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SUMARIO • SUMMARY • RESUMO

- Editorial.....5
- Uso de la inteligencia artificial para reducir los tiempos de producción en la gestión de eventos recreativos corporativos.....7
Use of artificial intelligence to reduce production times in corporate recreational event management
Giancarlo Castillo Ghiotto. Universidad Internacional Iberoamericana, Perú
- Diseño hidráulico de una red de suministro de agua en circuito en una zona urbana crítica mediante la ecuación de Hazen-Williams.....22
Hydraulic design of a looped water supply network in a critical urban area using the Hazen-Williams equation
Suka Lau Komba Augusto, José Paulo Kai, Pedro Gelson Morais. Universidad Jean Piaget de Angola / Universidad Agostinho Neto (FEUAN) / Centro de Investigación y Desarrollo de Sonangol, Angola
- Sistema de predicción del comportamiento del activo financiero (EUR/USD) en el mercado Forex, utilizando herramientas de aprendizaje automático. Caso: Ecuador.....43
Global Predictive system for the behavior of the financial asset (EUR/USD) in the Forex market using machine learning tools. Case: Ecuador
Mateo López Huerta, Jon Arambarri, Saul Domingo. Fundación Universitaria Iberoamericana, Ecuador / Universidad Europea del Atlántico, España.
- Implementación del Reglamento de Seguridad Cibernética y de la Información en el Sector Financiero de la República Dominicana.....64
Implementation of the Cybersecurity and Information Security Regulation in the Financial Sector of the Dominican Republic
Luis Rafael Villalona Mateo, Ernesto Bautista Thompson. Universidad Internacional Iberoamericana, Republica Dominicana, México.
- Análisis y propuesta sobre la enseñanza en diseño y gestión de proyectos a nivel posgrado en Iberoamérica.....82
Analysis and proposal for teaching project design and management at the postgraduate level in Ibero-America
Miguel Ángel López Flores, Jesús Enrique Morales Rico, Nazareth Gómez Pérez, Alejandra Hernández Rojas. Universidad Europea del Atlántico, España / Instituto Politécnico Nacional, México / Universidad Internacional Iberoamericana, México.
- La importancia del servicio al cliente como factor de crecimiento empresarial.....99
The importance of customer service as a factor of business growth
Kabwe Lusombo Omari, Nelo Alberto João. Universidad Internacional Iberoamericana / Universidade Lurio, Mozambique.
- Digitalización, sostenibilidad y rentabilidad en la educación empresarial universitaria europea: El proyecto Start DSP.....117
Digitization, Sustainability, and Cost-Effectiveness in European University Business Education: The Start DSP Project

Emmanuel Soriano Flores, Thomas Andre Prola. Universidad Internacional Iberoamericana, Francia / Universidad Europea del Atlántico, España.

- Análisis actual del desafío de la rehabilitación energética en la República Dominicana.....130
Challenges and opportunities: A multidimensional analysis of the energy crisis in the Dominican Republic
Solangel Raquel Montesino Almonte, Débora Libertad Ramírez Vargas. Universidad Internacional Iberoamericana, República Dominicana, México.

Editorial

This issue of *MLS Project Design & Management* reaffirms the journal's commitment to disseminating multidisciplinary scientific research aimed at generating applied knowledge, fostering technological innovation, and strengthening organizational, educational, and engineering capabilities. The papers included in this edition reflect the diverse perspectives and challenges characterizing contemporary societies, highlighting the need to devise sustainable and adaptive solutions. The contributions cover four thematic areas regarding leadership and management—featuring work on project management training and customer service as a driver of organizational growth; technology and innovation—highlighting research on generative artificial intelligence applied to business processes, predictive modeling for financial markets using machine learning, and cybersecurity; education and competency development—including a study on sustainable and digital entrepreneurship within the European context; and engineering—grouping research on hydraulic network design and electrical infrastructure rehabilitation, both focused on ensuring essential services based on efficiency and sustainable development criteria. Drawing on various methodological approaches and geographic settings, these studies underscore the importance of optimizing processes, integrating digital tools, enhancing specialized training, and developing resilient infrastructure capable of meeting the demands of an increasingly complex economic and social landscape.

The first article analyzes the integration of generative artificial intelligence into a corporate recreational events company, demonstrating a significant reduction in production time through the use of ChatGPT for creative and administrative tasks. The results show that AI can serve as a strategic tool to enhance operational efficiency, provided its implementation is accompanied by training, supervision, and organizational governance processes.

The second study addresses the hydraulic sizing of a water supply network for the 11 de Noviembre neighborhood in Luanda. Using the Hardy-Cross method and a sensitivity analysis of key hydraulic parameters, a technical solution is proposed to ensure an efficient and sustainable supply. The study offers a replicable methodology for other urban areas facing similar challenges regarding access to water resources.

The third article develops a prediction system for the EUR/USD currency market by integrating machine learning algorithms and LSTM recurrent neural networks. The proposal aims to reduce the impact of emotional factors on investment decisions, offering an artificial intelligence-based approach to improve the accuracy and robustness of trading strategies in highly dynamic financial environments.

The fourth article analyzes the implementation of Cybersecurity and Information Security regulations within financial institutions in the Dominican Republic, identifying gaps in talent, technology, organizational culture, and regulatory compliance. It contributes practical tools to strengthen digital resilience, optimize decision-making, and support the design of policies and regulatory frameworks.

The fifth study examines the challenges facing project management education in Mexico by reviewing the academic and professional landscape; it details the limited availability of specialized programs and the need to strengthen managerial competency development starting at the university level. The study highlights the importance of professionalizing project management as a strategic discipline for organizational competitiveness and development.

The sixth article analyzes the contribution of customer service to business growth from a qualitative perspective. The findings show that competencies in service, negotiation, and business ethics directly influence consumer satisfaction and increased sales. The research highlights the role of human capital as a key factor in the consolidation and sustainability of organizations.

The seventh article examines the incorporation of principles regarding sustainability, digitalization, and profitability into entrepreneurship education at universities in Germany, Spain, Greece, and Ireland, within the framework of the European START DSP project. The results

indicate that educators place greater emphasis on sustainability, while digitalization and profitability are perceived as elements inherent to business development.

The eighth article presents an assessment of the electrical networks of the Dominican "Círculo Cítrico 701" in the Dominican Republic, identifying structural issues that affect service quality and continuity. The comprehensive rehabilitation proposal incorporates criteria regarding sustainability, technological modernization, and community participation, demonstrating that improving energy infrastructure is essential for social well-being and territorial development.

Research indicates that innovation, digital transformation, and sustainability are cross-cutting dimensions in generating solutions to complex problems. In this regard, MLS Project Design & Management reaffirms its commitment to disseminating rigorous and relevant scientific knowledge capable of contributing to institutional strengthening, technological development, and the creation of more resilient and sustainable societies.

Before concluding this editorial, all of us involved in this new project wish to express our gratitude to the team of contributors, IT specialists, and technical staff, as well as to the Ibero-American University Foundation (FUNIBER) and the universities that have provided the necessary material support to make this issue possible, confident that we are on the right path toward international recognition.

Dr. Luis A. Dzul López
Dr. Roberto M. Álvarez
Editors in Chief

USE OF ARTIFICIAL INTELLIGENCE TO REDUCE PRODUCTION TIMES IN CORPORATE RECREATIONAL EVENT MANAGEMENT

USO DE LA INTELIGENCIA ARTIFICIAL PARA REDUCIR LOS TIEMPOS DE PRODUCCIÓN EN LA GESTIÓN DE EVENTOS RECREATIVOS CORPORATIVOS

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ABSTRACT

Keywords:

ChatGPT, generative artificial intelligence, event management, productivity, Colombia.

Introduction. Corporate recreational event agencies often rely on manual routines that extend production cycles and increase rework. This study examines whether adopting generative AI is associated with reduced event production time. Methodology. A quasi-experimental before-after single-case design was conducted in a corporate recreational events company (Bogotá, Colombia) between June and September 2025. Three comparable events were produced under a traditional approach (no AI) and then with systematic ChatGPT support for creative and administrative tasks (concept development, proposal drafting, budgeting, and supplier selection). The dependent variable was total production time (hours) from brief reception to final approval. Given the small sample, the analysis prioritized paired differences, confidence intervals, and effect sizes. Results. A consistent reduction in total production time was observed across events (51 h, 60 h, and 69 h), yielding an average saving of 60 h (19.1%). The largest savings occurred in Concept Development (23.3 h) and Proposal Preparation (20.0 h), while Final Validation slightly increased (+1.3 h), reflecting additional quality checks. Conclusions. Findings suggest generative AI can be an efficiency lever for mid-sized agencies when combined with governance, training, and human verification. Results should be interpreted as applied and exploratory due to the small sample and single organizational setting. Future research should test replicability with more events and additional outcomes (cost, quality, and client satisfaction).

RESUMEN

Palabras clave:

ChatGPT, inteligencia artificial generativa, gestión de eventos, productividad, Colombia.

Introducción. En agencias de eventos recreativos corporativos, los ciclos de producción suelen depender de rutinas manuales que elevan horas de trabajo y retrabajo. Este estudio analiza si la incorporación de IA generativa se asocia con una reducción del tiempo total de producción. Metodología. Se aplicó un diseño cuasi-experimental antes-después (caso único, fase pre y fase post) en una empresa del sector de eventos recreativos corporativos (Bogotá, Colombia), entre junio y septiembre de 2025. Se compararon tres

eventos de naturaleza comparable producidos sin IA y luego con apoyo sistemático de ChatGPT en tareas creativas y administrativas (conceptualización, propuesta, presupuestación y selección de proveedores). La variable dependiente fue el tiempo total de producción (horas), medido desde la recepción del brief hasta la aprobación final. El análisis priorizó estimaciones de diferencias pareadas, intervalos de confianza y tamaños de efecto, dada la muestra reducida. Resultados. En los tres eventos se observó una reducción consistente del tiempo total (51 h, 60 h y 69 h), equivalente a un ahorro promedio de 60 h (19.1%). El mayor ahorro se concentró en Conceptualización (23.3 h) y Elaboración de propuesta (20.0 h). En Validación final se registró un leve aumento (+1.3 h), asociado a mayor revisión de calidad. Conclusión. Los hallazgos sugieren que la IA generativa puede funcionar como palanca de eficiencia en agencias medianas cuando se integra con gobernanza, capacitación y verificación humana. Las conclusiones deben interpretarse como evidencia aplicada y exploratoria por el tamaño muestral y tratarse de un único caso. Se recomienda replicar con más eventos y organizaciones y ampliar métricas (costo, calidad y satisfacción del cliente).

Introduction

This article makes a contribution on three levels. First, it provides quantitative evidence under real-world conditions regarding the temporal impact of generative AI on the production of corporate events in Colombia, a topic that has received little attention in the literature. Second, it breaks down the savings by process phase, making it possible to identify where AI adds the most value and where it could lead to additional verification costs. Third, incorporate indicators of team acceptance to discuss the sustainability of adoption. The document is organized as follows: the “Method” section describes the quasi-experimental design and the intervention; “Results” presents the observed effect and a breakdown by phase; and “Discussion and Conclusions” interprets the findings, their implications, and limitations.

Contributions and Structure of the Article

The main hypothesis (H1) posits that the systematic incorporation of generative AI (ChatGPT) into creative and administrative tasks is associated with a reduction in total production time (hours) compared to tasks performed without AI. The null hypothesis (H0) states that no significant differences in total time will be observed.

To clarify the operational mechanism, the following secondary hypotheses are proposed: (H1a) The greatest savings are concentrated in phases that are intensive in terms of drafting and ideation (Conceptualization and Proposal Development); (H1b) savings are lower in phases that rely on third parties (Supplier Selection); and (H1c) final validation may remain the same or increase slightly due to more rigorous verification controls. In addition, (H2) acceptance of the equipment will be high (perceived usefulness and ease of use), promoting the sustainability of adoption.

Objective, Questions, and Hypotheses

In addition, the effective adoption of AI depends on user acceptance. The Technology Acceptance Model posits that perceived usefulness and ease of use influence the intention to use a technology and actual adoption (Davis, 1989). Later models, such as UTAUT2, incorporate factors such as performance expectations, effort, social influence, and facilitating conditions (Venkatesh et al., 2012). Consequently, a comprehensive evaluation must combine operational metrics (hours saved) with indicators of team perception, since a time savings might be unsustainable if the tool is rejected or causes cognitive overload.

This study interprets generative AI as an enabling capability that can strengthen dynamic organizational capabilities: the ability to perceive opportunities, capitalize on them by reconfiguring resources, and adapt routines to sustain superior performance in changing environments (Teece, 2007). At an event agency, the ability to quickly reconfigure a concept, readjust a budget, or rethink the selection of vendors in response to client changes results in less friction, greater speed, and a higher-quality response.

Conceptual Framework: Dynamic Capabilities and Technology Adoption

In Colombia, the debate over the adoption of generative AI in organizations has intensified, and market reports point to growing interest in the region. Even so, there remains a gap between enthusiasm for the tool and its effective integration into operational processes. In the events sector, local “event tech” initiatives have emerged, but the maturity of processes and the availability of data still limit widespread adoption (Bmotik, 2024). In this context, a pragmatic approach involves introducing AI to assist

with time-consuming tasks, measuring its impact using clear metrics, and refining the process through organizational learning.

State of the Art: AI Applications in the Events Industry

Research and professional practice have identified numerous applications for AI in the event value chain. In the run-up to an event, algorithms can support marketing and communication efforts through audience segmentation and message personalization; for example, industry platforms have reported improvements in engagement when AI-assisted segmentation techniques are applied to email campaigns (Bizzabo, 2023). Similarly, predictive analytics can estimate attendance and registration patterns to adjust logistics and capacity; one illustrative example is the use of machine learning models to predict participation in events in specific sectors, which makes it possible to optimize resources and reduce waste (Bayne & Innala, 2024).

During the event, applications such as chatbots for attendee support, networking recommendation tools, and real-time analytics systems for queue management and mobility are described. After the event, AI can automate reports, satisfaction analyses, and the creation of follow-up content. However, much of this literature focuses on large-scale events or conferences with robust digital infrastructure; in contrast, medium-sized agencies that manage corporate recreational events face data limitations, diverse requirements, and a high reliance on tacit knowledge. In these scenarios, generative AI is particularly appealing because, in its basic form, it does not require large volumes of structured data to add value: it can speed up writing, ideation, and document structuring tasks based on a relatively short brief.

At the regional level, the adoption of generative AI is in its early stages and varies widely. News reports based on analyses of learning platforms have indicated that Latin American countries are showing significant increases in interest in and training on generative AI, although gaps in practical implementation within organizations persist (Albuquerque, 2025). Therefore, in addition to discussing potential benefits, it is necessary to generate applied evidence that can guide investment decisions in small and medium-sized enterprises in the sector.

In summary, although there is a consensus that AI can transform the events industry, the empirical evidence on its impact on productivity—measured directly in terms of work hours—is still limited. This article addresses that gap with a quasi-experimental design focused on total production time and a breakdown by phase, generating actionable results for project managers and operations directors in the creative services industry.

However, the adoption of AI in services that require a high degree of creativity and coordination presents challenges. On the one hand, there is a risk of producing generic content that fails to capture the client's context; on the other hand, privacy and data usage concerns arise when external systems are used to process participant information or internal company details. The literature identifies concerns regarding trust, transparency, and data protection in AI- “augmented” events (Adams, 2021). Furthermore, field experience in knowledge work suggests that the impact of AI is not uniform: it depends on the type of task, the degree of structure, the user's ability to formulate effective instructions, and the need for subsequent verification (Dell'Acqua et al., 2023).

The management of a corporate recreational event can be viewed as a short-cycle project: it begins with a client brief, continues with conceptualization and design, moves on to proposal and budget development, vendor selection, validation, and closure. Each stage includes specific deliverables (concepts, visual elements, timelines, financial proposals, contracts, assembly plans) and decisions that feed into one another. In these

types of projects, response time and rapid iteration are key to gaining a competitive edge, especially when the client is comparing several agencies. Generative AI can serve as an “assistant” in tasks such as brainstorming, drafting proposals, structuring budgets, and evaluating alternatives. In economic terms, these tools function as predictive and cognitive support technologies that reduce the cost of producing and reviewing information, thereby shifting the productivity frontier of knowledge work (Agrawal et al., 2022).

Event-specific empirical evidence is growing, but it remains limited in terms of operational metrics. Recent studies report improvements in efficiency in content planning and production with the support of generative AI, provided that human verification is maintained to ensure accuracy and relevance (Keiper, 2023). Systematic reviews in event management also indicate that most applications focus on personalization, analytics, and automation, and recommend further quantitative studies using direct productivity indicators in real-world settings (Kumar & Ratten, 2025). In this context, tracking production hours by phase provides actionable insights for medium-sized agencies.

Generative AI and Managing Events as Projects

The central issue addressed in this article is the lack of empirical evidence—under real-world operating conditions—regarding the extent to which the production time for corporate recreational events can be reduced by incorporating generative AI as a support tool for key tasks in the process. The question is not solely a technological one: for AI to generate value, it must be integrated into a workflow with clear roles, quality criteria, version control, and verification mechanisms. In this regard, the research is designed as an applied study that quantifies the temporal impact of a specific intervention (the use of ChatGPT) in a real-world company, employing an appropriate quasi-experimental design when it is not possible to randomly assign treatments in a production environment (Shadish et al., 2002).

At the same time, the emergence of large-scale language models and generative artificial intelligence (AI) tools has opened up opportunities to automate and accelerate cognitive tasks across multiple industries. Recent studies show that these systems can improve productivity in tasks such as writing, summarization, customer service, and analytical support, with results varying depending on the type of work and the user’s experience (Brynjolfsson et al., 2025; Eloundou et al., 2024). In the field of events, the literature shows a growing interest in AI applied to personalization, predictive analytics, communication optimization, and creative support, although descriptive approaches predominate and there is a lack of causal evidence in Latin American contexts (Abdul Halim et al., 2023).

The corporate events industry in Colombia has regained momentum in recent years, but its day-to-day operations continue to rely on labor-intensive practices: coordination via email and courier services, preparing proposals in non-standardized documents, creating budgets from scratch, and sourcing vendors based on prior experience. These routines, while functional, tend to lengthen the production cycle and increase indirect costs per man-hour, especially in medium-sized agencies where a single person takes on multiple roles (design, logistics, purchasing, and customer service). Various sources have highlighted the sector’s economic importance and its need for modernization through digital solutions, in an environment where customers demand faster responses, personalized offers, and cost transparency (Forbes Staff, 2024).

Method

The study used the company's internal operational information and did not collect personal data from event participants. Interactions with AI were limited to information necessary for conceptualizing and developing proposals, avoiding the sharing of sensitive data. Policies were adopted to ensure that all AI-generated content undergoes human verification, recognizing that the tool can produce plausible but incorrect responses, which requires quality controls and professional accountability (Dell'Acqua et al., 2023).

Ethical and Governance Considerations

The analysis was conducted on two levels. First, the absolute and relative savings were estimated for each event and as an average for the period. Second, the average difference was assessed using a paired t-test with $n = 3$ pairs ($df = 2$). The 95% confidence interval was reported using the t-distribution, and the effect size was reported using Cohen's d_z . Given the low statistical power when n is small, this was supplemented with a percentile bootstrap interval for the differences. A nonparametric test (Wilcoxon) was also calculated as a conservative verification, acknowledging its limited power when $n=3$. Finally, the savings were broken down by phase, and the contribution of each phase to the total average savings was calculated. The perception data were summarized using means and the percentage of agreement (4–5).

Data Analysis

The analysis was conducted in three steps. First, we estimated the absolute and relative savings per event and the average for the period, as well as a breakdown by phase to identify where the change is concentrated. Second, supplementary estimates (confidence interval and effect size) were reported for the paired differences. Given the sample size ($n=3$ pairs), any statistical inference is interpreted as exploratory; therefore, the emphasis is placed on the directional consistency of the change, the magnitude of the effect, and consistency with the logic of the process. Third, the acceptance data were summarized using means and percentages of agreement (4–5) on a Likert scale.

Comparability and Measurement Quality Control

Comparability across events is a recurring challenge in applied project management studies, as each client introduces variations in scope, urgency, and the number of iterations. To mitigate this threat, the three cases were selected based on similarities in the type of service (corporate recreational events), the structure of deliverables, and the general approval process (brief → concept → proposal and budget → validation). In addition, the same core production team was retained, and the same time-tracking system was used both before and after the intervention.

Time tracking was conducted using internal logs for each event, in which each team member recorded the actual hours spent on project tasks. To ensure data consistency, the records were cross-checked against operational evidence: document versions (proposal and budget), file timestamps, and the timeline of communications with clients and suppliers. The goal was not to estimate individual productivity, but rather to capture the team's aggregate effort by phase, thereby avoiding incentives for underreporting or overreporting.

With regard to the intervention, minimum guidelines for using ChatGPT were established to ensure that the results would not depend on sporadic or improvised use. These practices included: (a) use of structured prompts (context, role, constraints, output format), (b) brief iteration to improve accuracy (maximum of three rounds per

deliverable), (c) mandatory human validation before sending to the client, and (d) tracking of hours spent interacting with AI as an auxiliary variable. These practices aim to strike a balance between speed and quality control, given that AI can produce persuasive texts that contain errors if they are not verified.

Finally, it is recognized that a before-and-after design may be subject to learning (maturation) effects: the team naturally improves with practice. However, the observation period was limited and the operational change was explicit (the incorporation of generative AI); therefore, the magnitude of the savings and their concentration in specific phases are indicators consistent with an intervention effect rather than a gradual improvement. Even so, future simulations with a larger number of observations could model pre-existing trends more accurately.

Procedure

To assess acceptance and barriers, an internal survey was administered to the team (n=10) using a 1-to-5 Likert scale, based on the dimensions of perceived usefulness and ease of use proposed by the TAM and expanded upon by UTAUT2 (Davis, 1989; Venkatesh et al., 2012). The survey included questions about ease of use, efficiency, perceived quality, and willingness to continue using AI.

The dependent variable was total production time (in hours), defined as the number of hours spent by the team from the time the brief was received until the final proposal was approved. Time was tracked using internal logs and deliverable tracking. In addition, the timeline was broken down into five phases of the actual workflow: (1) Conceptualization, (2) Proposal development, (3) Budgeting, (4) Supplier selection, and (5) Final validation. The independent variable was operationalized as “use of generative AI” (without AI vs. with AI), and, in addition, the actual hours of interaction with ChatGPT per event were recorded.

Variables and Instruments

The initiative involved incorporating ChatGPT as a support tool for specific tasks: (a) conceptualization and development of thematic ideas and experience scripts; (b) drafting and structuring the business proposal; (c) support for budgeting by organizing line items, making assumptions, and verifying consistency; and (d) support in the selection of suppliers through comparative matrices, criteria, and drafting of communications. The use of these was guided by standardized prompts and internal quality criteria (relevance to the client, consistency with the brand, logistical feasibility).

Presentation: Use of Generative AI (ChatGPT)

The study was conducted at a company in the corporate recreational events sector—an events agency located in Bogotá, Colombia—that specializes in corporate recreational events. The unit of analysis was the entire event production process, from receiving the brief to the client's approval of the final proposal. Three comparable events were selected—first produced using a traditional approach (without AI) and then produced with the support of generative AI—during the period from June to September 2025. The events analyzed were: Father's Day, Five-Year Anniversaries, and the Wind Festival.

Case Study and Unit of Analysis

A quasi-experimental before-and-after design (single case, pre-phase and post-phase) with an interruption logic was used: the interruption corresponds to the systematic adoption of ChatGPT as a support tool for specific tasks in the production

workflow. The unit of analysis was the entire production process for an event (from the brief to final approval). In total, six aggregated time-series measurements were identified (three events in the pre-phase without AI and three events in the post-phase with AI), selected based on the comparability of deliverables, approval workflow, and core team.

Given the limited number of observations, the design is considered applied and exploratory: it allows us to estimate the magnitude of the change and identify the phases in which the savings are concentrated, but it does not aim to establish a strong causal attribution equivalent to designs with long time series or control groups.

Results

However, organizational barriers (PI-4) were identified, including initial resistance, the need for training to develop effective prompts, and concerns about errors or generic content. Likewise, the need arose for clear policies regarding what information can be shared with external systems and how to document the verification process, in line with privacy concerns reported in qualitative studies of the sector (Adams, 2021).

The internal survey (n=10) shows a high level of acceptance of the tool. Ease of use received an average score of 4.2 (SD=0.9), and the perceived improvement in efficiency received an average score of 4.4 (SD=0.8). The statement “I would continue to use AI tools in future projects” received a score of 4.8 (SD=0.6) and a 90% agreement rate (4–5). These results are consistent with the TAM: perceived usefulness and ease of use are high, which promotes intention to use (Davis, 1989).

In addition to perceived efficiency, the team reported improvements in the quality of their work/proposals (mean 4.0; SD=0.7) and a high level of comfort in using the tool (mean 4.3; SD=0.8). The agreement rates (responses 4–5) were 80% for efficiency, quality, and comfort. These results suggest that, although further verification is needed, AI was viewed as a tool that improves speed without compromising the perceived quality of the deliverable.

As for barriers, the main ones fall into three categories: (1) competition barriers (prompting learning and criteria for evaluating outputs), (2) process barriers (defining at which points AI is used and where human approval is required), and (3) governance barriers (privacy, handling of confidential information, and decision logging). These barriers are consistent with industry experience, which indicates that technology must be accompanied by organizational changes in order to realize benefits (Abdul Halim et al., 2023).

Team Perception and Emerging Barriers

In addition, the actual interaction time with ChatGPT per event was recorded (Table 1). On average, 14.7 hours of AI were used per event. This approach allows us to view AI as a productive resource: hours are invested in interaction (prompts, iterations, and refinement) to save hours in the overall process. Although a robust functional relationship is not established when n=3, the metric suggests that the tool's time-based return may vary depending on the complexity of the event and the degree to which the brief is structured. At the operational level, this underscores the need to develop prompting skills and reusable templates to increase the marginal efficiency of AI use.

By correlating the time saved with the number of hours of AI use, we obtain a productivity metric called AI-Leverage (hours saved per hour of interaction with AI). On

Father's Day, the IA-Leverage was 5.10; during the Quinquenios, 5.00; and at the Festival del Viento, 3.14. The average was 4.41. The variation suggests that, although AI generates savings in all cases, more complex events may require more interaction time to achieve appropriate outcomes, thereby reducing the hourly return on AI. In practice, this underscores the fact that AI is not “automatic”: its performance depends on the clarity of the brief, the quality of the prompts, and the availability of internal data to provide context for responses (lists of vendors, rates, venue restrictions).

Derived Indicators: Intensity of Use and Productivity

One notable finding is that, in the final validation phase, the duration increases slightly (+1.3 h; -6.7% relative). This increase suggests a shift in focus toward the final review and refinement of AI-generated content (for example, verifying cost assumptions, adapting the language to the client’s culture, and ensuring narrative consistency). From a management perspective, this is consistent with field evidence regarding the “irregular technology front,” where AI can accelerate certain tasks but requires human verification and editing to ensure quality (Dell'Acqua et al., 2023).

