martínez, 2015; Camacol, 2023
Difficulty of prediction	- Unexpected or atypical events- Low frequency and high severity- High uncertainty	Appiah, 2020; Orihuela & Orihuela, 2016
Variable impact	- Minor losses up to operational interruption- Financial, legal, or reputational damages	Henao, 2013; Camacol, 2023

Source: Own elaboration (2025).

3.2. Operational Risks Associated with the Construction Sector

In the construction industry, operational risks are a critical source of loss and disruption due to the complexity of processes, reliance on skilled labor, and exposure to external factors. These risks are

related not only to internal events, such as personnel, process, or system failures, but also to external conditions, such as political and environmental events or regulatory changes that directly impact project execution (Mafioly Yacamán, 2021). Additionally, these risks can amplify the effect of threats if not managed in an integrated manner (Cuadros, Cruces Arévalo & Ortiz, 2024). Operational risks also represent a significant factor in cost overruns and delays, highlighting the need for preventive measures and continuous monitoring (Sánchez Soto, 2024).

Consequently, these operational risks are increasingly complex and multidimensional. Their modern management demands integrated, quantitative approaches adapted to specific contexts to reduce their impact on time, cost, and security. In this sense, identifying and categorizing these risks is essential to guaranteeing the continuity, efficiency, and safety of the project's activities.

Due to the industry's inherent complexity, which is characterized by the coordination of multiple actors, the intensive use of resources, and a demanding regulatory environment, risks can originate from management, processes, and regulations, as well as internal functions related to human capital and commercial operations (Sánchez Soto, 2024; Cuadros, Cruces Arévalo, & Ortiz, 2024). They must be approached comprehensively to reduce cost overruns, improve operational performance, and strengthen organizational sustainability since each category directly influences project execution (Sagbini Balcázar, 2021; Pabón Trujillo & Carrillo Orduz, 2022). Finally, operational risks related to management, processes, the legal and regulatory framework, and human resources, marketing, and sales are classified.

3.3. Methodology

This descriptive, quantitative, non-experimental, and longitudinal research study aims to analyze the financial efficiency and operational risks of housing construction companies in Armenia, Quindío, during the period from 2019 to 2023. The population comprises companies registered in the SIIS system and classified under ISIC codes F4111 and F4112. The sample includes entities with complete financial information from the analyzed years. Secondary data from official sources is used and processed with statistical techniques and the Python programming language to guarantee objectivity and replicability. The study employs Data Envelopment Analysis (DEA), an output-oriented CCR model, to estimate relative efficiency while considering various inputs (direct costs, administrative expenses, and personnel) and outputs (operating margin, return on assets, and budget compliance). This methodological design allows us to identify performance gaps, establish efficient units, and formulate strategic recommendations that strengthen the financial management, sustainability, and competitiveness of the regional construction sector. To identify operational risks, a structured survey with Likert-type questions was used, which was validated by expert judgment (Arias, 2012; Charnes, Cooper, & Rhodes, 1978). The survey was administered to 20 construction companies operating in the municipality of Armenia. All of the companies are legally constituted and involved in developing residential and/or non-residential projects.

4. RESULTS

Regarding the results, the analysis of the records between 2019 and 2023, company records were estimated from 2020 onwards, where there is evidence of a marked business concentration in the construction of residential buildings (ISIC F4111), compared to a lower participation in non-residential buildings (F4112), which reflects a limited productive diversification and a dependence on the local housing market (Camara de Comercio de Armenia, 2019-2023).

Table 4: Construction Companies by Major ISIC Classification (2020–2023).

Year	Residential Buildings (F4111)	Non-residential buildings (F4112)	Total
2020	47	3	50
2021	42	3	45
2022	35	2	37
2023	35	1	36

Table 4 shows that most construction companies in Armenia focus on housing construction, while non-residential infrastructure is marginal. This concentration represents a structural risk, as low diversification limits sectoral resilience and the ability to adapt to new urban demands.