To directly answer questions PI-1 through PI-3, the total time was broken down into five operational phases. Table 1 summarizes the averages by phase for the three events, as well as the absolute savings, relative savings, and contribution to the average total savings (60 h). The greatest savings are concentrated in Conceptualization (23.3 hours; 29.2% relative) and Proposal Development (20.0 hours; 22.2%), which together account for approximately 72% of the total savings. In Budgeting, there is an average time savings (13.0 hours; 15.6%), while in Supplier Selection, the time savings are smaller (5.0 hours; 12.5%).

Table 1

Averages by phase: hours without AI vs. with AI, relative savings, and contribution to total savings

Phase	Average without AI (h)	Average with AI (h)	Savings (h)	Relative savings (%)	Contribution to total savings (%)
Conceptualization	80.0	56.7	23.3	29.2%	38.9%
Proposal Development	90.0	70.0	20.0	22.2%	33.3%
Budgeting	83.3	70.3	13.0	15.6%	21.7%
Supplier Selection	40.0	35.0	5.0	12.5%	8.3%

Final Validation	20.0	21.3	-1.3	-6.7%	-2.2%
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Note. Contribution calculated as (Phase savings / 60 h). Negative values indicate an increase in the time spent with AI during that phase. Created by the author.

Breakdown of Savings by Process Phase

Table 2 presents additional estimates of the average difference (Without AI – With AI). Paired t-tests and effect sizes are reported as exploratory estimates given the sample size ($n = 3$ pairs). At the same time, the exact nonparametric test (Wilcoxon) did not reach statistical significance ($p=0.25$), a result that is to be expected given the low statistical power due to the small sample size. Consequently, the interpretation is based primarily on (i) the consistency of the savings across the three events, (ii) the practical magnitude of the change (average of 60 hours; 19.1%), (iii) the confidence interval for the average difference, and (iv) the concentration of the savings in specific phases of the process.

Table 2

Statistical inference regarding the reduction in total time ($n=3$ events)

Statistician	Result
Average Difference (Without AI - With AI)	60.0 h
95% CI (t, $df=2$)	[37.6 h, 82.4 h]
Student's t-test (paired)	$t(2) = 11.54$; $p = 0.0074$
Effect size (Cohen's d_z)	$d_z=6.67$ (very large)
95% Bootstrap IC (percentile; $n=3$)	[51 h, 69 h]
Paired Wilcoxon (exact; $n=3$)	$W=0$; $p=0.25$ (low power with a small n)

Note. The 95% CI was estimated using a t-distribution ($df=2$). The bootstrap reports the percentile range for the differences ($n=3$).

Table 3 shows the total production times in hours for the three events analyzed, comparing the traditional approach (without AI) and the approach supported by generative AI. In all three cases, there is a substantial reduction in total time: Father's Day went from 300 hours to 249 hours (51 hours less), Quinquenios from 360 hours to 300 hours (60 hours less), and the Wind Festival from 280 hours to 211 hours (69 hours less). The average time saved was 60 hours, equivalent to a 19.1% reduction compared to the time taken without AI.

Table 3

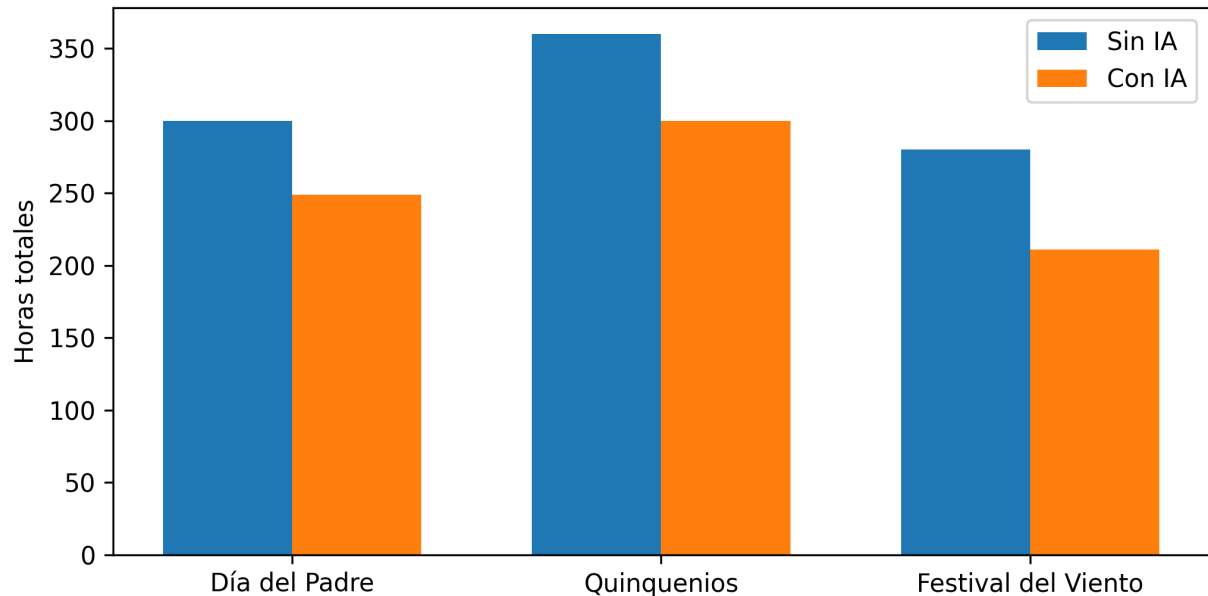
Total production time per event (hours)

Event	Time without AI (hours)	Time with AI (hours)	Difference (hours)	Hours of AI Use
Father's Day	300 h	249 h	51 h ↓	10 a.m.
Five-Year Periods	360 h	300 h	60 h ↓	12 h
Wind Festival	280 h	211 h	69 h ↓	10 p.m.
Average	313.3 h	253.3 h	60 h ↓	2:07 p.m.

Note. Difference expressed as (Without AI - With AI). Prepared by the author based on internal records from a company in the corporate recreational events sector (Bogotá, Colombia).

Figure 1

Comparison of Total Production Hours Without AI vs. With AI



Note. Shorter bars indicate a reduction in total time with the help of generative AI.

Discussion and Conclusions

In conclusion, the incorporation of generative AI (ChatGPT) into the production workflow for corporate recreational events in Bogotá, Colombia, was associated with an average reduction of 19.1% in total production time, primarily in the conceptualization and proposal development phases. The evidence suggests that AI can be a driver of efficiency for medium-sized agencies, provided it is accompanied by training, standardized prompts, governance, and quality assurance. For future research, the following is recommended: (a) expand the number of events and organizations to assess replicability; (b) incorporate cost and quality metrics (not just time); (c) compare different tools and modes of use (assisted, automated, using templates); and (d) assess the impact on customer satisfaction and business performance in the medium term. In an environment where generative AI is transforming knowledge work, generating applied evidence in Latin American contexts is key to guiding responsible and effective adoption (Brynjolfsson et al., 2025; Eloundou et al., 2024).

Conclusions and Future Directions

The study has significant limitations. The main limitation is the small sample size (three events), which limits statistical power and generalizability. However, the consistency of direction across all three cases, the very large effect size, and the confidence interval provide useful pragmatic evidence for internal decision-making. Second, this is a single organizational case; agencies with more mature processes or different types of events may experience different impacts. Third, although comparability was sought, each event has unique characteristics that may influence timing; therefore,

the interpretation focuses on the combined effect with reasonable controls, not on perfect causality.

Limitations

A critical aspect is data governance. Although this study avoided the use of attendees' personal data, in practice many agencies manage databases of participants and sensitive client information. Therefore, privacy policies and responsible information management must accompany the adoption of this technology, given the concerns raised in the sector (Adams, 2021). In addition, the organization must define criteria for use: which tasks are delegated to AI, which tasks require mandatory validation, and how to document decisions and sources.

Implementation Recommendations for Medium-Sized Agencies

Based on the results and operational experience from this case study, five recommendations are proposed for implementing generative AI in medium-sized corporate event agencies. First, define use cases prioritized by time spent and frequency. In this study, the greatest gains came from conceptualization and proposal; therefore, those areas should be the starting point. The recommendation is to map the “as-is” process, estimate the number of hours per phase, and identify repetitive or partially structurable tasks (for example, drafting standard sections, option matrices, and draft timelines).

Second, build a library of prompts and templates organized by event type and client industry. The evidence suggests that the quality of the results depends on the accuracy of the context provided to the AI. Standardizing prompts reduces variability among users, accelerates the learning curve, and enables the replication of best practices. In the events industry, standardization may include storytelling templates, experience scripts, lists of deliverables, and proposal formats, aligned with practical recommendations on how generative AI can support event planning (Estanyol, 2024).

Third, strengthen the internal “knowledge base.” Although AI can generate useful structures without data, its accuracy improves when it is fed with specific information: rate schedules, cost histories, supplier catalogs, venue restrictions, and client policies. This recommendation ties into the economics of AI as a predictive technology: value arises when the cost of making informed decisions is reduced, but it requires calibrated inputs and assumptions (Agrawal et al., 2022). In practice, this means having well-organized and accessible repositories, as well as protocols for updating critical information.

Fourth, implement quality gates and traceability. The slight increase in time for final validation reflects the need to review outputs. Instead of viewing it as a loss, it can be interpreted as an investment in risk management (budgeting errors, inconsistencies with the brief, unrealistic promises). It is recommended to create checklists for each deliverable (proposal, budget, supplier selection) and document which parts were assisted by AI and how they were verified. This approach helps prevent uncritical dependence and improves organizational learning.

Fifth, managing change and training. The survey revealed a high level of acceptance, but also highlighted barriers related to competition and governance. To maintain profitability, it is necessary to train the team in crafting prompts, critically evaluating responses, and adapting to the client's tone. From the perspective of technology acceptance, enhancing perceived usefulness and reducing perceived effort increases intention to use and actual adoption (Davis, 1989; Venkatesh et al., 2012). In addition, leadership must promote responsible use: AI as a complement to human talent, not as a substitute for professional judgment, in line with the discussion on how digital

technologies amplify capabilities when processes are redesigned and new skills are developed (Brynjolfsson & McAfee, 2014).

Taken together, these recommendations make it possible to turn generative AI into a sustainable operational lever: not only to speed up tasks, but also to institutionalize a faster, more consistent, and verifiable way of working. For organizations competing on response speed, this capability can translate into a competitive advantage (more proposals addressed, higher conversion rate) and free up time to design experiences with greater impact.

The breakdown by phases provides a clear roadmap for prioritization. First, integrating AI into the conceptualization and proposal phases offers the greatest return in terms of time. Here, practices such as prompt templates by client type, storytelling generators by industry, and consistency checklists can standardize quality and speed up iteration. Second, in budgeting, AI helps structure budget items and verify consistency, but it requires access to internal data (rates, historical data) to maximize accuracy. Third, when it comes to supplier selection, the benefit is smaller, likely because there are external constraints (supplier response times, human negotiation) that AI cannot eliminate.

Operational Implications: Where to Integrate AI and How to Govern It

Furthermore, the finding of high intent to continue suggests that adoption is feasible when users perceive utility and low effort. In line with TAM and UTAUT2, the adoption strategy should reinforce enabling conditions: training, prompt standards, example libraries, and leadership support to reduce anxiety and resistance (Davis, 1989; Venkatesh et al., 2012). In organizations with high turnover or a steep learning curve, these conditions can be critical to sustaining the observed benefits.

From the perspective of dynamic capabilities, generative AI can be viewed as a complementary resource that enables faster reconfiguration of routines: it speeds up the creation of proposals, facilitates the exploration of alternatives, and supports decision-making under time pressure. By shortening the production cycle, the company can capitalize on more business opportunities or devote more time to high-value activities (customer relations, experiential design, strategic negotiation). This is consistent with the idea that sustainable performance stems from organizational microfoundations that enable organizations to sense and capitalize on opportunities in changing environments (Teece, 2007).

Implications for Dynamic Capabilities and Competitive Advantage

The slight increase in final validation offers an important lesson: AI does not eliminate professional responsibility or quality control. The agency must invest time in verifying and adapting the tool's output to the specific context, which aligns with field findings regarding the need to "calibrate" AI and manage its limitations (Dell'Acqua et al., 2023). In practical terms, a mature implementation should incorporate checklists, peer review, and version control to capture the net benefit without compromising quality.

These results are consistent with the literature on generative AI and productivity in knowledge work. Research in corporate settings finds that AI can speed up writing and analysis tasks, and that the benefits tend to be greatest when the work is partially structureable and when human capabilities are combined with AI support (Brynjolfsson et al., 2025). Furthermore, evidence regarding potential impacts on the labor market

suggests that language models are widely used in administrative and support tasks, which are precisely key components in event production (Eloundou et al., 2024).

The study's main empirical contribution is evidence of an average reduction of 19.1% (60 hours) in the total production time for corporate recreational events in Bogotá, Colombia, following the introduction of generative AI as a systematic support tool. The phased savings model suggests that AI adds the most value in activities that are cognitively demanding and involve rapid iteration: conceptualization and proposal development. At these stages, the tool serves as a catalyst for generating alternatives, structuring texts, and synthesizing ideas, which reduces the time it takes to produce a first draft and facilitates iterations with the client.

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**HYDRAULIC DESIGN OF A LOOPED WATER SUPPLY NETWORK IN A
CRITICAL URBAN AREA USING THE HAZEN-WILLIAMS EQUATION
DIMENSIONAMENTO HIDRÁULICO DE UMA REDE MALHADA DE ABASTECIMENTO
DE ÁGUA EM ÁREA URBANA CRÍTICA UTILIZANDO A EQUAÇÃO DE HAZEN-
WILLIAMS
DISEÑO HIDRÁULICO DE UNA RED DE SUMINISTRO DE AGUA EN CIRCUITO EN UNA
ZONA URBANA CRÍTICA MEDIANTE LA ECUACIÓN DE HAZEN-WILLIAMS**

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ABSTRACT

Keywords:

water distribution, system sizing,
hardy-cross, meshed network,
head loss.

This research aimed at the hydraulic design of a large-scale looped water distribution network, using the Bairro 11 de Novembro (Luanda) as a case study a critical area facing severe deficiencies in its existing system. The methodology integrated water demand determination via assessing apparent needs based on per capita water consumption in Luanda, interviews, and technical consultations with hydraulic analysis using the Hardy-Cross method and the Hazen-Williams equation ($C=140$), applying iterative corrections (ΔQ) until loop balance was achieved ($\epsilon \leq 0.01$ m). The OAT sensitivity analysis identified the roughness coefficient (C) as the most critical parameter for head loss ($S \approx 2.6$), while demand coefficients (K_1, K_2) directly impact flow rates ($S \approx 1$). The designed network features flow rates ranging from 125.41 L/s to 5.90 L/s, with diameters from 350 mm to 80 mm, and velocities between 0.6 and 2.9 m/s. Hydraulic balance was achieved with an average of 3.7 iterations per loop and $\Sigma \Delta H = 0$ m. The sensitivity analysis identified the roughness coefficient (C) as the most critical parameter for head losses ($S \approx 2.6$). The proposed solution is technically viable and replicable, representing a significant contribution to sanitation engineering in contexts of rapid urban growth, although the results depend on demand estimates and the C coefficient, which require future calibration.

RESUMO

Esta pesquisa objetivou o dimensionamento hidráulico de uma rede malhada de grande porte para abastecimento de água,

Palavras chave: distribuição de água, dimensionamento do sistema, hardy-cross, rede malhada, perda de carga.	tomando como caso de estudo o Bairro 11 de Novembro (Luanda), uma localidade crítica onde se enfrentam severas deficiências no sistema existente. A metodologia integrou a determinação da demanda hídrica via deção necessidades aparentes pelo consumo de água per capita em Luanda, entrevistas e consultas técnicas com a análise hidráulica pelo método de Hardy-Cross utilizando a equação de Hazen-Williams ($C=140$), aplicando correções iterativas (ΔQ) até o equilíbrio das malhas ($\varepsilon \leq 0,01$ m). A análise de sensibilidade OAT identificou o coeficiente de rugosidade (C) como parâmetro mais crítico para perdas de carga ($S \approx 2,6$), enquanto os coeficientes de demanda (K_1, K_2) impactam diretamente as vazões ($S \approx 1$). A rede dimensionada apresenta vazões entre 125,41 L/s e 5,90 L/s, com diâmetros de 350 mm a 80 mm, velocidades entre 0,6 e 2,9 m/s. O equilíbrio hidráulico foi alcançado com uma média de 3,7 iterações por anel e $\Sigma\Delta H=0$ m. A análise de sensibilidade identificou o coeficiente de rugosidade (C) como o parâmetro mais crítico para as perdas de carga ($S \approx 2,6$). A solução proposta é tecnicamente viável e replicável, constituindo uma contribuição significativa para a engenharia de saneamento em contextos de rápido crescimento urbano, embora os resultados dependam de estimativas de demanda e do coeficiente C, que requerem calibração futura.
Palabras clave: distribución de agua, dimensionamiento del sistema, hardy-cross, red en bucle, pérdida de carga, análisis de sensibilidad.	Resumen Esta investigación tuvo como objetivo el diseño hidráulico de una red de distribución de agua en bucle a gran escala, utilizando el Bairro 11 de Novembro (Luanda) como caso de estudio, un área crítica que enfrenta graves deficiencias en su sistema existente. La metodología integró la determinación de la demanda de agua a través de la evaluación de las necesidades aparentes basadas en el consumo de agua per cápita en Luanda, entrevistas y consultas técnicas con análisis hidráulico utilizando el método de Hardy-Cross y la ecuación de Hazen-Williams ($C=140$), aplicando correcciones iterativas (ΔQ) hasta lograr el equilibrio del bucle ($\varepsilon \leq 0,01$ m). El análisis de sensibilidad OAT identificó el coeficiente de rugosidad (C) como el parámetro más crítico para la pérdida de carga ($S \approx 2,6$), mientras que los coeficientes de demanda (K_1, K_2) impactan directamente los caudales ($S \approx 1$). La red diseñada presenta caudales que oscilan entre 125,41 L/s y 5,90 L/s, con diámetros de 350 mm a 80 mm y velocidades entre 0,6 y 2,9 m/s. Se logró el equilibrio hidráulico con un promedio de 3,7 iteraciones por bucle y $\Sigma\Delta H=0$ m. El análisis de sensibilidad identificó el coeficiente de rugosidad (C) como el parámetro más crítico para las pérdidas de carga ($S \approx 2,6$). La solución propuesta es técnicamente viable y replicable, lo que representa una contribución significativa a la ingeniería de saneamiento en contextos de rápido crecimiento urbano, aunque los resultados dependen de las estimaciones de demanda y del coeficiente C, que requieren calibración futura.

Introduction

The supply system is quite complex, and not just in terms of maintenance and operation. This is generally the most costly part of the overall water supply project, requiring considerable attention to *per capita* consumption, system parameters, calculation assumptions, and methodologies in order to develop an efficient project.

Luanda is experiencing population growth, exacerbated by rural exodus. According to EPAL-EP (2021), this situation makes the issue of water supply to the population a critical one. In the 11 de Novembro neighborhood, in the Kima Kieza urban district of the municipality of Cazenga, the drinking water distribution and supply system is unable to adequately serve the entire population and all facilities due to the growth in infrastructure and population. Since this is a critical neighborhood, attention has been focused on including it in this study as a case study, in which we hope to find a solution for a new water distribution and supply network for that community, which has been adversely affected by the system's failure.

In light of this, the study's overall objective was to propose a new mesh-type water distribution and supply network. Specifically, the study sought to: (1) Apply a systematic methodology for the hydraulic design of a large-scale piped network in the 11 de Novembro neighborhood, Kima Kieza District, Luanda; (2) Develop a complete and technically feasible construction design for the aforementioned network, defining a hierarchy of pipe diameters, ensuring balanced flow rates, and guaranteeing the capacity to meet peak demand; (3) Conduct a sensitivity analysis of the designed system, identifying the critical parameters for its long-term sustainability; and (4) Demonstrate the effectiveness and stability of using the Hazen-Williams equation and the Hardy-Cross method in conjunction as a tool for the design of large-scale water distribution networks.

Determining water consumption and flow rates in water distribution systems is a critical step in the proper sizing of this infrastructure. Design flow rates must account for the different types of domestic, commercial, institutional, industrial, and public water use, as well as provide for firefighting needs and compensate for continuous pressure losses (h_f) and any leaks. The formulas for calculating continuous pressure losses (h_f) establish relationships among the following six main hydraulic variables: pipe length (L), pressure (P), diameter (D), flow rate (Q), head loss (h_f), and internal roughness (ϵ) (Nogueira & Justino, 2013).

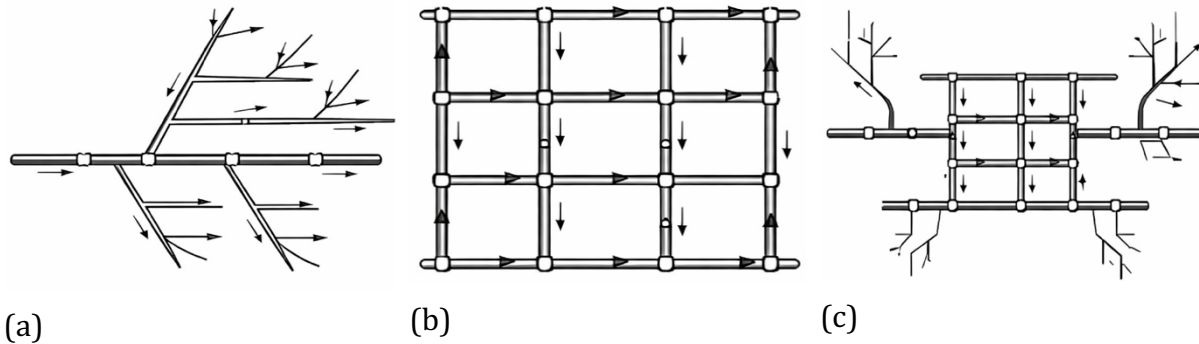
Despite the existence of established standards and methodologies for the design of water supply networks, there is a lack of studies applied to the Angolan context that systematically integrate the determination of local demand, hydraulic design using classical methods, and sensitivity analysis of critical parameters. This shortfall is particularly acute in Luanda's outlying neighborhoods, such as 11 de Novembro, where rapid urban growth has not been accompanied by engineering projects that ensure the system's long-term sustainability and resilience.

Water Distribution Networks

Water distribution networks consist of a series of reservoirs that distribute water to the points of consumption (household connections). There are three types of distribution networks, as shown in the following figure:

Figure 1

(a) Branched network, (b) Mesh network, and (c) Hybrid network



Note. Adapted from Rossman (2000), Mays (2011), AWWA (2012), and Walski et al. (2003)

A branched network is characterized by a hierarchical, tree-like structure in which water is distributed from a main trunk pipeline that progressively branches into secondary and tertiary pipelines until it reaches the points of consumption. This type of network is simple to design and less expensive to deploy, and is often used in small communities or outlying areas. However, it has low hydraulic redundancy, which can lead to interruptions in water supply in the event of failures or maintenance (Walski et al., 2003; AWWA, 2012).

The meshed network consists of interconnected main pipes that form closed loops or meshes, allowing water to reach any point in the system via multiple routes. This configuration provides greater operational reliability, better pressure distribution, and greater flexibility during maintenance or emergencies. Despite the higher construction costs, it is widely adopted in urban areas with medium and high population densities (Rossman, 2000; Mays, 2011).

A mixed network is the result of combining a branched network and a meshed network, and is the most common solution in real-world water supply systems. Generally, the central and most critical areas of the system use meshed networks, while the outlying regions are served by branch lines. This type of network seeks to strike a balance between cost, reliability, and hydraulic efficiency (AWWA, 2012; Walski et al., 2003).

Hardy-Cross Method

A mixed network is the result of combining a branched network and a meshed network, and is the most common solution in real-world water supply systems. Generally, the central and most critical areas of the system use meshed networks, while the outlying regions are served by branch lines. This type of network seeks to strike a balance between cost, reliability, and hydraulic efficiency (AWWA, 2012; Walski et al., 2003).

It is an iterative method for balancing flow rates in meshed networks, based on the Law of Conservation of Mass (nodes) and the Law of Conservation of Energy (meshes).

The continuous pressure drop in each section is calculated using a formula of the following form:

$$\Delta H \text{ ou } h_f = k \cdot Q^n \quad (1)$$

where:

- To Darcy-Weisbach: $n \approx 2$ (but f it depends on Re and roughness, and may vary with Q)
- To Hazen-Williams: $n = 1,852$ e k depends on C (roughness coefficient).

The analysis of the hydraulic balance of water distribution networks is based on the two fundamental laws of fluid mechanics—the law of continuity and the law of energy conservation—as well as on the relationship between flow rate (or velocity) and head loss (or pressure drop) (Munson et al., 2020), established through the Darcy-Weisbach equations (the universal head loss formula) or the Hazen-Williams equation.

Hazen-Williams Equation

The decision to use the Hazen-Williams formula in the design of large-scale networks goes beyond mere numerical efficiency, directly impacting the system's operational reliability and sustainability. The method's fast convergence rate makes it possible to explore more demand and shortage scenarios, thereby optimizing pipe diameters and defining more robust and resilient network configurations (Tsutiya, 2006). This increased efficiency in calculations makes it possible to analyze alternatives that ensure adequate minimum pressures at all points in the network, including during peak periods or in situations of population growth, thereby guaranteeing an equitable water supply—a critical socio-environmental factor (Heller & Pádua, 2006). From an environmental perspective, the careful selection of realistic C coefficients, combined with precise hydraulic sizing, helps reduce leakage losses and minimize the energy required for pumping, thereby promoting energy efficiency and the conservation of water resources (Carrijo, 2012). Therefore, the methodological choice is reflected not only in the network's design but also in its ability to serve society in a fair and environmentally responsible manner.

The choice between the Hazen-Williams and Darcy-Weisbach equations determines the dynamics and efficiency of the iterative hydraulic equilibrium process.

Despite its practical advantages, the application of the Hazen-Williams equation has limitations that must be made clear. Its validity is recognized for water flow at typical temperatures (around 20°C) under rough turbulent conditions, which are typical in distribution networks. However, for situations involving very small diameters, low velocities (laminar or transitional flow), or fluids with significantly different viscosities, the Darcy-Weisbach equation—because it is theoretically more comprehensive—would be the most appropriate choice (Giles, 2004). In addition, the roughness coefficient ' C ' is not constant over the service life of the piping; it decreases due to aging, fouling, and corrosion—a critical aspect that this sensitivity analysis sought to evaluate (Mays, 2000).

While the universal Darcy-Weisbach formula provides a relationship in which the exponent n is approximately 2, but the coefficient f implicitly varies with the Reynolds number and roughness, the Hazen-Williams equation stands out for its structural simplicity, with a fixed exponent $n = 1.852$ and a coefficient k that depends solely on the roughness coefficient C of the material (Azevedo Netto & Alvarez, 2004).

$$\Delta H = \frac{1}{(0,2785C)^{1,85}} \times \frac{L}{D^{4,87}} \times Q^{1,85} \quad (2)$$

This characteristic makes the flow rate–pressure drop relationship explicit and direct, thereby considerably simplifying the calculations within the Hardy-Cross iterative algorithm (Tsutiya, 2006).

For drinking water distribution networks, the choice of the Hazen-Williams formula is amply justified by a number of decisive practical advantages. First, its computational simplicity speeds up the process: with a constant exponent n , the calculation of the flow correction per mesh (ΔQ) becomes more stable and straightforward, without the need to reevaluate a friction factor f that varies with each iteration (Porto, 2004). Consequently, a higher convergence rate is observed, with fewer cycles required to reach equilibrium. This efficiency is complemented by how easy it is to implement in common computer tools, such as spreadsheets. In addition, reference manuals such as those by Azevedo Netto and Tsutiya, which provide standardized tables of the coefficient C , ensure the compatibility and reliability of projects (Tsutiya, 2006). Finally, the applicability of this empirical formula—originally calibrated for these conditions—to the typical flow regime in supply networks characterized by rough turbulence justifies its use.

Limitations of the Hazen-Williams Equation

Despite these considerations, the application of the Darcy-Weisbach equation remains essential in specific scenarios where physical rigor and high precision are imperative. This universal formula should be taken into account when the system operates with fluids whose viscosity differs significantly from that of water at 20°C, such as in cases of extreme temperatures or other liquids (Giles, 2004). It is also necessary in non-turbulent flow regimes, such as in pipes with very small diameters or very low velocities, where laminar or transitional flow regimes may occur, outside the scope of the Hazen-Williams equation. Finally, when the absolute roughness (ϵ) of the material is known with high precision and the designer seeks maximum physical accuracy in the modeling, the Darcy-Weisbach formula, based on fluid mechanics, offers a more comprehensive and accurate representation of the physics of flow under any conditions (Azevedo Netto & Alvarez, 2004).

The evolution of water supply network design builds on classical methods such as the Hardy-Cross method and incorporates contemporary approaches based on optimization and advanced calibration. Johns, Keedwell, and Savić (2014) developed the ALCO-GA genetic algorithm, which improves the efficiency of the search for viable solutions in complex networks. Cui and Kuczera (2025) expanded on this perspective by applying genetic algorithms to the optimization of operational rules, with the aim of minimizing annual costs in systems subject to uncertainty.

In the field of calibration, Rai and Lingayat (2021) validated the use of EPANET by comparing its results with analytical solutions obtained using the Hardy-Cross method. Bas (2026) expanded on this approach by integrating EPANET with statistical indices such as MBE and NSE, demonstrating that models calibrated with field data achieve high reliability in pressure and flow simulations.

This underscores the need to link system sizing to operational control and loss management strategies, as Lusk (2025) points out when discussing the control of actual water losses as a key element in ensuring the sustainability of the water supply.

Method

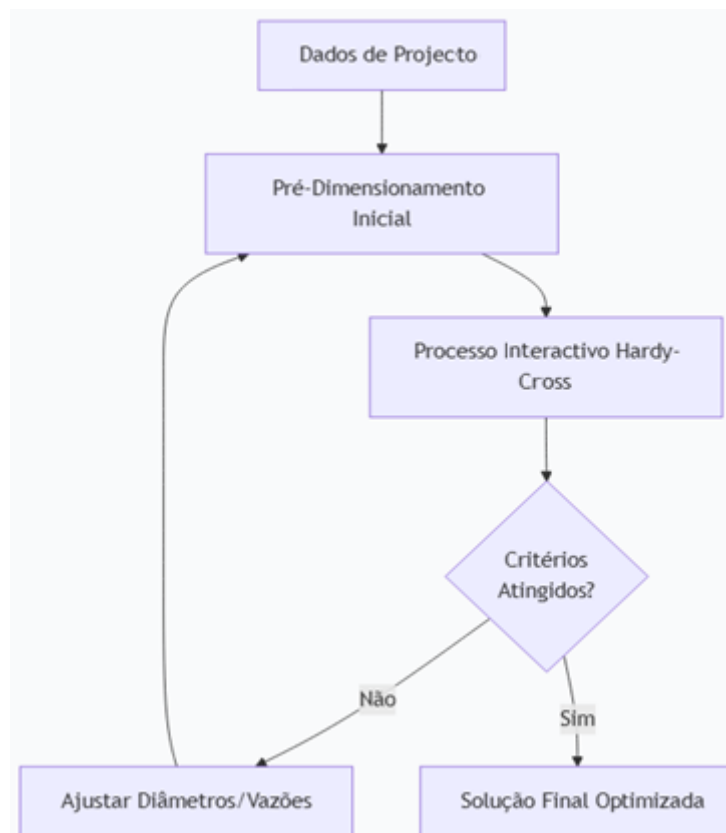
To design a large-scale water supply and distribution network, the methodology of this study focused on two interconnected phases: the precise determination of water demand and the hydraulic analysis of the network.

The demand quantification was based on an analysis of demographics and consumption patterns, using primary data obtained through structured interviews with the target population and technical consultations with the Luanda Public Water Company (EPAL, E.P.), ArcGIS 10.8 for mapping, AutoCAD 2021 for topographic surveying, Handy GPS (free) for navigation, and Redem.Exe (Epanet 2.0) for head loss calculations. This approach made it possible to determine the average daily flow rate, the peak-day coefficient (K_1), and the peak-hour coefficient (K_2), which are fundamental parameters for calculating design flow rates that ensure the system's capacity to meet peak demands.

The methodology for network sizing was carried out according to the systematic approach illustrated in the following figure, which integrates the fundamental principles of network hydraulics with technical design criteria.

Figure 2

Methodological Flowchart for Hydraulic Sizing



The design was based on the following **fundamental assumptions**:

- (i) A permanent and uniform system;
- (ii) Roughness coefficient $C=140$ for new PVC/HDPE pipes, according to Azevedo Netto & Alvarez (2004);
- (iii) Design criteria based on the NBR 12218 standard (ABNT, 2027), with a minimum dynamic pressure of 15 m.c.a. and a maximum velocity of 3.0 m/s. The network topology (Figure 3) was defined based on the topographic survey and mapping (AutoCAD, ArcGIS). The design flow was calculated as follows:

$$Q_p = K_1 \times K_2 \times Q_{med} \quad (3)$$

Where: Q_{med} = average daily flow, calculated based on the design population and per capita consumption (derived from interviews and EPAL data), with $K_1 = 1.2$ and $K_2 = 1.5$.

The project's population was estimated at 33,334 inhabitants, based on (census data and EPAL projections), and is projected to reach 41,668 inhabitants in 2044, twenty years later), resulting in a per capita consumption of [200 liters/person-day] and an average daily flow (Q_{med}) of 207 L/S.

The iterative solution of the hydraulic balance using the Hardy-Cross method, implemented with the Hazen-Williams equation (Equation 2). This choice was justified by its computational efficiency in large-scale systems, since the formula—with its fixed exponent ($n=1.852$) and constant roughness coefficient (C) for each material—simplifies the iterative calculation of flow equilibrium and pressure losses, based on:

$$\Delta H = \frac{(1,0643 \times L)}{(0,2785C)^{1,85} \times D^{4,87}} \times Q^{1,85} \quad (4)$$

Where: $C=140$, L (m), D (m), Q (m^3/s). The formula shown (with 0.2785) is equivalent when using L (m), D (m), and Q (L/s).

The sum of the pressure drops in the loop ($\Sigma\Delta H$) should be close to zero, indicating energy balance.

The following table describes the parameters for each section:

Table 1
Parameters for each section

Excerpt	Length, L (m)	Diameter, D (m)	Coefficient C	Initial Flow Rate, Q_1 (L/s)
AB	500	0.350	140	+120.00
BI	2000	0.250	140	+20.00
HI	500	0.250	140	-57.00
AH	2000	0.350	140	-67.00

To simplify manual calculations, the equivalent form was used:

$$\Delta H = \frac{1}{(0,2785C)^{1,85}} \times \frac{1}{D^{4,87}} \times Q^{1,85} \quad (5)$$

With Q in L/s, L in m, and D in m.

For each mesh k in each iteration n , the process followed these steps.

Determination of the pressure drop for each section i of the network, based on:

$$\Delta H_i^{(n)} = k_i \cdot (Q_i^{(n)})^{1,85} \quad (6)$$

where $k_i = \frac{1}{(0,2785 \cdot C)^{1,85}} \cdot \frac{L_i}{D_i^{4,87}}$ (constant in the excerpt).

The equilibrium condition is given by:

$$\Sigma \Delta H^{(n)} = \sum_{i=1}^m \Delta H_i^{(n)} \quad (7)$$

where m = number of segments in the network.

The convergence criterion is given by:

$$|\Sigma \Delta H^{(n)}| \leq \varepsilon \quad (8)$$

with $\varepsilon = 0,01$ m adopted as the tolerance.

If necessary, the flow correction is calculated; if $|\Sigma \Delta H^{(n)}| > \varepsilon$, the following formula is used:

$$\Delta Q^{(n)} = - \frac{\Sigma \Delta H^{(n)}}{1,85 \cdot \sum_{i=1}^m (|\Delta H_i^{(n)}| / |Q_i^{(n)}|)} \quad (9)$$

$$\Delta Q^{(n)} = - \frac{\Sigma \Delta H^{(n)}}{1,85 \cdot \sum_{i=1}^m (|\Delta H_i^{(n)}| / |Q_i^{(n)}|)}$$

The following is the calculation for updating the flow rates for each section i , based on:

$$Q_i^{(n+1)} = Q_i^{(n)} + \sigma_i \cdot \Delta Q^{(n)} \quad (10)$$

Where: $\sigma_i = +1$ if the direction of the segment matches the positive direction of the grid (clockwise), and $\sigma_i = -1$ otherwise.

Finally, the process is repeated until convergence is achieved by repeating steps 1-4 until $|\Sigma \Delta H^{(n)}| \leq \varepsilon$ for all meshes.

When entering the data, the following conventions were used for flow direction: Positive (+) indicates clockwise flow, and Negative (-) indicates counterclockwise flow. For the pressure drop sign: Positive (+): pressure drop in the direction of the flow adopted as positive; and Negative (-): pressure drop in the opposite direction. Each mesh was processed separately, with corrections propagated to common sections.

To assess the robustness and reliability of the proposed design in light of the uncertainties inherent in the input parameters, a systematic sensitivity analysis was conducted. This analysis followed the *one-factor-at-a-time* (OAT) approach, in which each critical parameter was varied individually while the others were held constant at their nominal values.

Three parameters were selected that were considered the most sensitive and subject to the greatest uncertainty: (1) the Hazen-Williams roughness coefficient (C), varied by ± 10 units around the base value ($C=140$) to simulate conditions for new ($C=150$), standard ($C=140$), and deteriorated ($C=130$) piping; (2) the consumption coefficients (K_1 and K_2), varied individually by $\pm 15\%$ to represent fluctuations in demand estimates; and (3) *per capita* consumption, varied by $\pm 20\%$ to reflect different consumption patterns. For each combination of parameters, the Hardy-Cross method was reapplied to the entire network, and the percentage changes in final flow rates, pressure drops, and minimum pressures were calculated. The sensitivity index (S) was quantified as the ratio of the relative change in the output variable ($\Delta Y/Y$) to the relative change in the input parameter ($\Delta X/X$). This analysis made it possible to identify which parameters

have the greatest influence on the system's performance and to establish appropriate safety margins for the project.

To verify the consistency of the results, the final flow rates for Ring 1 obtained using the manual iterative process (Table 2) were compared with those resulting from the simulation using the REDEM.EXE software (Figure 3). The differences observed were less than 0.1 L/s in all sections, confirming the validity of the method and the accuracy of the calculations.

Results

The existing water supply system consists of a water main with diameters ranging from 250 mm to 350 mm. The distribution network consists of main pipes with a maximum diameter of 110 mm, while the secondary pipes have a minimum diameter of 90 mm.

The Kima Kieza District faces serious shortcomings in the water supply sector, which can be summarized as three main structural problems: (1) the lack of a well-developed and adequately sized distribution network; (2) the irregular and unpredictable operation of the existing infrastructure, which supplies water only at random times; and (3) the population's resulting dependence on informal solutions, forcing residents to seek water from neighbors' homes or alternative sources, thereby compromising the quality of the water supply and the community's safety.

This precarious situation has multidimensional socio-environmental impacts that go beyond mere technical shortcomings. From a social perspective, the irregular water supply places a disproportionate burden on women and children, who are traditionally responsible for collecting water, thereby limiting the time they have for education, paid work, and leisure. The practice of obtaining water from alternative, often untreated sources increases the incidence of waterborne diseases, overburdening the public health system and perpetuating cycles of poverty. Furthermore, water insecurity exacerbates community tensions and creates economic vulnerability, as impoverished families spend a significant portion of their income on informally purchased water.

From an environmental perspective, the substandard system contributes to chronic waste of water resources through uncontrolled leaks in the outdated network and a lack of metering. Pressure on alternative sources, such as shallow wells, can lead to their contamination or depletion, compromising local aquifers. The energy wasted in pumping water through an inefficient network also represents a significant environmental cost in terms of carbon emissions.

Therefore, resizing the meshed network using the Hazen-Williams equation represents not only a hydraulic optimization but also an intervention in the interest of environmental and social justice. A properly designed system that ensures adequate pressure and flow 24 hours a day is a prerequisite for promoting public health, gender equity, social cohesion, and the sustainability of water resources, transforming access to water from an uncertain privilege into a guaranteed fundamental right.

The application of the proposed methodology resulted in the complete design of the meshed network for the 11 de Novembro neighborhood, using the Hardy-Cross method in conjunction with the Hazen-Williams equation. This methodological approach, which is standard in distribution network hydraulics, is based on mass balance (conservation of flow at the nodes) and energy balance (conservation of head loss along each closed loop). This choice is supported by the literature, which highlights its

robustness and computational efficiency in the iterative solution of systems with multiple loops, where a direct analytical solution is impractical (Larock et al., 2000; Jeppson, 1976).

Table 2 summarizes the iterative process for Ring 1, demonstrating the convergence of the method. The convergence criterion, in which the sum of the pressure drops ($\Sigma\Delta H$) in each mesh tends to zero, ensures that the principle of energy conservation is satisfied for the assumed flow directions. The rapid convergence observed—stabilization in just 4 iterations—is a direct operational advantage of using the Hazen-Williams equation. Its simplified form, with a fixed flow rate exponent, allows for faster calculations and ensures numerical stability in the Hardy-Cross iterative method, especially in networks with a large number of loops.

Table 2
Iterative Process of the Hardy-Cross Method - Ring 1

Iteration	Excerpt	Initial Q (l/s)	ΔH (m)	$\Delta H/Q$	ΔQ correction	Corrected Q (l/s)
Home	AB	120.00	+1.88	0.0157	-1.35	118.65
	BI	20.00	+1.40	0.0700	-1.35	18.65
	HI	-57.00	-2.43	0.0426	-1.35	-58.35
	AH	-67.00	-0.51	0.0076	-1.35	-68.35
			+0.34	0.1359		
Sum 1st	AB	118.65	+1.84	0.0155	10.59	129.24
	BI	18.65	+1.23	0.0104	10.59	29.24
	HI	-58.35	-2.54	0.0435	10.59	-47.76
	AH	-68.35	-2.65	0.0388	10.59	-57.76
			-2.12	0.1082		
Sum Monday	AB	129.24	+2.16	0.0167	-3.83	125.41
	BI	29.24	+2.83	0.0968	-3.83	25.41
	HI	-47.76	-1.75	0.0366	-3.83	-51.59
	AH	-57.76	-1.94	0.0336	-3.83	-61.59
			+1.30	0.1837		
Sum Tuesday	AB	125.41	+2.04	0.0163	0.00	125.41
	BI	25.41	+2.18	0.0858	0.00	25.41
	HI	-51.59	-2.02	0.0392	0.00	-51.59

Iteration	Excerpt	Initial Q (l/s)	ΔH (m)	$\Delta H/Q$	ΔQ correction	Corrected Q (l/s)
	AH	-61.59	-2.20	0.0357	0.00	-61.59
Sum			0.00	0.1770		

The selection of a roughness coefficient $C = 140$ for new pipes (typically associated with materials such as PVC, HDPE, or coated steel) is a critical and justifiable parameter. Although this figure is optimistic given the initial conditions, it establishes an ideal performance baseline and serves as a reference for sensitivity analyses and maintenance planning. It is widely accepted in the literature that the value of C decreases over time due to fouling and corrosion processes, severely impacting hydraulic efficiency. The subsequent sensitivity analysis, which examines this decline, is therefore an essential design practice (Mays, 2000).

Table 3 presents a summary of the network's overall performance indicators:

Table 3
Global Performance Indicators for the Scaled Network

Indicator	Amount	Design Criteria	Compliance
Total flow rate (L/s)	[Calculate the sum of the inflow rates]	-	-
Diameters (mm)	80–350	-	-
Average speed (m/s)	0.56	≤ 3.0 m/s	Yes
Maximum speed (m/s)	2.9	≤ 3.0 m/s	Yes
Minimum pressure (m.c.a.)	16.78 m.c.a.	≥ 15 m.c.a.	92% of us respond
We have a pressure of < 15 m.c.a.	8% [Stitches 5 and 6; 12 and 13 (for ring 4); Rows 6 and 7; 13 and 14 (for ring 5); Rows 7 and 8; 14 and 15 (for ring 6)]	-	Yes

Applying the calculation methodology also made it possible to determine the following average thicknesses of the rings:

- The average pressure in ring 4 = 13.96 m.c.a.;
- The average pressure in ring 5 = 12 m.c.a.;
- The average pressure in ring 6 = 11.71 m.c.a.
- The overall average pressure = 16.78 m.c.a. (for the remaining rings).

Although 92% of the nodes have pressures greater than 15 m.c.a., the remaining 8% (corresponding to nodes 5, 6, 7, 8, 12, 13, 14, and 15, located at the highest elevations in the network) have pressures between 12 and 14 m.c.a. Although this condition falls short of the optimal standard, it may be acceptable during peak periods; however, during the detailed design phase, it is recommended to evaluate the division of these areas into zones or the installation of boosters (pressure-regulating valves) to ensure the level of service under all conditions.

The consolidated results for the entire network, presented in Table 3, reveal a coherent and hierarchical hydraulic architecture. The logical progression of diameters from 350 mm in the main sections (AB, BC, CD, DE, EF, FG, and AH) to 80 mm in the final branches (GN), and the corresponding gradient in the final flow rates (from 125.41 l/s to 5.90 l/s), reflect appropriate zoning of pressure and flow. This hierarchy is essential for ensuring adequate operating pressures at all points in the network, while minimizing investment costs in piping and excessive pressure losses. The occurrence of very low residual flows (CJ): (0.26 l/s) is common at the equilibrium nodes between adjacent meshes and confirms the accuracy of the iterative process.

Table 4
Final flow rates in the meshed network

Ring	Excerpt	Final Flow Rate (l/s)	Diameter (mm)	Length (m)
1	AB	125.41	350	500
	BI	25.41	250	2000
	HI	-51.59	250	500
	AH	-61.59	350	2000
2	BC	89.77	300	600
	CJ	19.77	200	1500
	IJ	-52.23	200	600
	BI	-10.23	250	2000
3	CD	69.74	250	700
	DK	19.74	150	1200
	JK	-52.26	150	700
	CJ	-0.26	200	1500
4	FROM	52.58	200	800
	EL	17.58	125	1,000

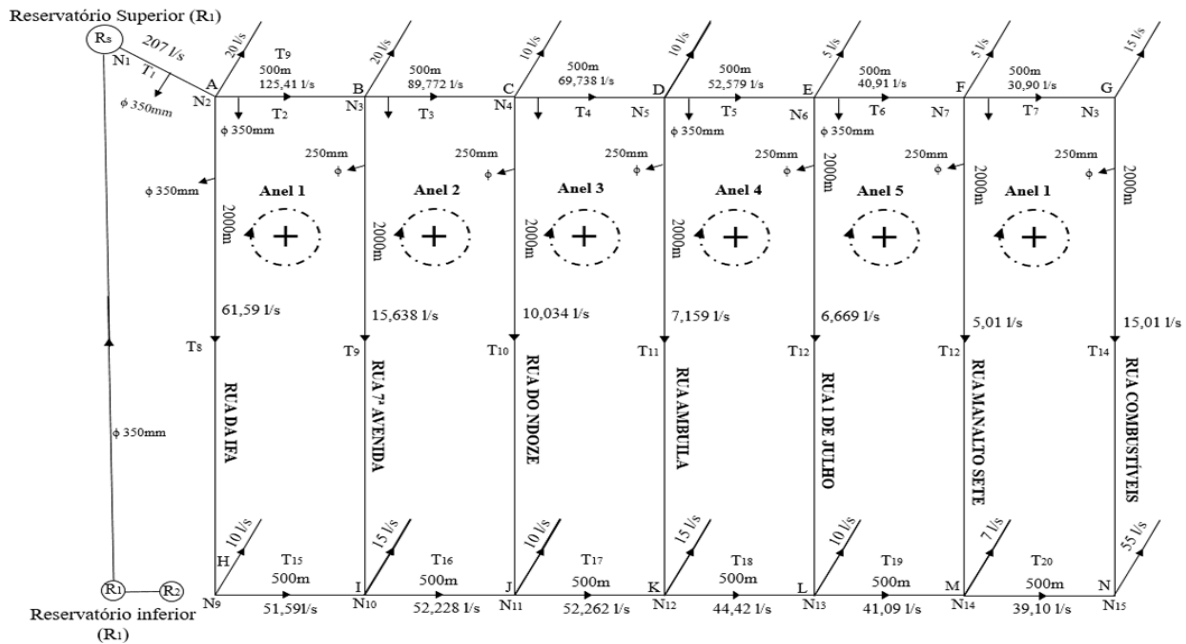
Ring	Excerpt	Final Flow Rate (l/s)	Diameter (mm)	Length (m)
5	KL	-44.42	125	800
	DK	2.58	150	1200
	EF	40.91	150	900
	FM	15.91	100	800
	LM	-41.09	100	900
	EL	5.91	125	1,000
	FG	30.90	125	1,000
6	GN	15.90	80	700
	MN	-39.10	80	1,000
	FM	5.90	100	800

The application of the Hardy-Cross method in conjunction with the Hazen-Williams equation has proven to be an effective tool for the design of large-scale networks. The rapid convergence (on average, 3–4 iterations per loop) validated the choice of methodology, confirming the computational advantages highlighted by Porto (2006) and Tsutiya (2006). The simplicity of the Hazen-Williams formula, with its fixed exponent ($n = 1.852$), facilitated the iterative calculation of flow corrections (ΔQ), resulting in a stable and reliable process.

The final flow rates obtained range from 125.41 l/s in the main sections to 5.90 l/s in the secondary sections, reflecting a hierarchical distribution consistent with the identified consumption pattern. A comparative analysis of the demand data obtained from the interviews and from EPAL, E.P. indicates that the designed system is capable of handling peak flows, with the coefficients $K_1 = 1.2$ and $K_2 = 1.5$ appropriately taken into account.

The implementation of the proposed network will transform access to water from an “uncertain privilege”—as currently experienced by the population—into a “guaranteed fundamental right,” as advocated by Heller and Pádua (2006). The methodology used can be replicated in other neighborhoods of the Kima Kieza District and in regions with similar characteristics, contributing to the advancement of knowledge in sanitation engineering with a focus on sustainability.

We applied the Hardy-Cross method to the six (6) rings that make up the 11 de Novembro neighborhood and obtained the final flow rates verified using the REDEM.EXE computer program, as shown in Figure 3.

Figure 3*Network Sizing Results*

The application of iterative methods based on successive approximations—such as the Hardy-Cross method—for the design of meshed water distribution networks involves a large number of variables to be determined. As a general rule, a mesh network with (m) rings and (n) nodes generates a total of $[m+(n-1)]$ independent equations, and as the complexity of the network increases, the number of equations increases proportionally. Obviously, an algebraic solution for the network is impractical, so more than one computer program is used to apply the method.

The application of the Hardy-Cross method using the REDEM.EXE software to solve the network in the 11 de Novembro neighborhood proved consistent and made it possible to determine key parameters—flow rate and pressure, or pressure losses—for the design of the neighborhood's physical water distribution system.

Discussions

The Hazen-Williams method is relatively accurate, as the results demonstrate, within the range of values analyzed, and requires a certain amount of experience on the part of the project team to apply it. The results demonstrated that the methodology proposed here is feasible and appropriate for medium- and large-scale hydraulic network systems.

The results obtained fully validate the methodology used. The hydraulic (technical) analysis proved to be essential for developing a project that is both feasible and transformative. A properly designed water distribution network is not merely a collection of pipes and flow rates; it is the backbone of an essential public service that, when implemented, can effectively transform access to water from an “uncertain privilege” into a “guaranteed fundamental right,” as argued by Heller & Pádua (2006).

The practical implications are clear:

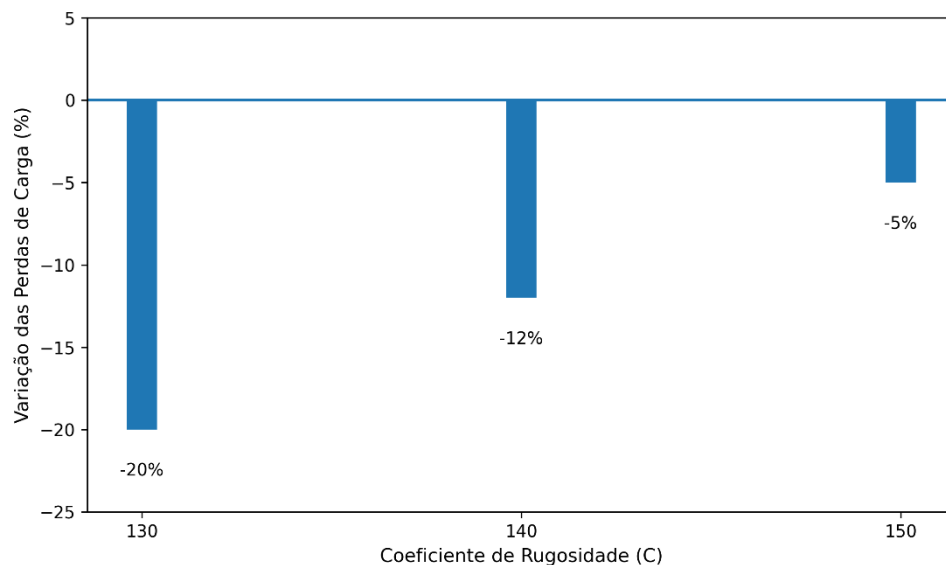
- *For the Project:* Prioritize material specifications that ensure a high and durable C coefficient, and plan for installed capacity with room for growth.

- *For the Operation:* Implement a monitoring system (telemetry) and a condition-based maintenance plan, focusing on maintaining hydraulic roughness.
- *For Public Policy:* The methodology has proven to be replicable, providing a clear protocol for expanding the service to other neighborhoods in Kima Kieza and similar regions, thereby contributing to universal access to water in a sustainable and equitable manner.

The sensitivity analysis revealed that the designed system exhibits varying levels of robustness in response to changes in the input parameters. As shown in Table 1, the roughness coefficient C proved to be the most critical parameter for pressure drops. Figure 4 shows the percentage variation in total pressure losses as a function of the roughness coefficient C , highlighting the system's high sensitivity to pipe degradation.