The evaluation of financial efficiency in construction companies in Armenia, Quindío, for the period 2019–2023 is carried out through the analysis of the main indicators extracted from the DEA database, namely, operating margin, return on investment (ROI), productivity, budget compliance and technical efficiency calculated using the Data Envelopment Analysis method. The construction of these average indicators per year allows the identification of trends, oscillations and patterns of sectoral behavior, as well as establishing objective comparisons over time, so that the analysis becomes

a robust tool for management and decision-making in the local construction sector.

Table 5: Average Financial and Technical Efficiency Indicators by Year (2019–2023).

Year	Operating margin (%)	ROI (%)	Productivity	Budget compliance (%)	Technical Efficiency (DEA)
2019	13,9	16,5	74,6	91,3	0,68
2020	12,7	15,2	71,8	90,2	0,64
2021	14,1	17,1	76,2	93,1	0,72
2022	13,2	16,2	72,9	92,4	0,70
2023	15,0	18,7	78,5	94,0	0,74

Table 5 shows stable and moderate operating margins with a slight increase in 2023, reflecting efficient cost management and adequate financial planning. DEA technical efficiency improves from 0.64 to 0.74 between 2020 and 2023, the sector is in a process of continuous improvement in the management of its productive capacities, this global behavior suggests that companies have managed to adapt to the changing conditions of the environment and that there are solid foundations to advance in the consolidation of management and control systems aimed at excellence and organizational sustainability (Arias, 2012).

Table 6: DEA Companies=1 per year.

Year	100% efficient companies (n)
2019	0
2020	0
2021	1
2022	0
2023	1

Table 6 shows that only in 2021 and 2023 did a company achieve DEA efficiency equal to one, evidencing the low proportion of actors in the technical frontier. This situation requires strengthening management and continuous improvement to increase the competitiveness and sustainability of the construction sector in Armenia. Similarly, the results enable us to identify the level of exposure to operational risks in construction companies in Armenia, Quindío, and to analyze its relationship with financial efficiency. This analysis is based on the components of the COSO ERM 2017 framework and its articulation with Data Envelopment Analysis (DEA). The analysis was structured into two groups of risks: operational risks associated with management, processes, and the regulatory framework; and risks linked to human resources, marketing, and sales. These risks have a differentiated impact on companies' financial performance. Operational risks associated with management, processes, and the regulatory framework. In general, the results show that most construction companies have a low-to-moderate level of risk in the planning and regulatory compliance phases. However, high-risk areas were identified that generate the efficient use of resources and affect financial performance. Regarding deficiency or incomplete information in the scope of the construction project, 60% of companies rated this risk as low, suggesting semi-structured planning practices. The remaining 40%, however, evaluated it at medium and high levels, showing that a significant proportion of projects have flaws in the initial scope definition. According to the DEA approach, these deficiencies result in increased costs and time, implying greater input without proportional financial results.

Regarding processes related to documentation and licensing, 70% of companies perceive them as low risk, reflecting adequate regulatory compliance. However, 20% rated it as high, indicating that legal procedures and document management sometimes cause delays and paralysis. This increases operating costs and affects companies' ability to stay close to the efficient frontier in terms of efficiency. As for pre-feasibility and feasibility studies, 65% of companies consider them low risk, indicating prior technical and financial analyses. However, 20% perceive them as high risk, indicating that incomplete studies compromise the financial viability of projects. This risk directly impacts financial efficiency because it is unrelated to the initial investment and expected results. A high-dispersion risk is related to inconsistencies between the actual dimensions of the land and the information contained in the purchase documents. Although 60% perceive this risk as low, 35% rate it as high, showing weaknesses in processes. According to the DEA approach, these errors generate structural inefficiencies by necessitating redesigns and adjustments that increase inputs without improving financial outputs.