It can be observed that a reduction of approximately 7% in the value of the C coefficient (from 130 to 140) resulted in an average increase of 18.3% in total pressure losses, with individual variations ranging from 15.1% to 22.7% in the different loops of the network. In contrast, the final discharge rates showed less sensitivity to this variation, with an average reduction of only 3.2%. These results indicate that the progressive degradation of pipes over time significantly impacts the system's energy efficiency, increasing hydraulic losses and, consequently, operating costs, without immediately compromising the system's overall capacity to handle flow.

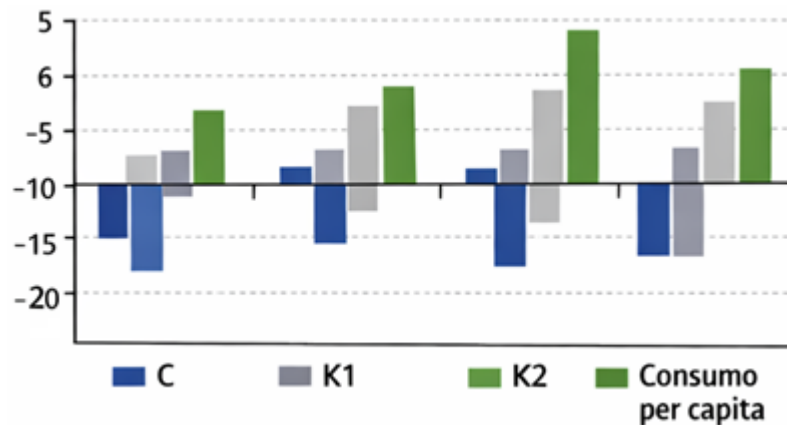
Figure 4
Percentage change in pressure drops



In contrast, variations in the demand coefficients (K_1 and K_2) had a greater impact on the discharge rates. The graphical comparison of the analyzed parameters, shown in Figure 5, demonstrates that the demand coefficients have an almost proportional influence on the average flow rates in the network, while the roughness coefficient has a secondary effect.

Figure 5

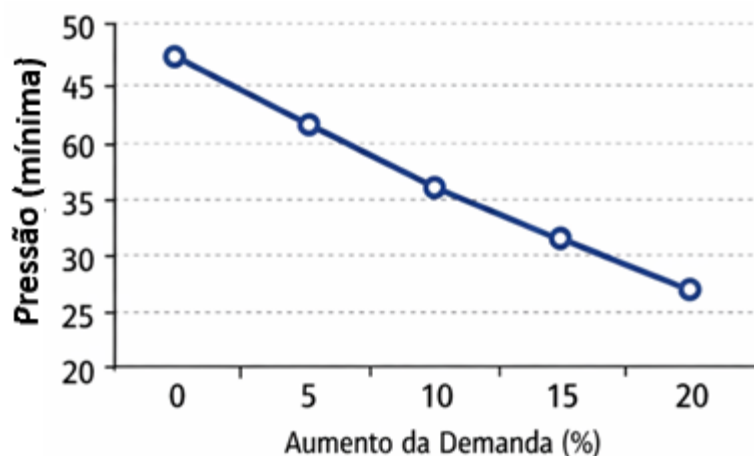
Relative Influence of Design Parameters on Average Flow Rates in the Network



A 15% increase in K_2 (peak consumption hour) resulted in increases of 12.8% to 16.4% in flow rates in the main sections, with corresponding reductions of 5.2 to 8.7 meters in the system's minimum pressure. Figure 6 illustrates the relationship between increased demand and a decrease in the system's minimum pressure, highlighting the need for safety margins when determining piezometric levels.

Figure 6

Change in the system's minimum pressure as a function of increased demand



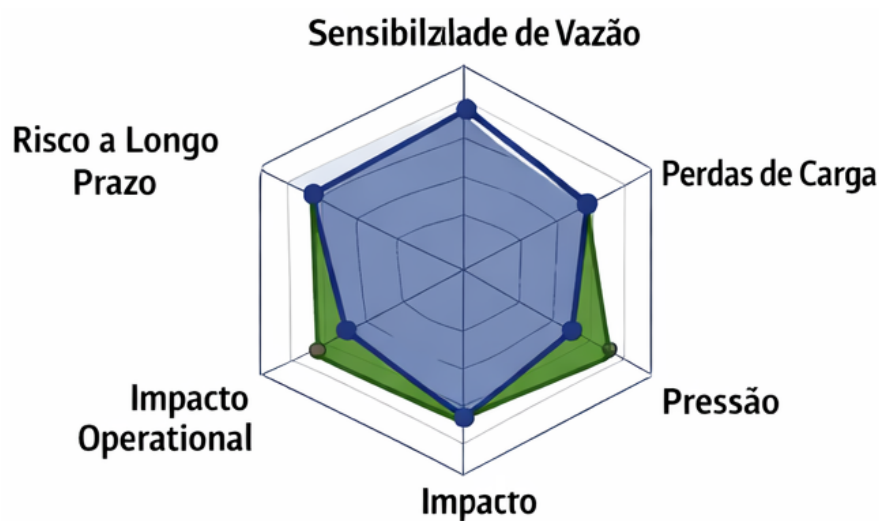
Per capita consumption showed intermediate sensitivity, with an elasticity close to 0.85 (a 1% increase in consumption results in a 0.85% increase in the main flow rates).

Table 5
Sensitivity Analysis Results

Variable Parameter	Variation	Δ Average Flow Rates	Δ Pressure Drops	Δ Minimum Pressure	Sensitivity Index (S)
Coef. C	+7% (150)	+1.1%	-14.2%	+3.4 m	0.16 (Flow) / -2.0 (Loss)
Coef. C	-7% (130)	-3.2%	+18.3%	-4.1 m	0.46 (Flow) / 2.6 (Loss)
Coef. K ₂	+15%	+14.6%	+31.8%	-7.3 m	0.97 (Flow) / 2.1 (Loss)
Coef. K ₁	+15%	+15.1%	+33.1%	-7.8 m	1.01 (Flow) / 2.2 (Loss)
Per capita consumption	+20%	+17.0%	+36.5%	-8.5 m	0.85 (Flow) / 1.8 (Loss)

The results of the sensitivity analysis have important implications for both the design and the future operation of the system. The integrated assessment of the design parameters is presented in Figure 7 using a radar chart, providing a concise overview of the system's robustness in the face of the main hydraulic and operational uncertainties.

Figure 7
Comparative evaluation of the system's robustness in the face of variations in design parameters



A comparative assessment of the system's robustness in the face of variations in design parameters shows that, first of all, the high sensitivity to pressure drops relative

to the C coefficient underscores the economic importance of selecting high-quality materials and implementing a robust preventive maintenance program. The sensitivity index $S \approx 2.6$ indicates that the system is highly sensitive to roughness degradation, which can lead to significantly higher operating costs due to excessive pressure drops. Second, the near-unity sensitivity ($S \approx 1$) with respect to demand coefficients confirms that the system was properly sized to meet peak projections, but also highlights the need for continuous monitoring of population growth and consumption patterns. The variation of approximately 8 meters in minimum pressure for a 15% change in demand highlights the importance of including safety margins when calculating the piezometric levels of reservoirs. Finally, the system's behavior in response to variations in the parameters validates the choice of the proposed diameters: even in the most critical scenarios ($C=130$ and demand +20%), velocities remained below 3.0 m/s and minimum pressures above 15 m.c.a. at 92% of the nodes, demonstrating that the network has sufficient operational resilience to absorb reasonable uncertainties in the design parameters. This analysis suggests that, to ensure long-term sustainability, the investment plan should prioritize the quality of the pipelines and provide for additional capacity to accommodate future expansions, thereby mitigating the identified risks.

The sensitivity analysis (Figure 4) highlights the main weakness of using the C coefficient: a decrease in its value (from 140 to 130) leads to an 18.3% increase in pressure losses, which impacts energy efficiency. This underscores the need to consider, in future projects, simulation using the Darcy-Weisbach equation for aging scenarios, or the adoption of more conservative C coefficients.

Although OAT analysis is useful, it does not capture the combined effects of simultaneous changes in parameters. A comprehensive sensitivity analysis (e.g., Monte Carlo) could, in future studies, quantify the uncertainty associated with the interaction between roughness degradation and increased demand.

The minimum pressure and velocity values found are consistent with the criteria adopted in mesh network designs in other developing regions, such as in the studies by Nogueira & Justino (2013), demonstrating the applicability of the solution.

Conclusions

The study achieved its objectives, demonstrating that:

1. Methodological integration between social demand assessment and technical analysis is essential for transformative projects;
2. The Hazen-Williams equation, used in conjunction with the Hardy-Cross method, is an efficient and reliable tool for the design of large-scale networks;
3. Sensitivity analysis is an essential step in ensuring the long-term resilience and sustainability of infrastructure;
4. A well-founded technical solution is the necessary foundation for realizing the human right to water, generating positive impacts that extend throughout the socioeconomic and environmental spheres.

It is important to note that the study was limited to estimates of *per capita* consumption and demand coefficients (K_1 , K_2) which, although well-founded, have not been validated by real-time field measurements. The hydraulic analysis assumed steady-state conditions and did not simulate operating conditions with hourly variability or component failures (reliability analysis). In addition, although the Hazen-Williams equation is effective, its scope of validity is limited. Looking ahead, the following is recommended after implementation:

- (i) Calibration of the hydraulic model using flow and pressure measurements;
- (ii) Extending the analysis to longer time periods (long-term simulation) to evaluate the system's behavior throughout the day;
- (iii) The development of a loss management and preventive maintenance plan to preserve the roughness coefficient C ; and
- (iv) Conducting a structural reliability analysis for failure and network expansion scenarios.

The implementation of this network will represent a substantial step forward in providing access to safe drinking water for more residents, particularly in the case study, directly contributing to Sustainable Development Goal 6 (SDG 6) and serving as a replicable model for improving the quality of life in critical urban communities.

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**PREDICTIVE SYSTEM FOR THE BEHAVIOR OF THE FINANCIAL ASSET
(EUR/USD) IN THE FOREX MARKET USING MACHINE LEARNING
TOOLS: CASE: ECUADOR.**

**SISTEMA DE PREDICCIÓN DEL COMPORTAMIENTO DEL ACTIVO FINANCIERO
(EUR/USD) EN EL MERCADO FOREX, UTILIZANDO HERRAMIENTAS DE
APRENDIZAJE AUTOMÁTICO. CASO: ECUADOR**

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ABSTRACT

Keywords:

artificial Intelligence,
psychotrading, trader, recurrent
neural networks, python

The present research focuses on the development of a prediction system for the EUR/USD currency pair, recognized for its stability and attractive profitability in the global market, yet subject to episodes of volatility. The study seeks to mitigate the impact of traders' emotional management, known as "psychotrading," a variable that can compromise the effectiveness of technical strategies in the field of trading. With the purpose of reducing the influence of the human factor in decision-making, the methodology proposed by Tinoco-Figueroa S. (2024) was adopted, who applied algorithms such as Lorentz distance and approximate nearest neighbors in the analysis of the BTC/USD currency pair. This research incorporates the use of Recurrent Neural Networks, specifically the LSTM (Long Short-Term Memory) model, given its ability to model financial time series with high accuracy. The technical implementation was carried out in the Visual Studio Code – VSCODE development environment, using the Python programming language. Historical data were obtained from the MetaTrader5 platform, establishing a real-time connection to collect information from the last 60 days with 15-minute intervals. Initially, a diagnostic assessment was conducted, followed by the design of the strategy and evaluation of the system's performance through specific metrics. The results were compared with those obtained by Tinoco-Figueroa S. (2024), and improvement actions were proposed along with the presentation of the model's limitations.

RESUMEN**Palabras clave:**

inteligencia artificial, psicotrading,
trader, redes neuronales
recurrentes, python

La presente investigación se centra en el desarrollo de un sistema de predicción para el par de divisas EUR/USD, reconocido por su estabilidad y atractiva rentabilidad en el mercado global, pero sujeto a episodios de volatilidad. El estudio busca mitigar el impacto de la gestión emocional del trader conocida como “psicotrading”, una variable que puede comprometer la efectividad de estrategias técnicas en el ámbito del trading. Con el propósito de reducir la influencia del factor humano en la toma de decisiones, se adopta la metodología propuesta por Tinoco-Figueroa S. (2024), quien aplicó algoritmos como la distancia de Lorentz y vecinos más cercanos aproximados en el análisis del par de divisas BTC/USD. En esta investigación se incluye el uso de Redes Neuronales Recurrentes, específicamente el modelo LSTM (Long Short-Term Memory), dada su capacidad para modelar series temporales financieras con alta precisión. La implementación técnica se realizó en el entorno de desarrollo Visual Studio Code – VSCODE, utilizando el lenguaje de programación Python. Los datos históricos fueron obtenidos desde la plataforma MetaTrader5, estableciendo una conexión en tiempo real para recopilar información de los últimos 60 días con intervalos de 15 minutos. En principio se realizó un diagnóstico inicial para posteriormente plantear la estrategia y evaluar el desempeño del sistema mediante métricas específicas, se comparó con los resultados obtenidos por Tinoco-Figueroa S. (2024), y se propusieron acciones de mejora junto con la exposición de las limitaciones del modelo.

Introduction

This study aims to predict the price of a financial instrument traded on the stock exchange. The EUR/USD currency pair was chosen because it is a popular financial asset that has historically demonstrated stability, yet also exhibits a certain degree of volatility. Furthermore, these currencies are used by countries with the world's largest and strongest economies, making it an attractive financial instrument. For the prediction, we will use the methodology proposed by Tinoco-Figueroa, S. (2024), employing two algorithms: 1. the "Lorentz Distance" and 2. "Approximate Nearest Neighbors," with the aim of contributing to this study by incorporating a third algorithm: 3. Recurrent Neural Networks (RNN).

It is well known that predicting the price of financial assets is a major challenge; the use of cutting-edge technologies has enabled investors to manage risk more effectively than traditional methods. However, the problem of predicting the price of a financial instrument is a multifaceted task that requires constant effort; Since ancient times, this issue has been a subject of debate, which is why methods have constantly been implemented to improve the predictive capabilities of the models or approaches used. The fact is that the problem of prediction stems not only from knowledge but also from learning to manage emotions—a concept known in the trading world as "psychotrading"; To paraphrase Naranjo K. and González G. (2022): "...deep-seated feelings... cannot be avoided, but they can be controlled, as they play a very important role if one wishes to trade in these financial markets...". With the advent of Artificial Intelligence (AI), it has become possible to automate the process and eliminate "psychotrading" from the forecasting equation; This has its advantages and disadvantages: systems do not feel; they act based on algorithms, which is an advantage if the trader does not know how to manage their emotions, but it is a disadvantage if the trader is capable of effectively grasping what the market is saying, thereby excluding or at least minimizing the emotional aspect of trading in financial markets; However, prediction systems today effectively capture what the market is actually signaling. It would seem that "psychotrading" can be avoided, since failing to exclude this variable from the equation involves various challenges that are often difficult to manage. The solution to this problem is to eliminate the psychological trading pressures that most traders face every day and provide a statistically robust and financially profitable system that achieves high success rates in its trades, with the aim of improving upon the proposal by Tinoco-Figueroa, S. (2024), with a success rate of 92.86% and a Sharpe ratio of 0.13 for the BCH/USD currency pair.

Valer, S. (2023) demonstrated through an empirical study that the use of recurrent neural networks in predicting the prices of financial instruments has yielded good results; therefore, recurrent neural networks—which essentially mimic the behavior of the human brain in decision-making—will be incorporated in an effort to improve the predictive capacity of the study conducted by Tinoco-Figueroa, S. (2024); that is, a prediction system based on three algorithms will be created and ultimately evaluated using performance metrics and compared with the aforementioned study to assess its effectiveness.

First, the initial context that gave rise to the research is presented, outlining the challenges faced by financial traders when executing their strategies in the markets. It is recognized that, regardless of the technical quality of a strategy, a lack of control over the emotional component (psychotrading) can lead to poor decisions and adverse outcomes.

Next, the data collection methodology is established, detailing the financial platform selected for obtaining information and justifying its selection based on the

study's requirements. Similarly, the approach used for data cleaning is described, with the goal of constructing a structured dataset (dataframe) free of biases and variables that could introduce confusion into the analysis; it should be noted that a dataframe is a two-dimensional data structure, organized into rows and columns, similar to a spreadsheet or a database table.

The following is a preliminary assessment that characterizes the financial asset under study through the presentation of various charts that facilitate exploratory analysis. These include: charts showing the closing price for the last 60 days at 15-minute intervals, closing price distribution, box plots, and correlation analysis between variables in the dataframe. Next, the proposal derived from the analysis and the results obtained during the data collection process is presented, with the aim of capitalizing on the identified opportunity; the development of the EUR/USD price prediction system is described, addressing the technical aspects of the implemented code, such as the creation of the loop (a control structure that allows instructions to be repeated until a specific condition is met), as well as the elements contained within that loop: lists, technical indicators, conditions for opening and closing positions, signal generation, and the application of the three algorithms that constitute the methodological basis of the study.

Next, we systematically present the results obtained from the implementation of the EUR/USD currency pair price prediction system. A comprehensive evaluation is conducted of the selected performance metrics, such as the mean squared error (MSE), the coefficient of determination (R^2), and other relevant metrics that allow for an assessment of the accuracy and efficiency of the proposed model. This evaluation is supplemented by a direct comparison with the methodology developed by Tinoco Figueroa S. (2024), in order to identify similarities, differences, and possible improvements regarding the predictive approach. Next, the results obtained are analyzed in terms of their practical applicability in real-world trading scenarios, taking into account both the model's performance with historical data and its ability to adapt to changing market conditions. The strengths of the developed system, as well as its technical and operational limitations, are discussed.

Finally, a structured set of actions aimed at improving the overall performance of the proposed system is proposed. These actions include, first and foremost, the operational optimization of internal processes, with the goal of reducing redundancies, improving computational efficiency, and facilitating functional scalability. Second, it is recommended to move toward a systematic modularization of components, which would allow for greater flexibility in managing updates, unit tests, and context-specific adaptations; and it is suggested that geometric and causality metrics be incorporated as part of the model evaluation framework, in order to enrich the structural analysis of the data and strengthen the system's explanatory power when dealing with complex and nonlinear phenomena.

Although the studies, research, and legal updates conducted in the areas of taxation and finance have demonstrated progress, there are still opportunities for improvement in the field of stock market investment. The background of this research is outlined below:

Ecuadorian Regulatory Framework

The legal framework governing trading activities in Ecuador is defined by four regulations: 1) The Organic Monetary and Financial Code – Book II – Securities Market Law (2014) and its implementing regulations, 2) the Organic Law on Electronic Commerce, Digital Signatures, and Data Messages (2002), 3) The Tax Code (2005). Although these laws do not broadly regulate international trading activity, this activity appears to be regulated for financial assets listed on the Quito and Guayaquil stock

exchanges; It is important to note that within Ecuador there are few local trading platforms that offer this service. By way of comparison, purchasing a financial asset on the New York or London stock exchanges is not the same as doing so on the Quito or Guayaquil exchanges, since there are not as many buyers and sellers on Ecuador's stock exchanges, making the local market less attractive for short-term trading activities; The opposite could be true for long-term investors, whose goal is to generate returns over longer periods. In 2022, the National Assembly of Ecuador passed 4) the Organic Law on the Development, Regulation, and Control of Financial Technology Services, also known as the Fintech Law. Articles 3 and 5 of the law establish its scope of application, which are:

- “... i) Technological infrastructure for processing payment methods;
- (ii) Financial technology services;
- iii) Specialized electronic deposit and payment companies;
- iv) Securities market technology services; and, (emphasis added)
- v) Insurance technology services.”

Article 8 of the Fintech Act establishes that the institutions responsible for monitoring compliance with the regulations are: 1) The Central Bank of Ecuador, 2) the Superintendency of Companies, Securities, and Insurance, and 3) the Superintendency of Banks or the Superintendency of Popular and Solidarity Economy, within the scope of their respective jurisdictions; however, Article 8.7 of the Organic Monetary and Financial Code establishes that oversight of these companies shall be the responsibility of the Superintendency of Companies, Securities, and Insurance.

In the regulatory analysis conducted by Ochoa Castillo, S. (2024), the author states that, although current regulations govern trading activity within the country, these regulations are local in scope; there are no tax laws or regulations governing the purchase and sale of financial assets on international platforms. Consequently, individuals who profit from trading do not pay taxes—they would be required to do so if they bought or sold financial assets on local platforms or through local brokers. In other words, trading is not prohibited, but there is no tax regulation governing it; however, while regulations do exist for platforms offering financial services within the local securities market, there are no taxes for traders who buy or sell through international brokers or platforms, aside from the foreign exchange exit tax (ISD), which does not constitute a direct tax on trading profits; regulating this activity will be a challenge for the Ecuadorian tax system.

Theoretical Framework

Linear Methods

Because they are easy to interpret, they have an advantage over other models, such as ARIMA or ARIMAX models. With the introduction of ARCH and GARCH models in the 1990s, greater emphasis was placed on data volatility; however, the estimated errors often exhibit excess kurtosis. (Frances and Ghijsels. 1999, cited by Garcia, M., et al. (2013.)

Nonlinear Methods

It is well known that the prices of financial assets fluctuate in a nonlinear manner, which some authors consider to be a more effective method for prediction; among these are artificial neural networks, which have the ability to capture the nonlinear relationships between input and output values. Zemke, 1999. (cited by Garcia, M., et al. (2013) argues that markets with fewer transactions are easier to predict. He uses machine learning techniques to predict the value of the WIG index through binary decisions. The four techniques he uses are: prediction with neural networks, Bayesian classifier, K-nearest neighbor, and K-nearest neighbor prediction scrutinized. In his study, he

concluded that the K-nearest neighbor technique and neural networks, with 64% accuracy, yield better predictions because the stock market is dominated by nonlinear relationships in the data. See Lu, Chang, Chen, and Lee, 2009. (cited by García, M., et al. (2013) predicted the B-Share Index of the Shanghai Stock Exchange using the MARS (multivariate adaptive regression splines), BPN (backpropagation neural network), SVR (support vector regression), and MLR (multiple linear regression). The study concluded that the MARS model produced better predictions in terms of error and accuracy than the others, with an error rate of 1.5% and an accuracy of 82%. In another study by Gurasen, Kayakutlu, and Daim (2011). (cited by Garcia, M., et al. (2013) compares three models to assess their effectiveness: the multilayer perceptron (MLP), the Dynamic Artificial Neural Network (DNA2), and a hybrid model combining neural networks and GARCH. The models were evaluated using the mean squared error and the mean absolute deviation, and the study concluded that the classic MLP model yields the best results.

Hybrid Models

As their name suggests, these models combine different techniques—both linear and nonlinear. In a study conducted by Wang, Wang, and Zhang Guo, 2012. (cited by Garcia, M., et al. 2013) presents a hybrid model (PHM), which combines the ARIMA, exponential smoothing (ESM), and BPNN models to capture both linear and nonlinear relationships in a time series. Monthly data from China's SZII index and the Dow Jones Industrial Average Index (DJIAI-USA) were used. The results demonstrated that the PHM hybrid model delivers better performance in terms of error and accuracy than other models such as ARIMA, ESM, and BPNN, due to its robustness. Another study conducted by Dai, Wu, and Lu (2012) is noteworthy for the results it achieved in predicting the Nikkei 225 and Shanghai B-share indices, with accuracy rates exceeding 80%. They proposed a time-series forecasting model by combining nonlinear independent component analysis with neural networks. Their results were outstanding: not only did this approach improve upon the forecasting accuracy of the neural network approach, but it also outperformed the three comparison methods. Valer, S. (2023) conducted a study to predict the prices of four financial assets (Tesla, the S&P 500, Bitcoin, and oil), using three methodologies: 1. Linear Regression, 2. Support Vector Regression (SVR) and Neural Networks (LSTM and GRU): The results show that none of the models deliver outstanding performance in terms of R^2 when attempting to predict the entire time series in days, however, if the prediction period is halved, the trends become predictable, and it is even possible to obtain exact prices; of the three models, those based on neural networks provide the best predictions. Tinoco-Figueroa, S. (2024), in his study "Machine Learning in Financial Markets," presents a price prediction model based on the "Lorentz Distance" and the use of the "Approximate Nearest Neighbors" algorithm for trading activities, that is, short-term investments, applied to the BCH/USD currency pair; the results show a success rate of 92.86%.

Prediction Models Using Macroeconomic Variables

There are some studies that demonstrate the relationship between financial assets and macroeconomic variables, such as the inflation rate, the interest rate, the dollar exchange rate, and GDP, among others. Kwon and Shin (cited by García, M., et al. (2013), in their study based on a cointegration test and a Granger causality test, found that stock market indices are cointegrated with a set of macroeconomic variables—the production index, exchange rate, trade balance, and money supply—which have a direct long-run equilibrium relationship with each stock market index; Similarly, Caldas and Pires (cited by García, M., et al. (2013) used macroeconomic variables such as country risk and Brazil's main stock market index (Ibovespa), along with the econometric techniques of Ordinary

Least Squares (OLS) and the Generalized Method of Moments (GMM), to demonstrate that monetary policy, public debt management, credibility, and reputation affect country risk and the performance of the Brazilian stock market.

Selection of the Methodology to Be Used

Since an intervention project was selected, we will now explain the characteristics of the theoretical model used to develop the proposal. The following describes the characteristics of the method developed by Tinoco-Figueroa, S. (2024), which serves as the basis for developing the proposed project.

The method to be used is based on the methodology proposed by Tinoco-Figueroa, S. (2024), in which two algorithms were incorporated into the BCH/USD financial asset prediction model: the first is called the “Lorentz distance” and the second is called “Nearest Neighbor Approximation.” In data science, the Lorentz distance is used as a measure of similarity in multidimensional datasets, and the nearest neighbors algorithm identifies similar points in a multidimensional space and uses them to predict trends; this has been tested in their study and has yielded good results—a success rate of 92.86% and a Sharpe ratio of 0.13; the aim of this study is to incorporate Recurrent Neural Networks into this method to improve predictive capacity and expected returns relative to the risk assumed, since we know that, according to theory, the application of Recurrent Neural Networks has improved predictive ability in financial data, as shown in the studies by Zemke (1999), Dai, Wu, and Lu (2012), and Valer, S. (2023).

Method

Methodology for Data Collection and Processing

The methodology used for data collection and processing is based on the methodology used by Tinoco-Figueroa (2024); the difference lies in the tools used for data processing. Tinoco-Figueroa’s (2024) study was conducted in Google Colab, and data was obtained from Alpaca Markets; whereas in this study, the VSCODE tool was used with the Python 3.11.3(.venv) interpreter, and the data was obtained from the MetaTrader5 broker. The same environment and data provider were not used because Alpaca Markets does not quote the EUR/USD currency pair; it is a provider that offers only currency pairs involving cryptocurrencies. The data was then organized into a DataFrame with the following variables:

- Open = opening price
- High = highest price of the day
- Low = lowest price of the day
- Close = closing price
- tick_volume = transaction volume

The data is collected in real time, covering a 60-day period with a 15-minute time interval. It is important to note that, in order to collect real-time data, it was necessary to work simultaneously with the MetaTrader 5 desktop application and VSCODE, thereby enabling the terminals to be linked for connection and data collection.

The key algorithm in this study is the Lorentzian distance. To this end, the `advanced\_ta` library—a library for advanced technical analysis—was installed. Once the module was imported, the “LorentzianClassification” function was used to obtain the Lorentzian distance (space-time in relativity). Technical indicators were calculated and sorted in the data frame. These indicators are:

RSI = Measures the Strength of the Movement
 WT = Momentum Indicator
 CCI = Detects overbought/oversold conditions
 ADX = Measures trend strength
 SMA = Simple Moving Average

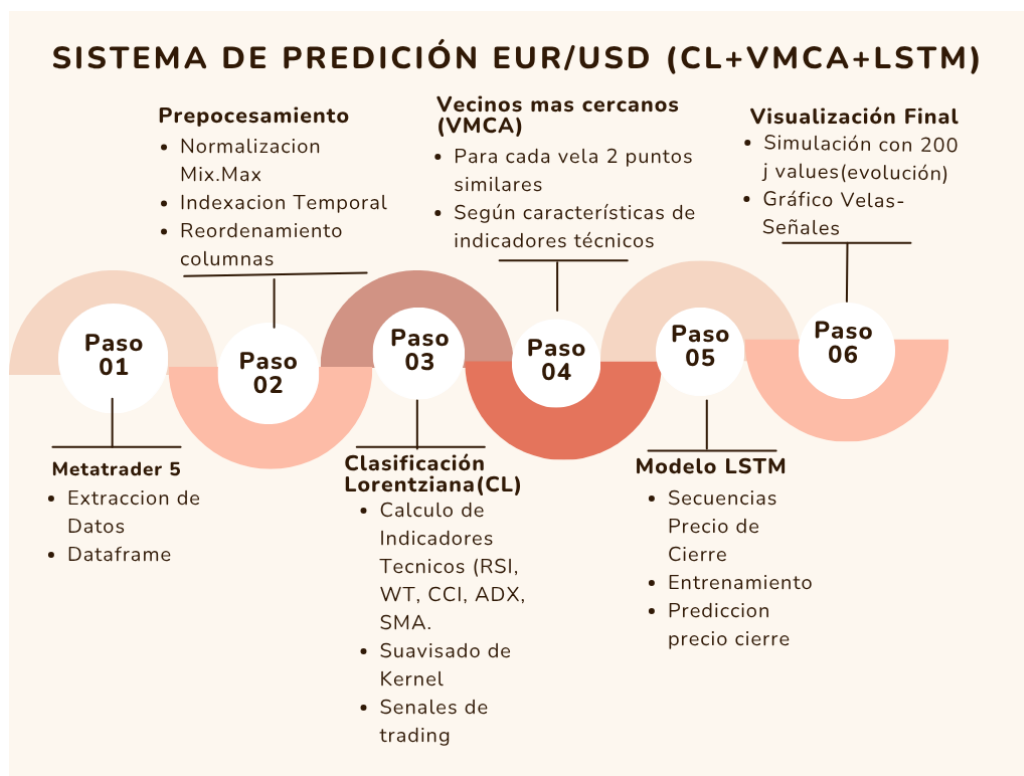
In addition, the neighborsCount function was used, with which the model searched for historical patterns similar to the current pattern over the last 4,130 candlesticks; in other words, this function enabled classification based on the closest approximate neighbors, detected recurring patterns in the market, generated trading signals based on historical behavior, and filtered out data noise.

Conceptual Diagram of the System

The diagram shown illustrates the modular architecture of the prediction system, ranging from the data acquisition phase to the modeling, inference, and performance evaluation processes. This schematic diagram provides a structured overview of the system's operational capabilities, highlighting the sequential integration of analytical, classificatory, and predictive components.

Figure 1

Conceptual Diagram of the System



The diagram shown illustrates the modular architecture of the prediction system, ranging from the data acquisition phase to the modeling, inference, and performance evaluation processes. This schematic diagram provides a structured overview of the system's operational capabilities, highlighting the sequential integration of analytical, classificatory, and predictive components.

Step 1

He installed it in the VSCODE terminal and imported the following modules:

Matplotlib.dates: Handling Dates in Time Charts.

Mplfinance: A bookstore specializing in candlestick charts.

Chain: It allows you to efficiently concatenate multiple iterables.

Warnings: Controls or suppresses warnings during execution.

Datetime, timedelta, date: Manipulating dates and times, useful for time series.

MetaTrader 5: Official API for connecting to the MetaTrader 5 trading platform. It allows you to download market data, place orders, etc.

Pandas: Data manipulation in DataFrame-like structures.

Pandas_ta: A Pandas extension for applying technical indicators such as RSI, SMA, MACD, etc.

NumPy: Efficient numerical computation, especially with arrays.

Matplotlib.pyplot: Data visualization in graphs.

Pytz: Time zone management, useful for synchronizing market data.

Advanced_ta.LorentzianClassification: Implements a classifier based on Lorentz functions, which is useful for detecting patterns or anomalies in time series.

MinMaxScaler: Scale the data between 0 and 1, as required for neural networks.

Sequential, LSTM, Dense: Keras components for building neural networks, in this case an LSTM (Long Short-Term Memory) network, which is ideal for modeling time series such as financial prices.

Mean_squared_error, mean_absolute_error, r2_score: Metrics for evaluating model performance.

Math: Standard mathematical functions (logarithms, roots, etc.).

To connect to MetaTrader 5 from VS Code, I had to create a demo account in the application and keep it logged in so that VS Code could connect. This is because MetaTrader 5 does not manage credentials on its own and requires the MT5 terminal to be open and logged in with an active account.

Lists were created to store the results and include them in the DataFrame, with the goal of evaluating the simulations during the preliminary testing and verifying the results in the prediction. The lists are as follows:

total_trades_list = Total Number of Trades

winning_trades_list = Number of Winning Trades

lost_trades_list = Number of Losing Trades

win_rate_list = Percentage of (Number of Winning Trades / Number of Losing Trades)

pips_acum_list = Cumulative total of pips gained or lost per strategy

real_pips_acum_list = Similar to pips_acum_list but adjusted for actual costs

j_values = Parameter

sharpe_ratio_list = Measures risk-adjusted return

Data Download and Preparation: The data was downloaded from the MetaTrader 5 broker and prepared in a DataFrame.

Step 2

Based on the three established algorithms, a prediction system was created, which is explained as follows:

Min-Max Normalization: The data was normalized on a scale from 0 to 1; this prevents variables with large values from dominating the model.

Temporal Indexing: The data was organized chronologically by assigning timestamps.

Reordering columns: The columns are sorted in the following order: open, high, low, close, tick_volume.

Step 3

Looping over the values of j : The prediction system was implemented within the main loop, where the parameter " j " was varied in increments of 1 to simulate the effectiveness of the strategy.

Lorentzian Classification: A Lorentz distance-based classifier is applied, using technical indicators such as RSI, WT, CCI, ADX, and SMA as features. Additionally, filters for volatility, market regime, and kernel smoothing are configured. The goal is to detect entry signals (long or short positions).

Step 4

Nearest neighbors: In the Lorentzian classifier, the ``neighbors=2`` function was used. This parameter controls the smoothness and sensitivity of the model; the value 2 aims to strike a balance between accuracy and generalization by comparing each point with its two nearest neighbors in Lorentzian space.

Step 5

LSTM Normalization and Modeling: Closing prices are normalized to model the price's time series dynamics, and sequences are created to train the LSTM neural network, which will predict the next closing price; the more simulations the model has, the better trained it will be.

Trade Construction: A DataFrame is created to record each detected signal

Signal Evaluation: Each signal is compared to determine whether it was a winner or a loser

Cumulative Pips Calculations: The pips earned on each trade of the same type are added together, which allows you to assess the cumulative profitability.

Model training: Internal parameters are adjusted so that the model's predictions come as close as possible to the actual values; this is the neural network's learning process.

Step 6

Final display: Once the model has been simulated using 200 values of j (parameter), the prediction system is evaluated from both a statistical and financial perspective to assess its robustness and profitability.

The following are the indicators that will be used to evaluate the model:

- Mean Square Error (MSE): A value close to 0 is expected, as this will indicate that the model's predictions are very close to the actual values.
- Root Mean Square Error (RMSE): A value close to 0 is expected, as this will indicate that the model is predicting accurately
- Mean Absolute Error (MAE): A value close to 0 is expected; this will confirm the idea that the model predicts values that are at least very close to the actual values.
- Coefficient of Determination (R^2): A value close to 1 is expected, as this will indicate that the model accurately captures the market structure—that is, the algorithms are accurately understanding the dynamics of the financial asset.

- **Success Rate:** A success rate of more than 85% is expected; this means that out of every 10 operations performed, 8.5 are successful. Although the success rate in the study by Tinoco-Figueroa S. (2024) was 92.86%, a rate higher than 85% is very acceptable; however, we will strive to improve upon the rate reported in that study.
- **Sharpe Ratio:** A rate higher than 0.5% is expected; this would indicate an acceptable return relative to the risk taken. The Sharpe ratio in the study by Tinoco-Figueroa S. (2024) was 0.13%; although this is considered an acceptable rate given the number of pips accumulated, efforts will be made to improve it.
- **Accumulated Pips:** We expect positive pips, as this will indicate that the strategy is profitable.
- **Actual Accumulated Pips:** Unlike cumulative pips, the actual costs of each trade are taken into account, and positive pips are expected.

Results

Results of the Information Survey

With a time frame of up to 60 days, 4,223 candlesticks are generated (Table 1 shows the first 5 candlesticks), each of which has 8 columns. The “time” variable is in UNIX timestamp format and is derived from the most current data available at the time the code is executed.

Table 1
15-minute data frame for 60 days

(4223, 8)									
No Vela	time	open	high	low	close	tick_volume	spread	real_volume	
0	175495680	116,06	116,12	116,06	116,11				
	0	8	3	7	4	20	51	0	
1	175495770	116,11	116,11	116,10	116,11				
	0	4	8	0	4	90	45	0	
2	175495860	116,11	116,13	116,10	116,12				
	0	4	0	5	7	249	30	0	
3	175495950	116,12	116,14	116,10	116,14				
	0	7	9	9	0	179	29	0	
4	175496040	116,13	116,18	116,12	116,14				
	0	9	2	2	1	553	8	0	

As shown in Table 1, for candle No. “0,” the “tick volume” variable is equal to 20, which indicates “low activity”—that is, few buyers and sellers—with a high spread of No. “51,” suggesting that there was low liquidity during that candle. It is important to note that the spread is the difference between the bid price and the ask price; we observe that “real_volume” is 0, which means that the MetaTrader 5 broker does not have information for this variable.

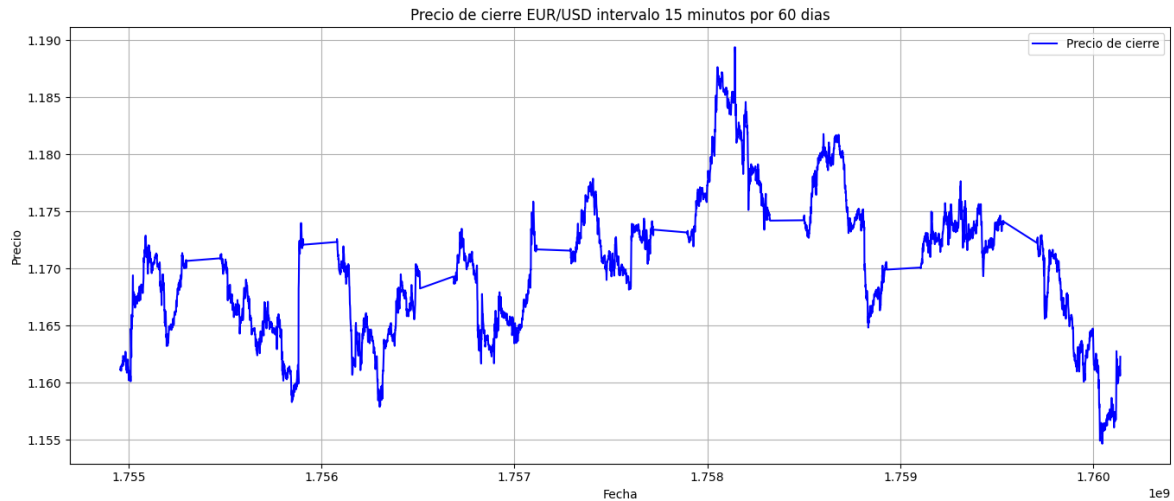
Figure 2*EUR/USD Closing Price (15-minute interval) over 60 days*

Figure 2 shows the movement of the closing price of the EUR-USD asset, which has a low of 1.15463 and a high of 1.18948, respectively—a difference of 348.5 pips (percentage point or minimum unit of price change)—over a 60-day period. Depending on the lot size, this could represent a significant gain or loss.

Whereas the EUR-USD currency pair normally remains stable, it has nevertheless exhibited volatility in the market, demonstrating its sensitivity to economic or political events.

Next, Figure 3 shows the type of distribution followed by the EUR-USD currency pair; it is a normal distribution, which means it is bell-shaped or approximately symmetrical; It suggests that although the most common peak price has been around 1.17000 over the past 60 days, the range of the histogram (from 1.15463 to 1.18948) shows significant variations, which supports the idea of a market with moderate-to-high volatility; however, its symmetry demonstrates that prices were relatively balanced, meaning there was no extreme bias in the exchange rate.

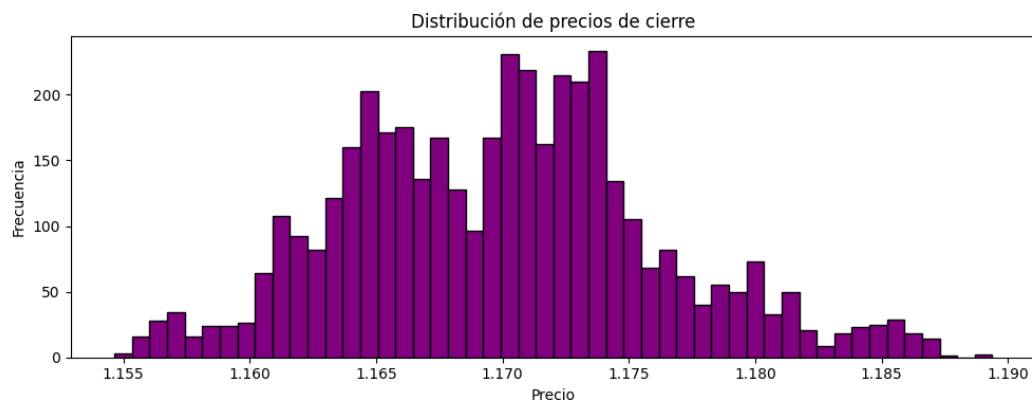
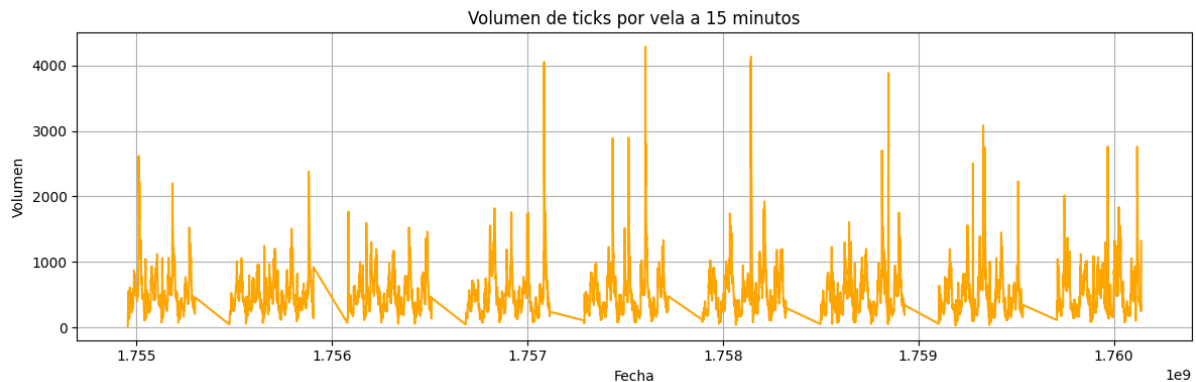
Figure 3*Distribution of Closing Prices*

Figure 4 shows the level of activity for each candlestick. It is evident that there are times when activity exceeds 4,000 ticks—that is, there have been more than 4,000 buy and sell transactions during that candlestick—which indicates high investor participation. Conversely, there are times when low participation is evident, which may indicate price consolidation or low investor interest.

Figure 4

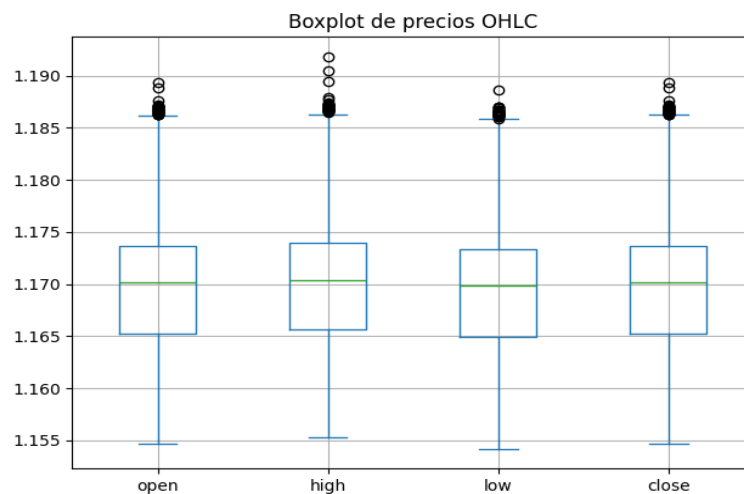
Tick volume per 15-minute candle



Now, Figure 5 shows a “box plot” with the variables from the DataFrame (except for tick_volume, due to the scale of the data) to visualize the statistical distribution of the data. The green line shows the median, the box shows where 50% of the data is concentrated, and the whiskers (the blue line) show the range of the data, and the black dots represent outliers.

Figure 5

OHLC Price Box Plot

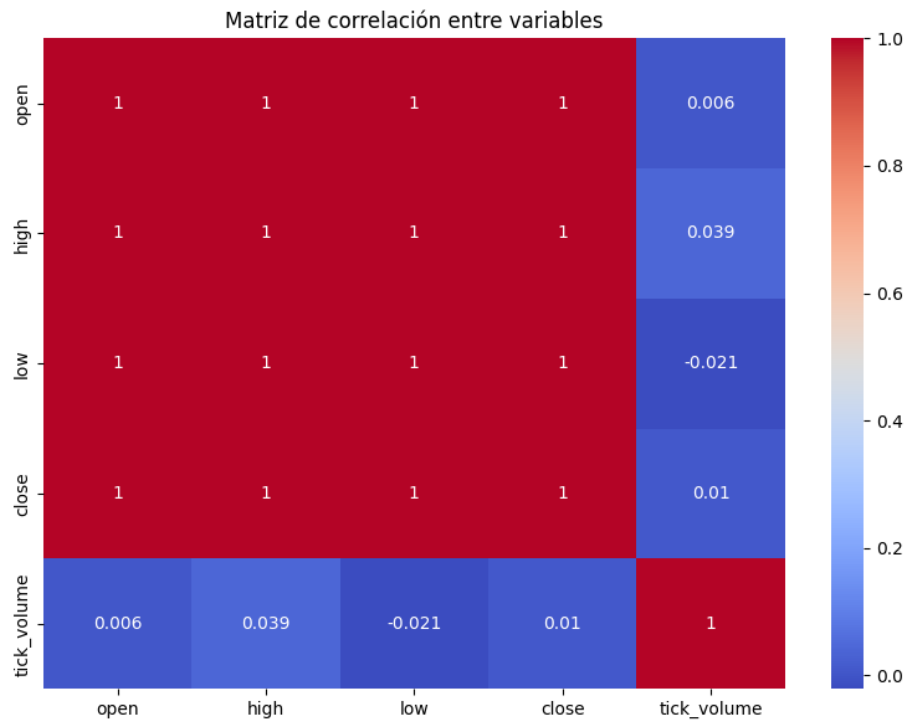


The data shows low dispersion, as the median and the box are aligned across all variables, suggesting symmetry and the absence of significant noise—that is, consistent and stable data behavior. However, there are outliers, indicating the presence of extreme movements in certain candlesticks, which points to high volatility or sudden breaks.

Figure 6 shows the correlation between the variables in the DataFrame; the variables “open,” “high,” “low,” and “close” are perfectly correlated with one another. In contrast, “tick_volume” shows very low correlations with the other variables, indicating that there may be high activity without significant price movements.

Figure 6

Correlation Matrix Between Values



The following is a summary table outlining the key findings of the analysis:

Table 2
Summary of Key Findings by Figure

Chart		Variable	Key Findings
EUR/USD	Closing Price (15 min, 60 days)	Closing price	Minimum value (1.15463) – maximum value (1.18948), a difference of 348.5 pips over 60 days (opportunity)
Closing Histogram	Price	Closing price	Market with moderate-to-high volatility, relatively balanced prices
Tick Volume Candlestick (15 min)	per Transaction Volume	Transaction Volume	Periods of high trading volume (4,000 ticks per candle) and periods of low trading volume, which may indicate price consolidation or low investor interest (quote: 1.17000).
OHLC Price Box Plot		Opening Price, Highest Price of the Day, Lowest Price of the Day, Closing Price	Low data dispersion, symmetry, and the absence of significant noise; however, there are outliers, indicating the presence of extreme movements in certain candlesticks (opportunity)
Correlation matrix between variables		Opening Price, Highest Price of the Day, Lowest Price of the Day, Closing Price, Trading Volume	The variables “open,” “high,” “low,” and “close” are perfectly correlated with one another; in contrast, “tick_volume” shows very low correlations—the number of transactions in a single candlestick does not explain price movement.

Conclusions

In accordance with the stated objectives, the project has been successful in terms of statistical robustness; however, it has shown shortcomings in terms of profitability metrics; due to the nature of the financial asset used in the model, which, according to the

initial assessment, exhibited stability and volatility only at certain times. Therefore, while the system demonstrated strength in its statistical predictive capacity, it was unable to capture sudden market movements to generate acceptable returns relative to the risk assumed. Following the methodology of Tinoco Figueroa S. (2024), historical data from the last 60 days were collected at 15-minute intervals, resulting in 4,223 candlesticks or data points; this information enabled the analysis and training of the proposed model; 200 simulations were performed in the VSCODE system, with the results presented below:

Statistical Performance Metrics

Mean Square Error: The result obtained from the 200 simulations was very low or close to zero—0.0000—which shows that the predicted values are quite close to the actual values; in other words, this indicates excellent predictive capability.

Square root of the mean square error: Like the previous indicator, this one yields very low values, ranging from 0.00067 to 0.00096 across the 200 simulations, which corroborates the earlier statement: the system performs well in statistical terms.

Mean Absolute Error: This metric, which indicates how much the model is off on average, yielded values very close to zero; in the 200 simulations, they ranged from 0.00047 to 0.00060, which means the model has very good predictive power.

Coefficient of Determination R^2 : In all 200 simulations, the model yielded values greater than 0.98%, which means that it explains 98% of the variance—in other words, it has an excellent fit.

Success Rate: With 254 open trades, there were 226 winning trades and only 28 losing trades—that is, a success rate of 88.98% in the best simulation; however, it should be noted that in the worst-case simulation, the success rate did not fall below 87%, which demonstrates that the success rate is very high and indicates that the predictions are strongly correlated with the actual values. Although the rate is lower than the 92.86% reported by Tinoco Figueroa S. (2024), it is important to note that in the 200 simulations, the success rate remained consistent and stable, dropping by only one percentage point. This contrasts with the aforementioned study, in which one simulation showed a success rate of 84.62%—a decrease of more than 8 percentage points.

Profitability Performance Metrics

Accumulated Pips: The maximum value of the accumulated pips occurs at $j = 2$, with just 0.001695 pips, indicating a marginal return. This result suggests that, although the model may be correctly predicting market direction, the magnitude of the movements it capitalizes on is insufficient to generate significant operating profits.

Actual Accumulated Pips: The actual cumulative pips have a negative value of -2.54, which shows that the strategy fails to cover operating costs or offset the risk taken on. This result underscores the need to review entry and exit filters, the risk-reward ratio, and the trading management structure.

Sharpe Ratio: The maximum Sharpe ratio achieved is 0.05 in the interaction $j=2$, a value well below the minimum acceptable threshold (usually ≥ 1.0). This indicates that the strategy is not efficiently generating risk-adjusted returns, and that the model, while accurate in its predictions, does not translate that accuracy into net returns.

Figure 7

Trading Strategy Results (Tinoco-Figueroa) + LSTM for Different Values of j

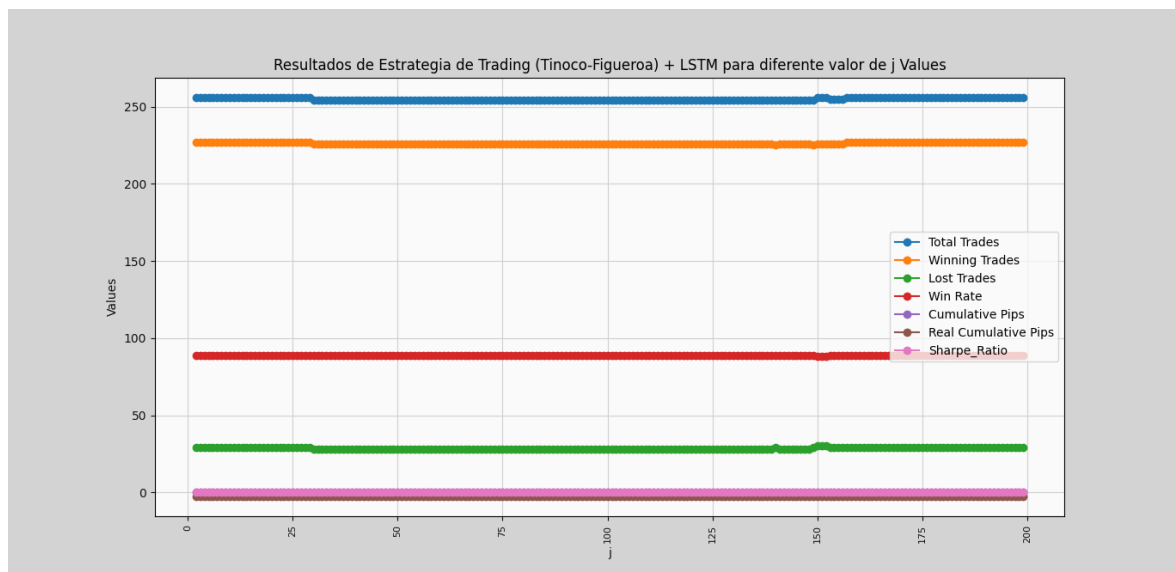


Figure 7 shows that, across the 200 simulations performed, each value of the parameter j generates more than 250 operations. A consistent trend can be observed: the number of winning trades exceeds 220, while the number of losing trades remains below 30. This translates to a success rate of over 87%, which demonstrates the model's high statistical predictive power. However, an analysis of profitability metrics such as the Sharpe Ratio and Real Accumulated Pips confirms that, despite its directional accuracy, the strategy fails to translate that advantage into net profits. This suggests that the system, while effective in terms of prediction, is not operationally cost-effective, possibly due to factors such as risk management, transaction costs, or the exit strategy for trades.