4.1. Operational Risks Associated with Human Resources, Marketing, And Sales

Results corresponding to risks related to human talent and marketing show greater exposure to risk compared to risks associated with technical and regulatory management. These risks have direct effects on liquidity and financial efficiency. Regarding the recruitment of competent personnel, 50% of companies perceive this risk as low. However, 35% rate it as high. In small companies or with contract work, a lack of qualified personnel increases operating costs and reduces productivity, affecting technical and financial efficiency. In the commercial field, 35% of companies consider the risk of selling less than 90% of the properties at the end of the project to be critical. While most companies achieve

their sales goals, they acknowledge that inadequate marketing compromises profitability and cash flow, resulting in lower financial outputs than anticipated. Finally, about 40% of companies perceive inconveniences in after-sales service, delays in deed procedures, and noncompliance in contractual, administrative, and technical closing phases as relevant risks. These results demonstrate that weaknesses in project closure impact financial efficiency and account for significant variations in the performance of construction companies.

5. CONCLUSION

The results enable an integrated interpretation of construction companies' performance in Armenia and Quindío from a financial efficiency perspective based on data envelopment analysis (DEA) and its relationship with the operational risks identified under the COSO ERM 2017 framework. The findings support the use of a two-stage DEA model in which financial efficiency is the first stage of analysis and operational risks are explanatory variables in the second stage. The first stage of the DEA model estimates the relative financial efficiency of construction companies based on the relationship between financial inputs (costs, assets, and working capital) and financial results (revenue, profitability, and liquidity). Descriptive results show that companies with lower operational risk, particularly in planning, regulatory compliance, and technical coordination, tend to be closer to the efficient frontier. This is consistent with literature indicating that operational stability is a key determinant of financial efficiency in capital-intensive sectors, such as construction.

In the second stage of the DEA analysis, the identified operational risks are incorporated as explanatory variables of the efficiency scores obtained in the first stage. In this context, risks associated with an incomplete project scope definition, pre-feasibility study errors, and coordination failures emerge as significant factors explaining differences in financial efficiency levels among the analyzed companies. These risks increase operating costs and execution times without generating proportional improvements in financial results, resulting in lower technical and financial efficiency levels.

Similarly, although most companies perceive the risks linked to regulatory compliance and document management as low, these risks have a high impact when they materialize. According to the DEA approach, these events generate structural inefficiencies by causing stoppages, sanctions, or redesigns that affect the optimal relationship between inputs and financial products. This result underscores the importance of the risk assessment component of COSO ERM as an indirect factor of financial efficiency. Operational risks associated with human resources have a particularly strong relationship with DEA efficiency levels. Staff turnover during project execution and hiring incompetent personnel increases training costs, reduces labor productivity, and generates rework. In the second stage of DEA, these factors significantly explain the variability in efficiency scores. This finding coincides with previous studies that highlight human capital as a critical input in efficiency models for the construction sector.

Additionally, marketing and closure risks, such as selling less than 90% of properties, delays in deeds, and post-sale issues, directly impact financial outputs. In DEA terms, these risks reduce the expected financial results relative to the committed inputs, causing companies to move away from the efficient frontier. Empirical evidence suggests that the poor management of these risks is responsible for the lower levels of financial efficiency observed in a significant portion of the sector. Overall, the findings demonstrate that operational risks represent not only isolated threats but also structural determinants of financial efficiency, justifying their incorporation into two-stage DEA models. From this perspective, COSO ERM 2017 consolidates as a complementary framework to DEA by enabling the identification, classification, and management of the risks that explain efficiency gaps between companies. Finally, this discussion provides empirical evidence supporting the idea that integrating management control, risk management, and financial efficiency through a two-stage DEA approach constitutes a robust analytical tool for the construction sector. This approach allows one to evaluate the relative performance of companies and identify strategic levers for improvement aimed at strengthening financial sustainability and business competitiveness in contexts of high operational uncertainty.

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