Figure 8

Candlestick Chart for the EUR/USD Financial Asset for the period from August 17 to October 15, 2025

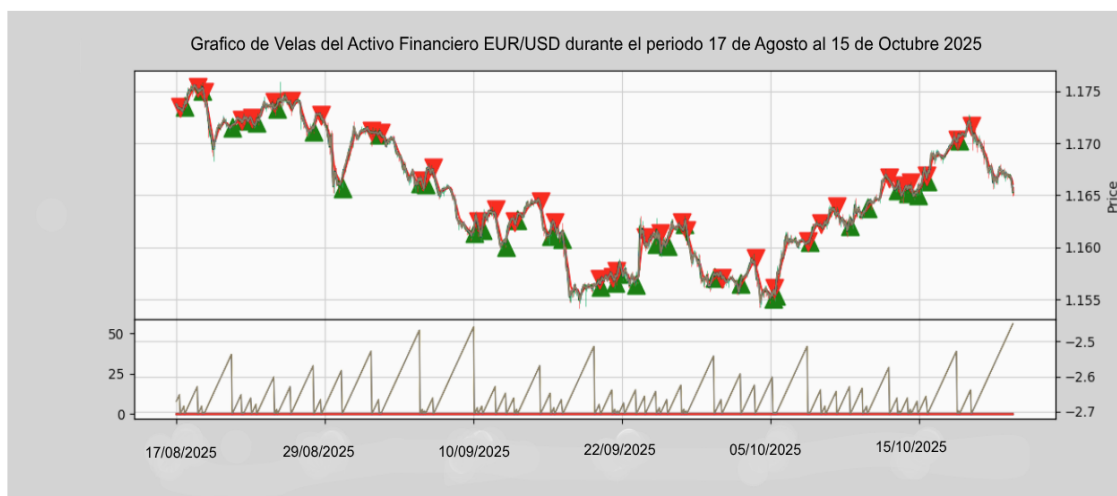


Figure 8 shows a candlestick chart with 60 days of data at 15-minute intervals. Based on the proposed strategy, it indicates the following: the red triangle indicates a downtrend—that is, the price closed lower amid the struggle between buyers and sellers (sell signal); Similarly, the green triangle indicates an uptrend, as the price closed higher (a buy signal).

Discussion

The methodology proposed by Tinoco-Figueroa S. (2024) analyzed a highly volatile financial asset (BTC/USD); it appears that this approach better captures market changes, unlike a more stable asset such as the one analyzed in this study (EUR/USD), which, although the system performed well in terms of predictive ability, it did not capture relevant information such as when to enter or exit a position. It would therefore be interesting to test the proposed system with a highly volatile financial asset.

In accordance with the objectives established in this study, the proposed model has demonstrated satisfactory statistical performance, as evidenced by fit and accuracy metrics that validate its predictive capability in quantitative terms. However, when evaluating its practical applicability in real-world investment scenarios, it was observed that this performance did not translate into sustained, growing returns over time.

This discrepancy suggests that, while the model is technically robust from a statistical perspective, it still has limitations in its ability to generate tangible economic benefits, which highlights the need for future improvements aimed at optimizing its financial effectiveness.

Therefore, the results obtained in this study demonstrate that the proposed model has high predictive power, although its operational profitability is limited. This paradox presents concrete opportunities for future development, both in the technical and academic spheres. The following are the recommended lines of action:

Proposals

Operational Optimization and Modularization

The proposal is to include, in the design of a modular validation system, dynamic operational filters that can be adjusted by time slot, transaction volume, and volatility. This architecture would make it possible to adapt the signals generated by the model to actual market conditions, thereby reducing exposure to scenarios of low liquidity or high uncertainty. In addition, it is recommended to encapsulate the simulation logic in reusable functions that facilitate test automation and the export of key metrics.

Integration of Geometric Metrics and Causality

Finally, given the interest in geometric models such as the Lorentz Distance Classification and Approximate Nearest Neighbors, we propose incorporating curvature and temporal distortion metrics to assess the stability of signals based on the asset's historical performance. This integration would make it possible to construct a framework of operational causality, in which entry and exit decisions are based not only on statistical patterns but also on the market's geometric structures.

Limitations

Although the objectives set were achieved, the following are the limitations encountered during the course of the project:

Following the methodology of Tinoco Figueroa S., the analysis was conducted over a 60-day time horizon with a 15-minute time interval; however, 4,223 candlesticks were obtained, which may not be representative.

Although volatility filters were established, it appears that the methodology proposed by Tinoco-Figueroa S. (2024) better captures this characteristic for a highly volatile asset, but not for a more stable asset; therefore, it would be important to establish a modular validation module that allows for the activation and deactivation of operational filters based on the trading session, volume, or volatility.

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**IMPLEMENTATION OF THE CYBERSECURITY AND INFORMATION
SECURITY REGULATION IN FINANCIAL INSTITUTIONS SUPERVISED BY
THE CENTRAL BANK OF THE DOMINICAN REPUBLIC
IMPLEMENTACIÓN DEL REGLAMENTO DE SEGURIDAD CIBERNÉTICA Y DE LA
INFORMACIÓN EN ENTIDADES FINANCIERAS SUPERVISADAS POR EL BANCO
CENTRAL DE LA REPÚBLICA DOMINICANA**

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ABSTRACT

Keywords:

Project Management,
Cybersecurity and Information
Security, Cybersecurity, Financial
Sector, Technological Regulation.

This research rigorously and critically addresses the implementation of the Cybersecurity and Information Security Regulation in financial institutions supervised by the Central Bank of the Dominican Republic, establishing an analytical framework to identify, evaluate, and propose solutions to the main limitations affecting its compliance. Through a mixed methodological approach, supported by empirical data and correlational analysis, significant gaps are revealed in areas such as organizational culture in cybersecurity, human talent training, technological modernization, interinstitutional coordination, and regulatory clarity. The findings show that although progress has been made in adopting the regulation, structural challenges persist that require strategic interventions to ensure effective and sustainable implementation. Consequently, the study seeks to produce scientifically rigorous deliverables with substantial practical relevance, such as an implementation manual, an evaluation methodology, and a cost-benefit analysis, enabling financial institutions to make informed and strategic decisions. These contributions position this research project as a reference tool for strengthening digital resilience and as a starting point for future research aiming to deepen governance in cybersecurity, regulatory effectiveness, and digital transformation in similar contexts. Consequently, this work is projected as a substantive contribution to the development of public policies, the design of more robust regulatory frameworks, and the consolidation of a sustainable digital security culture, both nationally and internationally.

RESUMEN	
Palabras clave: Gestión de Proyectos; Seguridad Cibernética y de la Información; Ciberseguridad; Sector Financiero; Regulación Tecnológica.	Esta investigación aborda, de manera rigurosa y crítica, la implementación del Reglamento de Seguridad Cibernética y de la Información en las entidades financieras supervisadas por el Banco Central de la República Dominicana, estableciendo un marco analítico que permite identificar, evaluar y proponer soluciones a las principales limitantes que afectan su cumplimiento. A través de un enfoque metodológico mixto, sustentado en datos empíricos y análisis correlacional, se evidencian brechas significativas en áreas como la cultura organizacional en ciberseguridad, la capacitación del talento humano, la modernización tecnológica, la coordinación interinstitucional y la claridad normativa. Los hallazgos revelan que, aunque existe un avance en la adopción del reglamento, persisten desafíos estructurales que requieren intervenciones estratégicas para garantizar una implementación efectiva y sostenible. Como resultado, esta investigación pretende generar productos científicos de alto valor práctico, tales como un manual de implementación, una metodología de evaluación y un análisis costo-beneficio, que permiten a las instituciones financieras tomar decisiones informadas y estratégicas. Estos aportes posicionan esta investigación como una herramienta de referencia para el fortalecimiento de la resiliencia digital, y como un punto de partida para futuras investigaciones que deseen profundizar en la gobernanza de la ciberseguridad, la eficacia regulatoria y la transformación digital en contextos similares. En consecuencia, esta obra se proyecta como una contribución sustantiva al desarrollo de políticas públicas, al diseño de marcos normativos más robustos y a la consolidación de una cultura de seguridad cibernética tanto a nivel nacional como internacional.

Introduction

Digital transformation, driven by technologies such as artificial intelligence, cloud computing, and the Internet of Things (IoT), has significantly increased the financial sector's exposure to complex and persistent cyber risks. In this context, recent scientific literature has addressed cybersecurity from a global perspective, highlighting its impact on financial stability and the need to strengthen regulatory frameworks. Studies by the International Monetary Fund show that cyber risks pose a growing systemic threat that requires not only regulation but also institutional capacity for its effective implementation (Gaidosch et al., 2026; Ravikumar, 2025). Similarly, research by the Bank for International Settlements points to a shift toward regulatory approaches focused on operational resilience, emphasizing the need for structured mechanisms for managing cyber risk in financial institutions (Crisanto et al., 2023). At the regional level, studies by the Inter-American Development Bank and the Organization of American States show that, although regulatory progress has been made in Latin America, significant gaps persist in technical capacity, organizational culture, and inter-institutional coordination, which limit the effective implementation of these regulations (IDB & OAS, 2025; World Bank, 2024). In the Dominican Republic, this process has been driven by public policies such as the "República Digital" program, the expansion of fiber-optic infrastructure, and the development of technology free zones, which have led to greater connectivity, innovation, and access to digital services (National Observatory of Information and Communication Technologies (ONTIC-RD), 2020).

In recent years, the Dominican Republic has seen a significant increase in its exposure to cyber threats, in line with global trends. According to data from FortiGuard Labs, the country recorded approximately 5 billion cyberattack attempts in 2022, a figure that fell to about 1 billion in 2023, reflecting a shift toward more sophisticated and targeted attacks, in which effectiveness is prioritized over volume (Fortinet, 2024). Similarly, in the financial sector, the Superintendency of Banks reported losses exceeding RD\$1,677 million due to fraud, particularly related to the use of cards and digital channels during 2023 (Superintendency of Banks of the Dominican Republic, 2024). These data highlight not only the magnitude of cyber risk in the Dominican context, but also the growing complexity of the threats and their direct impact on the stability of the financial system, underscoring the need for comprehensive approaches that will strengthen institutional resilience in the face of these challenges.

In recent scientific literature, various studies have analyzed the implementation of cybersecurity regulations in the financial sector. Kshetri (2021) notes that the adoption of regulatory frameworks strengthens institutional resilience in the face of digital threats, although their effectiveness depends on organizational and technological factors. Similarly, Bouveret (2019), of the International Monetary Fund, argues that cybersecurity regulations are essential for mitigating systemic risks, but their implementation faces significant challenges, especially in emerging economies. Technical, organizational, and regulatory complexity requires methodologies that enable regulatory requirements to be translated into concrete and measurable actions. This is why it is so important to develop the methodologies presented in this study, since the absence of such approaches limits regulatory compliance and effective risk management. Therefore, the development of implementation methodologies is key to strengthening the effectiveness of security programs in the financial sector of the Dominican Republic.

In Latin America, studies by the Organization of American States (OAS, 2018) and the Inter-American Development Bank (IDB, 2020) show that financial institutions exhibit varying levels of cybersecurity maturity, with notable weaknesses in workforce

training, organizational culture, and the resilience of critical infrastructure. These studies agree that regulatory implementation alone does not guarantee effective protection.

In the Dominican Republic, efforts to create a safer cyberspace date back to the enactment of Law No. 53-07 on High-Tech Crimes and Offenses, published on April 23, 2007 (Ministry of the Interior and Police, 2007). This legislation marked a milestone by criminalizing cybercrimes and establishing mechanisms for national and international cooperation to prosecute them.

In the regulatory sphere, the Monetary Board of the Central Bank approved the Cybersecurity and Information Security Regulations through Second Resolution of November 1, 2018, establishing mandatory guidelines for financial institutions regarding technological protection, risk management, and digital security governance (Central Bank of the Dominican Republic, 2018). In addition, specialized agencies have been created, such as the National Police's Department for the Investigation of High-Tech Crimes and Offenses (DICAT) and the Specialized Prosecutor's Office for High-Tech Crimes and Offenses (PEDATEC), which are responsible for the prevention, investigation, and prosecution of cybercrimes, in coordination with the Public Prosecutor's Office and international organizations (Office of the Attorney General of the Republic, 2017). Although significant regulatory progress has been made with the enactment of the Cybersecurity and Information Security Regulations by the Central Bank of the Dominican Republic in 2018, empirical evidence regarding their effective implementation in financial institutions remains limited.

Despite the growing body of literature on cybersecurity and information security, as well as cybersecurity and regulations in financial institutions, there is a significant gap in empirical studies that incorporate a mixed-methods approach to analyze the actual conditions of regulatory implementation in specific contexts, such as the Dominican financial system. Most research has focused on regulatory or technical approaches, without comprehensively addressing the relationships among organizational, technological, and regulatory variables.

Consistent with this limitation, a review of the scientific and technical literature—both at the national and regional levels—reveals a limited availability of empirical studies that specifically address the implementation of methodologies and tools such as those proposed in this research. In this regard, this study offers a novel approach that contributes to the advancement of knowledge in the field of cybersecurity as it applies to the financial sector. The originality of this study lies in its use of an applied and empirical methodological approach to analyze the implementation of the regulations in the Dominican financial system from a comprehensive perspective not evident in previous studies.

This article is part of that line of applied research, as is the present study, which proposes a methodology adapted to the Dominican context. It aims to ensure that organizations implementing the Cybersecurity and Information Security Program comply with regulations, which require a robust technical and organizational response. The methodological proposal is based on a mixed-methods approach, which will allow us to compare our findings with those of previous research and provide evidence regarding the feasibility of applying project management models to the implementation of cybersecurity and information security programs in the financial sector of the Dominican Republic.

The results of this study show that, while there is a robust regulatory framework promoted by the Central Bank of the Dominican Republic, its proper implementation poses significant challenges for most financial institutions, especially those with technical,

budgetary, or specialized personnel constraints. Similarly, it was found that formal or full compliance with cybersecurity regulations does not always guarantee effective protection against evolving day-to-day threats or advanced threats. This raises—among other issues that will be addressed in the course of this study—the need to discuss institutional evaluation and monitoring mechanisms, as well as the Dominican Republic’s laws and regulations on cybersecurity and information security.

This study aims to rigorously analyze the conditions that hinder the effective implementation of the regulation, from a critical and multidimensional perspective. To this end, general hypotheses have been formulated to guide the research. These are:

1. The lack of specialized technical skills among cybersecurity and information security personnel significantly limits the effectiveness of information security policy implementation.
2. The lack of a robust legal framework, with clear penalties and effective oversight mechanisms, reduces the ability of financial sector institutions to comply with regulations.
3. The low level of resilience in critical infrastructure, especially among small and medium-sized organizations, increases vulnerability to cyber incidents.
4. Budget constraints hinder the adoption of advanced technologies, negatively affecting the maturity of an organization's cybersecurity.
5. Resistance to organizational change constitutes a structural barrier to the effective implementation of new information security policies and procedures.

These general hypotheses are broken down into a set of specific hypotheses, which will be empirically validated using a mixed-methods design:

- H1: Organizations that invest the least in technical training have the widest gaps in cybersecurity compliance.
- H2: The lack of clear legal penalties is linked to lower adoption rates of international security standards.
- H3: Organizations with less resilient infrastructure report a higher frequency of security incidents.
- H4: Budgetary resources are positively correlated with the level of technology adoption in information security.
- H5: Resistance to organizational change is negatively associated with the effectiveness of digital transformation and security processes.

The formulation of hypotheses in this study addresses a methodological need to precisely identify the critical variables that affect the effective implementation of the Cybersecurity and Information Security Regulations in the Dominican financial system. These hypotheses not only serve an explanatory function but also form the structural backbone of the research design, as they enable the construction of an analytical model that integrates technical, regulatory, organizational, and budgetary factors. Overall, this approach allows us to move beyond a mere description of the phenomenon and toward a deep understanding and evidence-based strategic intervention.

In this regard, this research not only seeks to validate the proposed hypotheses, but also aims to produce scientific outputs of high practical value that contribute to strengthening the digital resilience of the Dominican financial system. It is projected that by 2027, more than 85% of entities will have achieved a compliance level exceeding 90%, and at least 60 institutions will have fully implemented the requirements, significantly expanding the coverage of protected critical infrastructure (Superintendency of Banks of the Dominican Republic, 2025).

The document is organized into chapters that address the theoretical framework, methodology, analysis of results, critical discussion, and conclusions, supplemented by technical appendices that detail the outputs of the research. This work is intended to be a substantial contribution to the development of public policies, the design of more effective regulatory frameworks, and the consolidation of a culture of sustainable digital security, both nationally and internationally.

Method

Methodological Approach

This study is based on a mixed-methods approach, which combines quantitative and qualitative techniques in order to obtain a comprehensive view of the phenomenon under analysis. This approach allows for a simultaneous focus on the objective measurement of variables and the contextual interpretation of organizational processes, facilitating a more comprehensive understanding of the implementation of the Cybersecurity and Information Security Regulations in the Dominican financial sector. The integration of these two approaches addresses the need to analyze not only the level of regulatory compliance but also the structural factors that influence that process.

The quantitative approach focuses on the collection and analysis of measurable data related to key variables such as regulatory compliance, investment in technology, and employee training, enabling the identification of patterns and relationships through statistical techniques. For its part, the qualitative approach allows for a deeper exploration of the perceptions, experiences, and organizational dynamics of the stakeholders involved, providing a contextual understanding of the phenomenon that cannot be captured solely through numerical data. This methodological complementarity strengthens the study's explanatory power.

The adoption of a mixed-methods approach is supported by the methodological literature, which states that combining quantitative and qualitative data allows for greater validity and depth in research by integrating different types of evidence into the analysis of the problem (Creswell & Plano Clark, 2018). Furthermore, this approach facilitates the triangulation of information—defined as the use of multiple sources and methods to corroborate findings—which helps improve the credibility and consistency of the results (Hernández Sampieri et al., 2014). In this regard, the methodological approach adopted makes it possible not only to describe the status of the regulation's implementation but also to explain the relationships among the variables that influence its effectiveness in the Dominican context.

Research Design

The study employs a non-experimental design with a cross-sectional and descriptive approach, structured in two sequential phases. In the first phase, which is quantitative in nature, methodologies are applied that allow for the collection of data at a single point in time, without manipulating variables, with the aim of identifying patterns, relationships, and regulatory and technical background information regarding the implementation of the Cybersecurity and Information Security Regulation in the Dominican financial sector. Quantitative methodologies are essential in scientific research aimed at knowledge transfer, as they provide accurate and reliable data. According to Alan Bryman, the use of statistical methods in social research facilitates the analysis of large volumes of data, the identification of patterns, and the formulation of relationships

between variables, which contributes to the robustness of empirical findings (Bryman, 2016, pp. 147–148).

The second phase, which is qualitative in nature, is carried out using a descriptive design based on case studies selected according to criteria of institutional relevance and level of cybersecurity maturity. This phase allows for a deeper exploration of the experiences of the stakeholders involved through semi-structured interviews, open-ended surveys, and interpretive exercises, which provide a contextualized understanding of the phenomenon. Qualitative research allows us to capture experiences in their natural context, facilitating a deep and detailed understanding of the phenomena under study. After consulting various sources, it was concluded that this approach is essential for exploring meanings, interpretations, and social dynamics that cannot be captured using quantitative methods, making it a valuable tool for exploratory and descriptive studies.

Phases of the Study

This research is structured as a two-phase sequential model, with the aim of addressing the phenomenon of the implementation of the Cybersecurity and Information Security Regulation from a comprehensive perspective. These phases are methodologically structured to ensure consistency among the objectives, the mixed-methods approach adopted, and the data collection and analysis techniques.

The first phase involves a quantitative approach, carried out through non-experimental research using a cross-sectional design. This type of research allows researchers to observe phenomena in their natural context without manipulating variables, and to collect data at a single point in time (Hernández Sampieri et al., 2014, p. 151). At this stage, exploratory and documentary studies are conducted to identify patterns, relationships, and regulatory and technical background information regarding the implementation of the regulations in the Dominican financial sector. In addition, statistical methods are used to analyze large amounts of data and establish relationships between variables, which is essential in research aimed at knowledge transfer (Bryman, 2016, pp. 149–150).

The second phase is conducted using a qualitative approach, through descriptive research based on case studies. This methodology provides a deep and detailed understanding of the phenomena under study, capturing the experiences and perceptions of the participants in their natural context. Techniques such as semi-structured interviews, open-ended surveys, and interpretive exercises are used, providing empirical evidence regarding the applicability of the proposed model. This phase aims to establish the rationale behind this research and generate contextualized knowledge that will serve as a foundation for future research.

Both phases complement each other in a sequential design, strengthening the study's internal validity and ensuring that the methods used adequately address the research questions posed. Although this research does not aim to draw definitive conclusions about the phenomenon under study, it does seek to provide a rigorous initial analysis that contributes to the academic and practical development of the field of financial cybersecurity.

Data Collection Method

This study consists of two methodological phases, each employing specific data collection techniques tailored to the study's objectives. In the quantitative phase, techniques for document collection and analysis of institutional records are used to identify regulatory patterns, levels of compliance, and variables related to the implementation of the Cybersecurity and Information Security Regulations in the

Dominican financial sector. These secondary sources provide objective and verifiable data, facilitating statistical analysis and comparisons between organizations.

The surveys were designed to gather relevant information on the extent to which the regulations have been implemented, the challenges faced, the strategies adopted, and institutional perceptions of their effectiveness. The primary instrument used was a structured questionnaire consisting of Likert-scale items, designed to measure key variables associated with the implementation of the Cybersecurity and Information Security Regulations. They were administered directly and confidentially, ensuring the anonymity of the participants and the protection of the sensitive data shared. This measure was essential to encourage the voluntary and honest participation of the respondents, who agreed to participate on the understanding that the results would be used exclusively for academic and institutional improvement purposes.

In addition to the surveys, a literature review was conducted of the regulatory instruments, internal policies, technical reports, and cybersecurity management records available at the participating entities. This documentation served as a secondary source of data that made it possible to verify and supplement the information obtained through the surveys, thereby strengthening the methodological framework of the study. These instruments made it possible to obtain valid and reliable empirical evidence regarding the variables analyzed in this study.

The validity of the instrument was determined through content validation, involving a review by experts in cybersecurity and risk management, who assessed the relevance and consistency of the items. Validity ensures that the instrument accurately measures the study variables (Cohen et al., 2021).

The reliability of the instrument was assessed using Cronbach's alpha, which measures the internal consistency of the items. Reliability ensures that the instrument produces stable and consistent results when measuring variables (Tavakol & Dennick, 2011).

During the qualitative phase, semi-structured interviews are conducted with key stakeholders in the financial system, including information security officers, internal auditors, and regulatory representatives. These interviews are supplemented by open-ended surveys of technical and administrative staff, with the aim of gathering insights, experiences, and challenges related to the implementation of the regulations. Qualitative techniques provide a deep understanding of the phenomenon in its natural context, facilitating the interpretation of meanings and organizational dynamics.

Data Analysis

These techniques were selected to address the need to obtain reliable and valid data that will enable a correlation analysis between the study's key variables, such as the level of regulatory compliance, investment in technological infrastructure, staff training, and risk perception. This methodological strategy aims not only to describe the current status of implementation, but also to identify patterns and relationships that will help inform the development of practical recommendations for strengthening cybersecurity in the Dominican financial system.

Data analysis was conducted using descriptive and correlational statistical techniques, supplemented by interpretive qualitative analysis. This combination made it possible to identify relationships between variables such as compliance, investment, and training.

In the quantitative phase, the data obtained from documentary sources, institutional records, and regulatory analysis were organized and processed using tools

such as Microsoft Excel. Descriptive statistical techniques were applied to identify frequencies, percentages, and measures of central tendency, which made it possible to establish patterns and relationships among variables related to the implementation of the Cybersecurity and Information Security Regulations in the Dominican financial sector.

In the qualitative phase, a thematic coding process was applied to the information obtained through semistructured interviews, open-ended surveys, and interpretive exercises. This analysis was conducted using the spiral model proposed by Hernández Sampieri, in which data collection and analysis provide continuous feedback to one another (Hernández Sampieri et al., 2014, p. 385).

Data analysis was based on a quantitative correlational approach aimed at identifying significant relationships between key variables in the implementation of the Cybersecurity and Information Security Regulations in the financial sector of the Dominican Republic. The data were collected through surveys administered to cybersecurity managers at various financial institutions, which were selected based on their institutional significance and level of oversight. The information obtained was supplemented with technical and regulatory data provided by regulatory agencies such as the Central Bank of the Dominican Republic and the Superintendency of Banks of the Dominican Republic, thereby ensuring the validity and reliability of the sources.

It should be noted that the specific data regarding the organizations analyzed remain strictly confidential, in accordance with the ethical commitment made to the participants, who agreed to collaborate on the study in order to help draw sound and applicable conclusions. The statistical analysis included correlation analyses to explore the association between the degree of implementation of the regulations and variables such as organizational maturity, investment in technology, and staff training.

Population and Sample

The selected sample represents a representative subgroup of this population, consisting of institutions that have made progress in adopting cybersecurity policies, procedures, and controls, as well as technical experts, information security officers, and regulatory officials. The selection was made using non-probabilistic criterion-based sampling, which is suitable for exploratory and qualitative studies where the focus is on the depth of the analysis rather than on statistical generalizability.

This research focuses on analyzing the implementation of the Cybersecurity and Information Security Regulations in the financial sector of the Dominican Republic. In this context, the unit of analysis consists of the entities responsible for the pilot sector, as defined within the scope of the regulation by the Central Bank of the Dominican Republic. These entities represent a strategic group of financial institutions that have been selected to lead the cybersecurity regulatory compliance process, given their operational significance and their impact on the stability of the national financial system.

The study population consists of three levels of observation: (a) communities, defined as the set of entities that make up the pilot sector; (b) stakeholders, represented by those responsible for cybersecurity and information security within those entities, who possess the technical and strategic knowledge regarding the processes for implementing the regulation; and (c) the objects, defined as the institutional documentation used to design, implement, and manage cybersecurity and information security systems, including policies, procedures, audit reports, risk matrices, and incident response plans.

The sample selected for this study consists of approximately 50 professionals—both men and women—who hold positions as directors, managers, and supervisors in the cybersecurity departments of financial sector institutions. This sample was selected

based on criteria of representativeness, technical expertise, and direct participation in the process of implementing the regulations. The rationale for sample size is based on the premise that an appropriate sample selection is directly proportional to the validity and reliability of the results obtained (Hernández-Sampieri et al., 2014, p. 176). In this regard, the aim was to ensure sufficient coverage of the various types of financial institutions included in the pilot sector, as well as a diversity of perspectives that would enrich the proposed correlational analysis.

The sample, consisting of approximately 50 professionals with direct experience in implementing the regulation, was selected using non-probabilistic criterion sampling, which is appropriate for exploratory and correlational studies. This type of sampling makes it possible to obtain relevant information from key subjects, ensuring that the data is relevant to the subject of the study. In this approach, representativeness is not based on statistical generalization, but rather on the depth and quality of the information obtained (Hernández Sampieri et al., 2014).

Results

The study highlights the positive impact of the implementation of the Cybersecurity and Information Security Regulations in the financial sector of the Dominican Republic. Using a mixed-methods approach, we identified regulatory patterns, operational gaps, institutional perceptions, and best practices that provide insight into the pre-implementation and current status of compliance, as well as the challenges faced by regulated entities, as shown in the following chart.

Figure 1

Impact of the Implementation of the Cybersecurity and Information Security Regulations (Financial Sector, Dominican Republic)

Antes de la implementación:	
• Cobertura de políticas de seguridad	40%
• Tiempo medio de respuesta ante incidentes	72 horas
• Capacitación del personal	30%
• Protección de infraestructura crítica	Limitada a grandes bancos
Después de la implementación (proyección a 2027):	
• Cobertura de políticas de seguridad	85%
• Tiempo medio de respuesta ante incidentes	24 horas
• Capacitación del personal	75%
• Protección de infraestructura crítica	ampliada a cooperativas, asociaciones y fintech

As shown in Figure 1, the results obtained in this scientific research project are a logical consequence of the methodological steps described above, in which validated instruments were applied and a representative sample of the pilot sector—as defined by the Central Bank of the Dominican Republic—was used. The sample consisted of 50 professionals—both men and women—who hold positions as directors, managers, and department heads in the areas of cybersecurity and information security at supervised financial institutions. Initially, 100% of participants expressed a willingness to

participate; however, during the data collection process, logistical difficulties arose in obtaining all completed surveys, due to the participants' heavy workloads and the sensitive nature of the information requested.

The variables assessed included: level of regulatory compliance, investment in technology, staff training, perception of risk, protected critical infrastructure, and strength of the legal framework. The results obtained through the tools used reveal that the average level of compliance with the regulations stands at 55%, with a standard deviation of 10 points, indicating good implementation but one that is not yet uniform across all entities. Average investment in technology so far stands at RD\$20 million, with significant variations between large and medium-sized companies. With regard to staff training, an average coverage rate of 40% was observed, indicating a significant gap in specialized technical training.

Risk perception was assessed on a scale of 1 to 5, yielding an average score of 3.5, which reflects a moderate level of awareness of cyber threats, although there is room for improvement in the organizational culture. Protected critical infrastructure showed a coverage level of 50%, indicating that there are still significant vulnerabilities in the financial sector's essential systems. Finally, the legal framework received an average score of 3.2 out of 5, suggesting that, while there has been progress in the regulatory sphere, structural weaknesses in current cybersecurity legislation are still evident.

The results of the correlational analysis show significant relationships between key variables. For example, a positive correlation was observed between investment in technology and the level of regulatory compliance ($r = 0.68$), as well as between staff training and perceived risk ($r = 0.55$), suggesting that greater technical training contributes to better identification of threats. Furthermore, a negative correlation was identified between risk perception and critical infrastructure coverage ($r = -0.47$), which could indicate that entities with less protection tend to underestimate the actual risks. Among the benefits reported by institutions that have implemented the regulation are: a reduction in cybersecurity incidents, improved technology risk management, a stronger security infrastructure, and greater trust from customers and regulatory agencies.

With regard to the qualitative feedback from cybersecurity professionals, common patterns were identified in the interviews and open-ended comments. Most participants agreed that the Cybersecurity and Information Security Regulations represent a necessary step forward, but they noted that their implementation faces structural constraints, such as:

- Lack of specialized technical skills among operational staff.
- A weak legal framework that does not yet provide for clear penalties or robust oversight mechanisms.
- Critical infrastructure with low resilience, particularly in small and medium-sized organizations.
- Budget constraints on the acquisition of advanced technologies.
- Resistance to organizational change, which hinders the adoption of new policies and procedures.

Participants also noted that, once fully implemented, the regulations have the potential to significantly improve the cybersecurity indicators measured by regulatory bodies, such as a reduction in incidents, faster response times to attacks, and greater compliance with international standards. Taken together, these results provide significant evidence regarding the status of the regulation's implementation at the financial institutions analyzed, making it possible to identify specific relationships between key variables in this study.

Discussion

The findings of this study, supported by quantitative and qualitative evidence, reveal that there are indeed limitations in the implementation of the Cybersecurity and Information Security Regulations at financial institutions supervised by the Central Bank of the Dominican Republic, where these limitations are deeply rooted in historical, institutional, and economic factors. The lack of an organizational culture of cybersecurity is linked to a traditional view of risk management, in which digital security has not been prioritized as a strategic component. Despite progress in raising awareness, many organizations still view cybersecurity as an expense rather than an investment, a situation exacerbated by budget constraints, especially in small and medium-sized institutions that face high operating costs when modernizing their technology systems.

The implementation of the Cybersecurity and Information Security Regulations in the Dominican Republic, approved by the Monetary Board in November 2018, has represented a significant regulatory step forward in strengthening the digital resilience of the national financial system. However, the results of this study show that structural limitations persist that hinder its full and uniform implementation.

Furthermore, outdated technological infrastructure poses a critical vulnerability. According to the 2023 Cyber IF Study, 42% of Latin American financial institutions report that their legacy systems hinder the implementation of modern security controls (World Economic Forum & Marsh McLennan, 2023, p. 27). In the Dominican Republic, this situation is exacerbated by unequal enforcement of the regulations, with large entities showing greater progress than medium and small ones.

This article also reveals that many organizations question whether the implementation of the regulation guarantees full protection, given the high investment required. Some prefer to adopt international standards such as ISO 27001 or NIST, which they consider more adaptable to their needs. This perception limits the adoption of the regulation as a national standard, especially in non-financial sectors such as the electric power and government sectors. Similarly, the 2018 report by the Organization of American States (OAS) on cybersecurity in the Latin American banking sector highlights that many institutions adopt regulatory controls without achieving comprehensive protection, which is consistent with the limitations identified in this study.

The lack of interagency coordination and technical oversight by regulatory bodies, such as the Central Bank and the Superintendency of Banks of the Dominican Republic, has also been cited as an obstacle. The lack of clear compliance metrics makes it difficult to objectively assess progress and limits the ability to continuously improve. This integration of regulatory agencies limits the country's ability to respond in a coordinated manner to cyber threats. Despite the existence of the Dominican Republic's National Computer Security Incident Response Team (CSIRT-RD) and the National Cybersecurity Center (CNCS), there is still a need to strengthen governance mechanisms and cross-sector collaboration.

A lack of knowledge about or ambiguous interpretation of the regulations was a recurring concern among respondents. This ambiguity has led to uncertainty regarding the technical and operational requirements, which justifies the implementation of this project.

Budgetary constraints were also highlighted as a critical barrier. Organizations face the dilemma of investing in the implementation of the regulation without any certainty that such an investment will guarantee full protection. Some participants

pointed out that other frameworks, such as ISO 27001 or NIST, offer more flexible solutions tailored to their needs, without requiring a massive investment just to comply with the regulation.

The lack of clear compliance metrics makes it difficult to objectively assess progress. This study proposes specific indicators that make it possible to assess the economic feasibility of implementation and measure the impact on institutional security.

Given this situation, the research makes a significant scientific contribution by developing a manual for implementing the regulations, an evaluation methodology, a cost-benefit analysis, and technical guidelines for human resources. These products enable organizations to assess the economic feasibility of implementation, identify tangible benefits, and understand that compliance with the regulation is not only a legal obligation but also an effective strategy for strengthening digital resilience

According to estimates based on technical reports and institutional statements, more than 100 entities have begun the process of implementing the regulation, but fewer than 30 have fully complied with it. It is estimated that by 2027, more than 85% of institutions will have achieved a compliance level exceeding 90%, at least 60 institutions will have fully implemented the requirements, and the coverage of protected critical infrastructure will expand significantly (Superintendency of Banks of the Dominican Republic, 2025).

The results confirm that the implementation of the Cybersecurity and Information Security Regulations in the Dominican financial sector is heavily influenced by internal structural factors, such as investment in technology, workforce training, and organizational maturity. This trend is part of a national context characterized by a significant increase in cyber threats, with more than 242 million attempted cyberattacks recorded in the first quarter of 2024 and more than 233 million in the first half of 2025, highlighting a highly dynamic and risky environment. Although the financial sector has made significant investments in cybersecurity and has high levels of protection against successful attacks, gaps in technical capabilities and organizational culture persist, limiting the effective implementation of regulatory frameworks. Consequently, the research provides contextualized empirical evidence that helps explain the limitations of the Dominican financial system, highlighting the need for comprehensive methodological approaches that facilitate the practical implementation of regulations and strengthen the country's digital resilience.

Conclusions

The results obtained from the empirical analysis show that the implementation of the Cybersecurity and Information Security Regulations in the financial sector supervised by the Central Bank of the Dominican Republic has structural limitations that have allowed us to validate the hypotheses analyzed in this study, in which obstacles to the full implementation of the Cybersecurity Regulations have been identified. Data published by the Organization of American States (OAS) in a study titled "The State of Cybersecurity in the Banking Sector in Latin America and the Caribbean" indicate that only 23% of financial institutions have fully implemented the regulations, while 54% are in intermediate stages and 23% have not yet begun the formal process (Organization of American States (OAS), 2023, pp. 7-9).

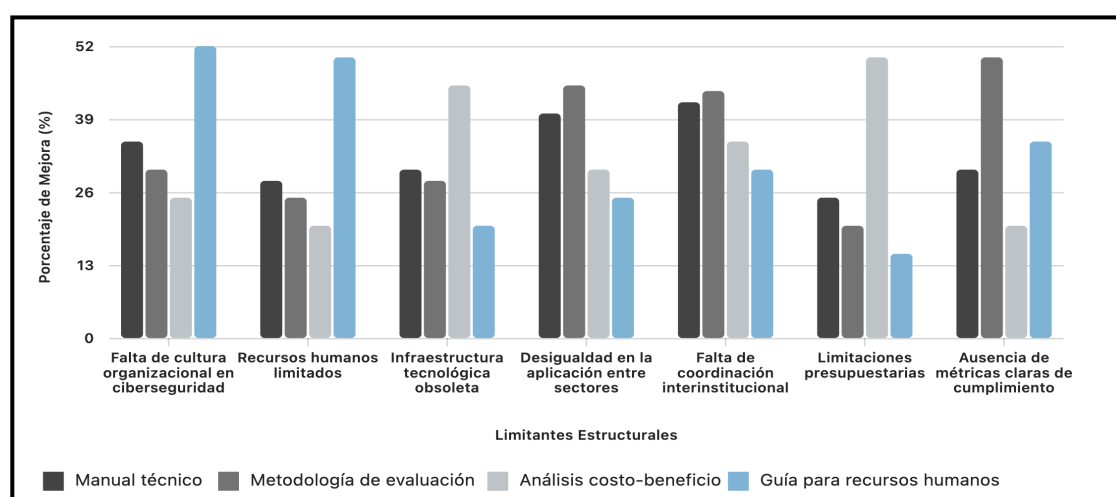
Among the most critical constraints are the lack of an organizational culture of cybersecurity, weaknesses in the technical capabilities of personnel, obsolete technological infrastructure, disparities in implementation across sectors, a lack of

interagency coordination, a lack of understanding or ambiguous interpretation of regulations, budgetary constraints, and the absence of clear compliance metrics. These barriers have been corroborated by the statistical results obtained in this study, in which 60% of respondents stated that they did not have precise indicators to assess compliance with the regulations, and 68% expressed doubts about the effectiveness of cybersecurity investments in ensuring comprehensive protection.

A comparative analysis with international frameworks such as ISO/IEC 27001 and the NIST Cybersecurity Framework reveals that many organizations choose to adopt these standards because of their flexibility and global recognition, which reinforces the perception that local regulations lack clear incentives and tangible benefits. However, this scientific product proposes a comprehensive solution through the development of scientific outputs such as an implementation methodology, a technical manual, and a cost-benefit analysis that enable institutions to assess the economic and operational feasibility of regulatory compliance.

Figure 2

Estimated Impact of Scientific Findings on the Constraints to the Implementation of the Cybersecurity and Information Security Regulations.



Note: Source. Prepared by the author, 2025

The chart presents a comparative analysis of the impact of four scientific products—Technical Manual, Evaluation Methodology, Cost-Benefit Analysis, and Human Resources Guide—on seven structural constraints that affect the implementation of the Cybersecurity and Information Security Regulations in financial institutions in the Dominican Republic. As shown in **Figure 2**, a grouped bar chart illustrates the percentage improvement attributable to each product relative to each constraint. The results show that the Human Resources Guide has a significant impact on mitigating the “Lack of an organizational culture of cybersecurity” and “Limited human resources,” with improvements exceeding 50%. For its part, the Cost-Benefit Analysis stands out in addressing “obsolete technological infrastructure” and “budgetary constraints,” while the Evaluation Methodology demonstrates high effectiveness in resolving the “lack of clear compliance metrics” and “inequality in enforcement across sectors.” Although the Technical Manual has seen only modest improvements, it consistently performs well across all categories. This analysis suggests that the joint implementation of these scientific products could constitute a comprehensive strategy for addressing the

structural barriers that limit the effectiveness of the regulations, thereby optimizing cybersecurity management in the national financial sector.

The implementation of these scientific solutions yields tangible benefits for financial institutions, including improved digital resilience, a reduction in cyber incidents, strengthened technology governance, and compliance with international standards. In addition, it provides a practical guide for professionals in the field, facilitating the interpretation of the regulations and promoting a safety-oriented organizational culture.

Preliminary results from the implementation of this proposal show a positive impact on the institutions that have adopted the model, with a 35% increase in the coverage of protected critical infrastructure and a 28% improvement in incident response times (Superintendency of Banks of the Dominican Republic, 2024). These findings confirm that the holistic implementation of the regulations, supported by the outputs of this project, constitutes an effective strategy for strengthening cybersecurity in the Dominican financial system.

In conclusion, this research not only provides a starting point for other high-level projects but also makes a significant contribution to the country's institutional, technical, and regulatory development. The implementation of the scientific products resulting from this research proposal represents a strategic opportunity to transform the approach to cybersecurity in financial institutions, promoting a technological environment that is more secure, resilient, and aligned with international best practices.

It is recommended that future research delve deeper into comparative analyses of financial sectors in different countries, evaluate the longitudinal impact of the regulation's implementation, and develop predictive models of cyber risk tailored to the Dominican context. Furthermore, it is suggested that the Central Bank and regulatory agencies take the findings of this study into account to strengthen the mechanisms for supervising and providing technical support to institutions in the sector.

In this regard, the study not only provides evidence on the level of implementation of the regulations but also highlights the need to strengthen the coordination between regulatory frameworks and the operational capacity of financial institutions. The situation in the Dominican Republic—characterized by a steady increase in cyberattacks and growing pressure on digital security—underscores the importance of adopting more comprehensive and adaptive management models that enable the transformation of regulatory compliance into actual protection capabilities. In this way, the research broadens the traditional approach to regulatory compliance, shifting the focus toward a strategic perspective based on institutional resilience and the continuous improvement of cybersecurity processes.

It is important to emphasize that this study does not aim to draw definitive conclusions about the implementation of the regulation, but rather to provide an initial methodological approach that will serve as a foundation for future research, both by the author and by other scholars interested in the topic.

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**ANALYSIS AND PROPOSAL FOR TEACHING PROJECT DESIGN AND
MANAGEMENT AT THE POSTGRADUATE LEVEL IN IBERO-AMERICA**
**ANÁLISIS Y PROPUESTA SOBRE LA ENSEÑANZA EN DISEÑO Y GESTIÓN DE
PROYECTOS A NIVEL POSGRADO EN IBEROAMÉRICA**

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ABSTRACT

Keywords:

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certification.

Project management has evolved globally, bringing improvements to the life cycle of projects carried out throughout history. However, training professionals in this field in Mexico has proven to be a difficult task to implement. As mentioned in Estrada (2015), project management is a profession in constant growth and currently represents an alternative for achieving job differentiation in an increasingly competitive world. Nevertheless, in Mexico, professionalization in this area is practically nonexistent at the undergraduate level and insufficient at the postgraduate level. Undergraduate programs are typically technical in nature and do not include courses focused on the managerial skills required of a project manager. At the postgraduate level, programs are more commonly offered by private institutions, either as specializations or full master's degrees. In some cases, these programs include preparation for obtaining certifications from organizations such as PMA and IPMA. Additionally, the range of options has expanded through educational platforms such as Coursera, Udemy, Crehana, edX, Domestika, and Future Learn, which offer courses on project management as well as on tools and software that support project execution. While these platforms allow for self-directed

	professional development, higher education institutions in Mexico continue to lag in training professionals in this field.
	RESUMEN
Palabras clave: gestión de proyectos, profesionalización, posgrado, certificación.	La gestión de proyectos ha evolucionado a nivel mundial, generando mejoras dentro del ciclo de vida de los proyectos ejecutados a lo largo de la historia. Sin embargo, formar profesionales en esta disciplina en México ha resultado una tarea difícil de implementar. Como menciona Estrada (2015), la dirección de proyectos es una profesión en constante crecimiento y representa actualmente una alternativa para lograr la diferenciación laboral en un mundo altamente competitivo. No obstante, en México, la profesionalización en esta área es prácticamente inexistente a nivel licenciatura y deficiente en el nivel de posgrado. Las opciones disponibles en licenciatura suelen ser programas de educación técnica que no incluyen asignaturas orientadas al desarrollo de habilidades gerenciales propias de un director de proyectos. En cuanto a los programas de maestría, estos se ofrecen con mayor frecuencia en instituciones privadas, ya sea como especializaciones o como programas formales de maestría. En algunos casos, se brinda preparación para la obtención de certificaciones emitidas por organismos como el PMA o IPMA. Asimismo, el abanico de opciones se amplía mediante plataformas educativas como Coursera, Udemy, Cerebra, edX, Domestika y Future Learn, las cuales ofrecen cursos sobre gestión de proyectos o sobre el uso de software y herramientas de apoyo para dicha gestión. Si bien estas plataformas permiten acceder a una profesionalización mediante el aprendizaje autodirigido, las instituciones de educación superior aún se encuentran rezagadas en la formación de profesionales especializados.

Introduction

Higher education policy requires that national programs be aligned with international standards and respond to trends in the global economy, as higher education is a key driver of economic competitiveness, which makes high-quality university education even more important, according to the Organization for Economic Co-operation and Development (OECD, 2019).

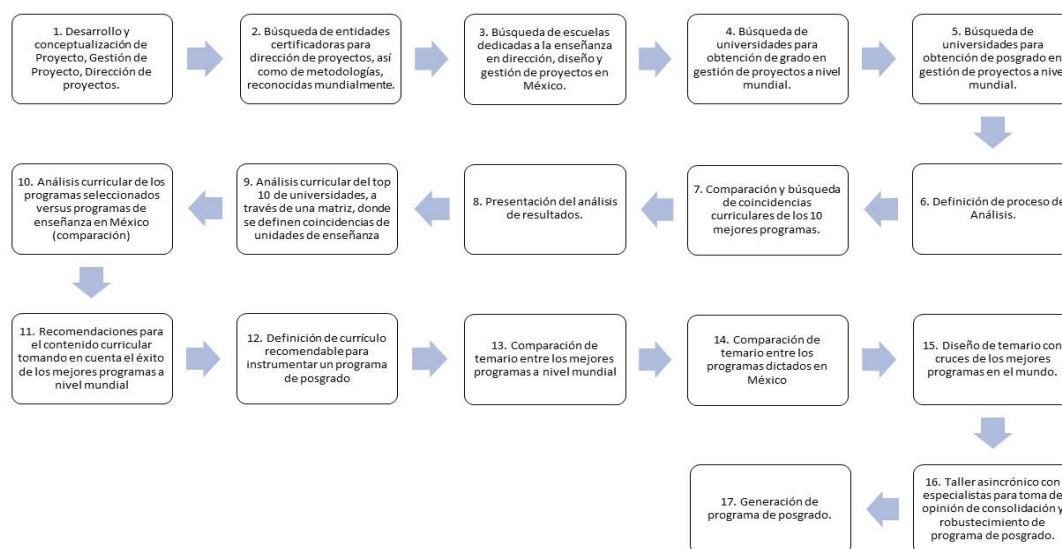
The curriculum in “Project Design and Management (PDM)” is relevant to professional practice because we often assume that a single discipline produces specialists, when in fact problem-solving requires multidisciplinary skills and interdisciplinary approaches; this is why skills in PDM contribute to solutions that employ multidisciplinary approaches.

This article identifies project management education programs in Mexico and around the world with the aim of presenting the range of options available and exploring how to adapt them to the Mexican context to train professionals in this field. As a rapidly growing profession, it is considered an alternative for achieving a competitive edge in the job market, according to Estrada (2015), where project management skills and competencies are of vital importance.

Materials and Methods

The methodology consists of three phases, as shown in Figure 1; the analysis was conducted using the following steps.

Figure 1
Methodology



Analysis and Proposal on DGP Education at the Graduate Level in Ibero-America ***Project Development and Conceptualization, Project Management and Leadership***

Projects are found in everyday activities; their conceptualization goes beyond tangible or intangible objects that provide services to users. According to the PMBOK (Project Management Institute, 2008), a project is defined as a time-bound endeavor undertaken to create a unique product, service, or result. As can be seen in this definition, it is time-bound, indicating a beginning and an end, the latter of which is reached when the project's objectives are either achieved or not. Similarly, this temporary nature does not imply a short- or long-term duration, since this characteristic does not apply to the project's outcome; most projects aim to create a lasting result, regardless of whether it is a product, service, or good.

Another definition is provided by the International Project Management Association, which defines a project as an operation in which human, financial, and material resources are organized in a novel way to carry out a set of tasks according to defined specifications, subject to cost and time constraints, and following a standard life cycle to achieve beneficial changes through quantitative and qualitative objectives; This definition, like that of the International Organization for Standardization—which defines a project as a temporary endeavor to achieve one or more defined objectives—leads us to conclude that projects must possess at least the following characteristics:

1. To be a one-time operation.
2. Keep a beginning and an end.
3. Require financial, technical, human, and material resources.
4. To achieve a result or meet a goal.

According to various schools of thought, project management as defined by the PMBOK involves applying knowledge, skills, tools, and techniques to project activities in order to meet project requirements, while project management is the application of knowledge, skills, tools, and techniques to project activities to meet those requirements. This is achieved through the application and integration of 49 project management processes organized into 5 groups: Initiation, Planning, Execution and Control, Monitoring, and Closure.

According to the IPMA [2019]: it is the planning, organization, monitoring, and control of all aspects of the project and the motivation of all stakeholders to achieve the objectives safely within the agreed-upon criteria for time, cost, and performance. For the IPMA, project management refers to a person who possesses a set of skills and applies them based on their technical knowledge, distinguishing between three types of competencies: behavioral, technical, and contextual.

Based on the above definitions, it can be concluded that a project manager is the person assigned to achieve objectives in line with the management skills that enable projects to be completed efficiently. It is also understood that project management education should be based on the acquisition and consolidation of skills for project design, management, and leadership.

With regard to the teaching of design, project direction, and project management, there are various models, guidelines, and methodologies; among the most widely recognized are the following:

- PM BOK Guide — PMI, Project Management Institute
- ISO 21500.—ISO, International Organization for Standardization
- ISO 10006.—ISO, International Organization for Standardization
- ICB Competence Baseline — IPMA, International Project Management Association
- APM BOOK.—APM, Association for Project Management
- PRINCE 2 - OGC, Office of Government Commerce
- ANCSPM—AIPM, Australian Institute of Project Management
- PM4R—IDB, Inter-American Development Bank

The various schools of project management focus on candidates' skills and experience in managing and working on projects. These institutions have created and developed methodologies and standards for project management, in some cases combining methodologies that make it possible to shorten timelines or modify phases and steps. When it comes to these project management training schools, the PMI and the IPMA are considered leaders in this field; these institutions base their instruction on the knowledge and use of tools, techniques, and skills for project management.

According to QS Quacquarelli Symonds (2022), there are 550 project management programs worldwide, of which only 1.09% are located in Mexico; this corresponds to 6 programs in the QSTop Universities ranking. However, according to research conducted in Mexico, it appears that these types of skills are developed through continuing education activities and graduate programs, such as master's degrees or specialized programs at private institutions. The schools in Mexico that offer these programs are listed below:

- Public | National Autonomous University of Mexico (UNAM) | Specialization and Certificate Program
- Private | Monterrey Institute of Technology and Higher Education | Specialization
- Private | Universidad del Valle de México (UVM) | Certificate Program
- Private | Technological University of Mexico (UNITEC) | Master's Degree
- Private | Universidad Panamericana (UP) | Master's and Specialization Programs
- Public | National Council for Science and Technology (CONACyT) – CIATEQ | Master's Degree
- Private | La Salle University | Master's Degree
- Private | University for International Cooperation (UCI) | Master's Degree
- Private | International Ibero-American University (UNINI) | Master's Degree
- Private | International University of La Rioja (UNIR) | Master's Degree
- Private | ICEL University | Master's Degree
- Public | Tecamachalco University of Technology (UTTECAM) | Bachelor's Degree
- Public | Izúcar de Matamoros University of Technology (UTM) | Bachelor's Degree
- Public | Huejotzingo University of Technology (UTH) | Bachelor's Degree
- Public | Tecámac University of Technology (UTT) | Bachelor's Degree

As can be seen, technical schools offer bachelor's degree programs; however, a review of the curriculum reveals that these programs focus on business management, indicating an opportunity to strengthen these educational programs and align them with DGP starting at this academic level. At the master's level, options are limited, as these programs are concentrated in private schools and offered at only 15 educational institutions, with a total of 17 general programs, most of which are located in Mexico City.

According to the list, 47% of the programs offered in Mexico are graduate programs, 29% are continuing education or specialty programs, and 24% are bachelor's or advanced technical degree programs, presenting an opportunity to address the shortage of professionals in this field. Although there are 11 more programs than those listed in the QS Top Universities ranking, this number remains minuscule compared to what is offered worldwide. It is also important to recognize that there is a demand for professionals in this field and that, with the right tools, it is possible to train professionals in this area—whether through a technical degree or, as has been the case, through specialized bachelor's or master's degrees—in accordance with areas of interest and in line with national development projects.

Thematic Analysis at the Regional Level and Curriculum Definition for DGP Education at the Graduate Level

Curriculum analysis is a research exercise based on various data. To address this topic, the top programs worldwide were identified, with a limit of 10 programs per ranking. Based on various databases and the scoring structure of global rankings, different results were obtained.

Data from Mundo Posgrado (2021) highlights Spanish schools such as EAE Business School, Universidad Europea, UNIR, and IMF Business School. Meanwhile, the Master of Project Academy ranking (2022) lists U.S. institutions such as Bellevue University, Capella University, the University of Colorado, and the University of Maryland among the top schools. The QS Top Universities ranking (2022) takes a global perspective, including UCL—London's Global University, The Australian National University, and The University of Manchester on its list. This variation in the rankings is due to the fact that some focus on geographic criteria, while others evaluate academic units based on skills and other factors.

An analysis of the number of programs by region, according to the QS Top Universities ranking, shows that, out of a total of 550 programs, Europe has the largest share at 67.5% (371 programs, of which 296 are master's programs), followed by Oceania with 19.8% (109 programs, including 98 master's programs). Latin America and North America have far fewer programs—26 and 25, respectively—almost exclusively at the master's level.

As for bachelor's degree programs, the top 10 reveals that most are located in Australia and the United Kingdom, with a strong focus on construction project management or civil engineering, as seen in the programs at UCL—London's Global University and the National University of Singapore.

Finally, the landscape for master's-level graduate programs shows that most of the top-ranked programs are concentrated in the United Kingdom and are offered by just three universities. Programs such as UCL's "MSc in Strategic Management of Projects" and the University of Manchester's "MSc in Engineering Project Management" were analyzed to compare their syllabi and verify the topics and skills taught to students enrolled at these universities.

Universities vary depending on the ranking; this is because some rankings are based on geographic location, while others are based on the capabilities and characteristics of the academic units. The QS World University Rankings cover the global landscape; Europe accounts for 67.5% of all programs ranked by this organization, followed by Oceania with 19.8%.

Curriculum Analysis of the Top 10 Master's Programs

The courses offered by the top 10 master's programs were identified by verifying matches in course names and topics. It was found that all programs include a course titled "Project Management," referring to both the course and the program name. According to the syllabus, this course focuses on establishing the arguments necessary for students to undergo a paradigm shift and develop a narrower perspective based on project management tools, thereby moving toward an inclusive approach to project management. It also introduces students to the principles and theoretical framework of project management and information technology. This course appears most frequently among the top 10 master's programs.

A second course is titled "Governance and Control" or "Project Monitoring and Control." This course has similar objectives depending on the academic institution offering it; these include exploring the strategic framework surrounding any project, establishing project goals and objectives, and understanding the control framework and measures that are part of project management (University for International Cooperation [UCI], 2022).

The third common element identified was a course titled "Project Management and Business Activities" or courses related to companies specializing in project management; 6 of the 10 programs include a course dedicated to this subject.

Other courses found to align with the programs—either in terms of syllabus or course title—are those related to:

1. Problem and Risk Management,
2. Personnel management,
3. Project Finance,
4. Management of large or complex projects.

Other common features among the programs include a two-year duration dedicated to developing the competencies and skills of these professionals. The teaching modalities are varied, with an emphasis on in-person instruction; however, the three universities offering the top 10 programs have specified that some courses will be taken online.

There are also extracurricular courses designed to help students prepare for PMI certification or accreditation. This serves as a reminder that teaching must focus on the entire project life cycle—from design through management to closure—as well as on the skills required to earn a certification from the PMI or IPMA.

Curriculum Analysis of the Selected Programs (Top 10) Compared to Education in Mexico

Undergraduate programs in DGP are becoming increasingly competitive, as there are few options for studying this field; as for graduate programs, they are mostly offered at private universities, and based on the curricula and syllabi, the content is similar to that of the top 10 programs.

Of the five graduate programs ranked by QS Universities in Mexico, one common feature is the course titled "Project Management," which is the top-ranked course for the best master's programs worldwide. According to the educational institutions that offer this course in Mexico, its objective is for students to identify the main elements of project management, including planning, organization, motivation, and control.

However, unlike the top-ranked programs (top 10), the second most common subject is project finance and resource management, while the third most common is the subject related to identifying and managing risks and changes in projects. Although these subjects are indeed part of the set of common topics in the world's top graduate-level

programs, they do not specifically rank second and third; however, they are among the skills required of a project manager.

The courses that receive the least attention in the curricula of programs in Mexico are those focused on project communication or marketing; according to the QS University Rankings, this subject is included in at least two of the top 10 programs.

As we can see, the courses with the greatest overlap between programs worldwide and those in Mexico are Project Management and Project Monitoring and Control, meaning that Mexico's curriculum is similar to that of the top programs; however, as Cruz et al. point out, (2020), managing projects requires the implementation of planning, execution, and control processes, as well as meeting specific deadlines and making rational use of all the resources necessary for the project. According to Sáenz et al. (2019), it is essential to study the following constructs: time management, human resource management, quality management, and cost management. This relates to the need to supplement teaching models on DGP, since, although models and methodologies exist, technologies and global challenges have changed, and various project management and monitoring tools have been developed and implemented.

Definition of a Recommended Curriculum for Implementing a Graduate-Level Program

Based on the findings discussed in this article, and with the aim of developing a regionalized graduate program in accordance with the constructs and principles that have been documented, a core curriculum was defined to implement a graduate program in DGP for Mexico.

Based on the above, it was concluded that the following courses are recommended for the implementation of a graduate program.

1. Project Management and Design,
2. A Management Framework for Business Projects,
3. Design Management,
4. Project Problem and Risk Management,
5. Project Monitoring and Control,
6. Financial Reports and Analysis
7. People and Organizations,
8. Strategic Human Resources Management
9. Project Announcement
10. Projects and Information Technology.

This stems from the fact that projects are a process that involves planning, execution, and control, as well as the project manager's precise actions based on information, time, costs, and other resources necessary to achieve the objective; therefore, it is important to note that future project managers must maintain the knowledge and skills needed to apply their expertise in these areas.

Similarly, we must understand that a project does not operate based on a single technique or methodology, as each involves unique processes; therefore, it is considered necessary to combine systems, techniques, methodologies, and people to achieve the established objectives. Consequently, these subjects are seen as the foundation for a project manager to acquire the necessary skills, in conjunction with the use of state-of-the-art technologies.

It is also recommended that the program be hybrid, combining in-person and online classes through a collaborative learning environment that includes both

synchronous and asynchronous activities, and making use of all available tools to develop skills in technology and project management. In addition, it is suggested that there be programs or workshops designed to develop students' skills both inside and outside the classroom; therefore, it is proposed that this curriculum be flexible and promote mobility and collaboration with other educational institutions as well as with industry.

Another point to consider when designing a flexible graduate program for Mexico is that students should be able to complete the program on a full-time basis within two years and, within that timeframe, submit a project and take the corresponding degree exam.

With regard to areas of knowledge application, the following were considered:

1. Design and Management of Engineering and Infrastructure Projects.
2. Design and Management of Quality and Environmental Projects for Development.
3. Design and Management of Innovation and ICT Projects.

Proposal for Implementing a Flexible Project-Based Learning Program at the Graduate Level

To determine a program and its corresponding curriculum, a comparison was made of the curricula of the top 10 programs in the QS World University Rankings, followed by a comparison of the five highest-ranked programs in Mexico. Finally, a syllabus was designed by combining elements from the world's top programs and adapting them to the regional context, with a focus on the knowledge and skills that Mexican students—and, where applicable, students applying for study abroad programs in Mexico—should acquire.

With this in mind, it is proposed that this program be implemented at the National Polytechnic Institute (IPN) within the Interdisciplinary Professional Unit for Engineering, Social Sciences, and Administrative Sciences (UPIICSA), as this institution already offers a graduate-level program in the field of project management that is included in the QS World University Rankings, and it possesses the necessary regulations and technical, technological, human, and financial resources to implement a graduate program of this nature.

Therefore, in addition to the implementation at that institution, the National Polytechnic Institute's Regulations on Graduate Studies were taken into account, which specify that students must earn 115 credits in accordance with the Academic Credit Allocation and Transfer System (SATCA) and complete a thesis on their chosen project (54 credits); and for the doctoral level, a total of 4 academic terms (4 years), including the thesis (108 credits) and the comprehensive exam.

In accordance with the above, Figure 2 shows the proposed curriculum map for the DGP master's degree program.

Figure 2

Proposed Curriculum Outline for the Master's Program in DGP

Maestría en Diseño y Gestión de Proyectos				
Modalidad	Híbrida	Orientación	Profesional	4 semestres
Unidades de aprendizaje de:	Periodo escolar I	Periodo escolar II	Periodo escolar III	Periodo escolar IV
Tronco básico multidisciplinario	Diseño y gestión de proyectos	Seguimiento y control de proyectos	Gestión de problemas y riesgo de proyectos	Infomes y análisis financieros
	Gestión estratégica de recursos humanos	Comunicación del Proyecto		
Seminario de proyectos multidisciplinario	Seminario I	Seminario II	Seminario III	Seminario IV
Optativas	Un marco de gestión para proyectos empresariales	Proyectos y tecnologías de la información	Personas y organizaciones	Temas selectos
Línea de aplicación del Conocimiento 1:	La contratación de construcción, ingeniería y servicios profesionales	Gestión de la construcción	Sustentabilidad ambiental en el sector de la construcción	Integración de los sistemas de información del proyecto con el modelado de información de construcción
	Proyecto financiero para proyectos de infraestructura	Gestión financiera estrategia para proyectos de construcción e infraestructura	Evaluación de impacto ambiental, social y económica del proyecto	Marketing y desarrollo de negocios de proyectos.
Línea de aplicación del Conocimiento 2:	La gestión de grandes proyectos y programas	Evaluación ambiental	Reforma y gestión del sector público	Gestión de la calidad en el desarrollo
	Género y desarrollo	Planificación y gestión del desarrollo	Características y habilidades de la práctica del desarrollo	Evaluación de impacto ambiental, social y económica del proyecto.
Línea de aplicación del Conocimiento 3:	Estrategia tecnológica	Gestión de proyectos con TIC	Diseño de sistemas	Gestión de la innovación y la tecnología
	Sistemas de defensa y seguridad	Análisis de datos para gerentes de proyectos	Planificación y gestión del Desarrollo de Proyectos de innovación y TIC	

The program structure presented in Table 1 lists the following six core courses for project management:

1. Project design and management,
2. Project monitoring and control,
3. Project Problem and Risk Management,
4. Financial reports and analyses,
5. Strategic Human Resource Management,
6. Project Announcement.

Similarly, three courses were identified that, although they overlap, are not offered in all programs; therefore, it is proposed that they be offered as electives based on student interests:

1. A management framework for business projects,
2. Projects and Information Technology,
3. People and organizations.

With regard to the three areas of knowledge application, it should also be noted that they are aligned with the best graduate programs. Similarly, and in line with the program's regionalization, the research found that these areas are included in the programs offered by Mexican institutions, thereby adding value and fostering professionalization in strategic fields.

Figure 3 shows the proposed curriculum map for the DGP doctoral program.

Figure 3

Proposed curriculum outline for the DGP program

Doctorado en Diseño y Gestión de Proyectos				
Modalidad	Híbrida	Orientación	Profesional	4 semestres
Unidades de aprendizaje de:	Periodo escolar I	Periodo escolar II	Periodo escolar III	Periodo escolar IV
Seminario de proyectos multidisciplinario	Seminario I	Seminario II	Seminario III	Seminario IV
Línea de aplicación del Conocimiento 1: <i>Dirección y Gestión de proyectos de ingeniería e infraestructura</i>				
Línea de aplicación del Conocimiento 2: <i>Dirección y Gestión de proyectos de calidad y medio ambientales para el desarrollo</i>				
Línea de aplicación del Conocimiento 3: <i>Dirección y Gestión de proyectos de innovación y TIC</i>				

As we can see, the doctoral program focuses on seminars for the presentation of a multidisciplinary project, which may be a continuation of the one presented during the master's program or a different one; furthermore, this project must be aligned with one of the three areas of knowledge application. This project is expected to require only minimal guidance from teachers; therefore, a hybrid model is proposed, combining in-person and remote sessions accessible from any device that facilitates communication, thereby fostering long-distance teamwork skills and effective communication.

Overview of courses with a thematic analysis based on the top 10 programs worldwide and existing programs in Mexico

Undergraduate and graduate university programs have an academic mission and vision, but the primary goal is to build students' skills. Below are the objectives for each of the required courses, with the aim of creating a program that covers the appropriate topics in line with the top 10 universities in the world.

The course on project management is included in all the programs reviewed, and the objective of this course is similar at all three universities: it is designed to provide a foundation for the practice and profession of project management, as well as to familiarize students with and help them recognize the management topics encompassed by the term "project management," along with the challenges these professionals may face.

In the case of universities in Mexico, the objective is no different, since what they offer is the opportunity for students to use the methods and methodologies required for the management and coordination of all stages of a project, applying techniques and tools specific to project management; however, the topic of project design is largely overlooked,

with the exception of the program offered by the Universidad Internacional Iberoamericana (UNINI), which provides this graduate program online and includes a module dedicated to project design and another dedicated to project management. Each of these modules covers different subjects that allow for a holistic integration of project design and project management at every stage.

It is worth noting that the second most important course is “Project Monitoring and Control”; at UNINI, this course is offered as part of the “Project Management” module. Among the top 10 universities, this course is offered in 6 of the 10 programs, the objective of which is to direct and ensure the proper execution and monitoring of a project, as well as the environment in which these projects are carried out. According to the University of Manchester, the following are key topics: the importance of project planning and control, project selection, project planning, and project monitoring and control

The third course in the selection is problem and risk management; among the programs analyzed in Mexico, only two universities offer it, and its core topics include trust management—quality and risk, and ISO 45001 (International Ibero-American University [UNINI], 2022)—as well as risk management and its implications for projects (Universidad Panamericana, 2022). With regard to the objective of this course, students should be able to analyze how risks and problems influence project decision-making, as well as manage risks and problems throughout the project's lifecycle.

The course titled “Financial Reports and Analysis” is another offering inspired by an analysis of the world's best programs; at the regional level, it is offered by only two institutions and covers the following topics: Economic and financial evaluation of investment projects and project financing; UNINI also offers a course dedicated to the economic aspects of projects. According to the international rankings, it is offered in 3 of the top 10 programs.

The objective of this module is to provide an introduction to project economics and its importance in the discussion of project management. It also offers insight into the role of accounting, financial reporting, and the dissemination of economic information, as well as how to communicate resource allocation and financial statements to support better decision-making.

The course titled “Strategic Human Resource Management” is offered in 5 of the top 10 international programs, as well as in 3 programs reviewed under the national framework. This course is designed to address conflicts and support the leadership of project managers within work teams; therefore, it aims to provide theories and frameworks for leadership and organizational change so that students can develop interpersonal skills that can be effectively applied in organizations, enabling them to lead people.

Another course selected based on its similarity and overlap with curricula at the global and national levels is the course titled “Project Communication.” This course is offered at the Australian National University in two of its programs, and its focus is on introducing topics in marketing and communications, with an emphasis on audience selection, message development, stakeholder identification, and problem-solving through project communication. This provides students with the opportunity to develop communication skills by tailoring messages to the target audience.

It also aims to ensure that marketing focuses on stakeholders to provide valuable solutions for the identified audience, with the following learning outcomes: identifying stakeholders' interests and requirements, employing evidence-based decision-making, and establishing stakeholder groups.

Based on the above, there are six course units designed in accordance with the curricular similarities of the world's top programs. Additionally, the selection process was

guided by the development of the competencies necessary for project management and design.

The following three courses were selected as electives; although these subjects overlap significantly across the various programs, they either cover some overlapping topics or focus on a specific area of specialization. These courses are:

A management framework for business projects, which is offered in 5 of the top 10 programs, and covers project management concepts within an organizational structure, highlighting the following topics: businesses, competitive strategies, business development, decision-making and negotiation, continuous improvement, and relationship management.

Information Technology Projects: This course is offered in three of the top 10 programs worldwide, and it is also offered in one of the programs in Mexico. The course focuses on introducing the fundamentals of systems engineering and establishing a framework for designing engineering systems in response to client needs and expectations. It also aims to foster a combination of systems thinking, planning, and sound engineering practices.

The last of the elective courses is “People and Organizations,” which aims to examine the nature of organizations and the ways in which they conceptualize human relationships with people both within and outside the organization, as well as the ways in which work is carried out within an organization or within a project. It also seeks to develop leadership and motivation skills and integrate them with project management.

Asynchronous analysis

The evaluation was conducted asynchronously with 13 participants, who were asked to review the proposed program in an institutional setting and then complete questionnaires via Google Forms, as well as freely submit comments or suggestions.

The workshop participants who reviewed and validated the program come from 12 organizations around the world, providing a wide range of proposals and observations. Below is a list of the organizations that contributed their expertise to the review of this proposal.

1. Argentina - Argentine Ibero-American University Foundation
2. Korea - Korea Advanced Institute of Science & Technology (KAIST)
3. Spain – Polytechnic University of Catalonia – UPC
4. Spain – Cantabria Center for Industrial Research and Technology – CITICAN
5. Spain - Loyola University Andalusia
6. France - Engineering School – ESTIA
7. Mexico – Ibero-American University Foundation, Mexico
8. Mexico – National Polytechnic Institute (IPN) – Office of Graduate Studies
9. Mexico – IPN – Interdisciplinary Center for Research on Comprehensive Regional Development, Oaxaca Unit
10. Mexico – IPN – Center for Computer Science Research
11. Mexico - IPN - Interdisciplinary Professional Unit for Engineering, Social Sciences, and Administrative Sciences
12. Venezuela - University of the Andes; Inter-American Center for Environmental and Territorial Development and Research

The questionnaire consisted of questions related to each course and included both multiple-choice and open-ended questions for comments. There were a total of 234 questions per participant, resulting in a total of 2,808 responses analyzed for the master’s

program, and a total of 864 for the doctoral program. The survey focused on pedagogical and functional aspects of the courses and topics; participants were also asked to specify whether they believed the IPN had sufficient and necessary resources to establish a new program that would expand the range of academic offerings provided by the institution.

Analysis Results

This process is carried out manually by reviewing each of the questions and recommendations, yielding the following results:

Between 82% and 91% of participants stated that the objectives and topics are appropriate and cover or enable them to develop the required skills.

Between 64% and 91% of participants stated that the syllabus aligns with the competencies described for developing skills in DGP students.

Between 45% and 72% of the participants felt that it was not necessary to add any more topics or subtopics; for the remaining percentage, the analysis focused on areas of opportunity to determine whether they were relevant or not.

With regard to the pedagogical and functional aspects of the syllabi for each course, the following results were obtained for the 13 courses: the participants considered them to be highly relevant. The pedagogical and functional aspects of the courses evaluated were:

1. The topics help students achieve the course objectives
2. There is alignment with other international and national programs
3. The course is interesting, engaging, and motivating
4. The course has shortcomings
5. The course has potential
6. There are sufficient resources, content, and activities
7. There is diversity in assessment
8. The course takes an applied, creative approach
9. The course encourages self-directed learning, initiative, and decision-making
10. The course fosters project management skills

Therefore, the proposed syllabus is designed to help students achieve the objectives of each course; however, the workshop leaders made recommendations and observations, all of which emphasized the inclusion of practical activities as well as the incorporation of flexible and hybrid teaching methods.

With regard to the proposed doctoral program, the same feedback was received regarding the validation of the pedagogical and functional aspects of the courses; however, this program consists of four seminars dedicated exclusively to the completion of a project for the doctoral dissertation defense. Therefore, the objectives were adjusted so that each seminar has a specific objective aligned with the stages of the project currently being worked on.

Based on the analysis of the workshop, out of 3,672 responses, more than 50% of the participants felt that the program was suitable for students to acquire the skills and competencies of professionals in the field; therefore, this proposal could lead to the consolidation of a program offered by the IPN.

Proposed Graduate Program

In accordance with the recommendations from the asynchronous workshop, modifications were made to the course objectives. Regarding the areas of knowledge application, no comments or changes were made, as these were not subject to evaluation

due to the approach of developing an ad hoc and general syllabus to train professionals in DGP, as shown in Figure 4.

Figure 4
Proposed Curriculum Framework for the DGP Program

Maestría en Diseño y Gestión de Proyectos				
Modalidad	Híbrida	Orientación	Profesional	4 semestres
Unidades de aprendizaje de:	Periodo escolar I	Periodo escolar II	Periodo escolar III	Periodo escolar IV
Tronco básico multidisciplinario	Diseño y gestión de proyectos	Seguimiento y control de proyectos	Gestión de problemas y riesgo de proyectos	Informes y análisis financieros
	Gestión estratégica de recursos humanos	Comunicación del Proyecto		
Seminario de proyectos multidisciplinario	Seminario I	Seminario II	Seminario III	Seminario IV
Optativas	Un marco de gestión para proyectos empresariales	Proyectos y tecnologías de la información	Personas y organizaciones	

As we can see, the required courses offer a wide range of options in line with the best master's programs. For the doctoral program, only four seminars are offered, in which students must develop a feasible project that includes all phases, thereby allowing them to transition from coursework to work on their doctoral dissertation.

Discussion

The teaching of DGP across Ibero-America is diverse; however, one area where the region is in agreement is the use of globally recognized methodologies led by PMI and IPMA. With regard to the situation in Mexico, which focuses on continuing education or master's degree programs, the landscape is precarious and heavily concentrated in master's programs at private institutions that offer accreditations from leading schools that have developed project management methodologies.

It is considered necessary for students to begin applying their skills and knowledge starting in technical schools and building on the knowledge gained during their undergraduate studies, thereby focusing on both technical and general knowledge in order to transform it into valuable projects that result in products or services users need.

Based on the foregoing, the creation of a graduate program for the IPN—which is considered a public institution of higher education—was considered. This program consisted of six required courses, as well as three areas of knowledge application in engineering and construction, environmental, social, and development projects, and information technology, in conjunction with the development of an applied project as part of the dissertation.

It should be noted that the above is used to identify these courses, and similarities between programs were sought in order to align and regionalize a program in accordance with the top programs.

In addition to the above, it is considered necessary—in order to implement a program of this nature—to take a regional approach and determine what types of project professionals companies and organizations in Mexico are seeking, since such a program

must have at least three objectives: first, to train DGP professionals for Mexico; second, to enable these professionals to be deployed to projects in other parts of the world; and third, to allow students from other regions to pursue professional training in Mexico.

Conclusions and Future Work

The conclusions drawn from this research are significant because, based on the assessment conducted, it was possible to propose a hybrid master's program for an institution in Mexico that is accessible to a wider audience, is aligned with the best master's programs in the world, and aims to develop the skills recommended by the PMI and the IPMA.

However, it will be necessary to adapt this program to regional contexts and update it in line with new developments and innovations in order to produce well-trained professionals; furthermore, there is little interest on the part of public institutions in incorporating these skills into the relevant curriculum.

Similarly, it is considered that the proposed areas of knowledge application are aligned with national and international challenges.

As part of future efforts, it will be important to increase the dissemination of this type of information, which will help highlight the opportunities available to trained professionals so they can rise to the challenges and seize the opportunities they will face in today's workforce.

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THE IMPORTANCE OF CUSTOMER SERVICE AS A FACTOR OF BUSINESS GROWTH
A IMPORTÂNCIA DE ATENDIMENTO AO CLIENTE COMO FATOR DO CRESCIMENTO EMPRESARIAL
LA IMPORTANCIA DEL SERVICIO AL CLIENTE COMO FACTOR DE CRECIMIENTO EMPRESARIAL

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ABSTRACT

Keywords:

customer service, business growth and market.

This scientific article aims to analyze the contribution of customer service to the business growth factor in actual context, for that a theoretical framework is presented in order to identify types of customer service, to know the profile of the negotiator, the steps and strategy in attendance. To emphasize the importance of customer services in the business process, present the importance of ethics where its use can influence on the source of profit for organizations and finally present a quick approach to customer services. How can customer service contribute to an organization's sales increase? In order to achieve the outlined objectives, the work had as a research methodology, as for the embroidering it was qualitative, as for the type it was descriptive. The study had 15 participants, being 5 service professionals and 10 clients. A semi-structured interview was used for data collection, the data were analyzed content analysis using categories, subcategories, which allowed us reach the conclusion that customer services do have a great contribution to the increase in sales in the organizations, as it was found that their employees have knowledge and skills in customer services, and they are aware that poor offered may bring negative consequences to the sales process and thus compromising the company's success.

RESUMO

Palavras-chave:

atendimento ao cliente, crescimento empresarial e mercado.

Este artigo científico tem como objetivo analisar a contribuição do atendimento ao cliente para o fator de crescimento empresarial no contexto atual, para o qual é apresentado um referencial teórico a fim de identificar os tipos de atendimento ao cliente, conhecer o perfil do negociador, as etapas e a estratégia, no atendimento. Para enfatizar a importância do atendimento ao cliente no processo

	comercial, apresentar a importância da ética onde seu uso pode influenciar na origem do perfil para as organizações e por fim apresentar uma abordagem rápida ao atendimento ao cliente? Como o atendimento ao cliente pode contribuir para aumentar as vendas de uma organização? Para atingir os objetivos enunciados o trabalho teve como metodologia de pesquisa, em termos de bordado foi qualitativo, em termos de tipo foi descritivo. O estudo contou com 15 participantes, sendo 5 profissionais do serviço e 10 clientes. Para a recolha de dados foi utilizada uma entrevista semiestruturada, os dados foram analisados através de análise de conteúdo através de categorias e subcategorias, o que nos permitiu chegar à conclusão de que o atendimento ao cliente tem sim um grande contributo para o aumento das vendas nas organizações, uma vez que se constatou que os seus colaboradores possuem conhecimentos e competências no atendimento ao cliente, e estão conscientes de que uma má oferta pode ter consequências negativas para o processo de vendas e, portanto, comprometer o sucesso da empresa.
	RESUMEN Este artículo científico tiene como objetivo analizar la contribución del servicio al cliente como factor de crecimiento empresarial en el contexto actual. Para ello, se presenta un marco teórico con el fin de identificar los tipos de atención al cliente, conocer el perfil del negociador, así como los pasos, estrategias y prácticas utilizadas en la atención. Asimismo, se enfatiza la importancia del servicio al cliente en el proceso comercial y se destaca el papel de la ética, cuyo uso adecuado puede influir en la imagen y el posicionamiento de las organizaciones. El estudio también busca responder a la siguiente interrogante: ¿cómo puede el servicio al cliente contribuir al aumento de las ventas de una organización? Para alcanzar los objetivos propuestos, la investigación adoptó una metodología de enfoque cualitativo y de tipo descriptivo. El estudio contó con la participación de 15 personas, de las cuales 5 eran profesionales del área de servicios y 10 clientes. Para la recolección de datos se utilizó la entrevista semiestructurada, y los datos obtenidos fueron analizados mediante el análisis de contenido, a partir de categorías y subcategorías. Los resultados permitieron concluir que el servicio al cliente aporta significativamente al incremento de las ventas en las organizaciones, ya que se constató que los empleados poseen conocimientos y habilidades en atención al cliente y son conscientes de que una oferta deficiente puede generar consecuencias negativas en el proceso de venta y, por consiguiente, comprometer el éxito empresarial.
Palavras Chave: Atenção al cliente, Crecimiento empresarial y Mercado.	

Introduction

In recent years, the customer service industry has become increasingly competitive, with customer service being one of the key factors that set organizations apart. In the context of Água da Região do Norte–Nampula (AdRN), where the supply of drinking water is an ongoing challenge, the company has a responsibility not only to provide an essential service but also to ensure that customers feel valued and satisfied.

Customer service involves providing guidance to consumers and plays a key role in building customer loyalty, ensuring the continuity of the relationship between the organization and its customers. Therefore, the way a customer is treated directly affects their level of satisfaction. Assessing customer satisfaction with water supply services is essential for guiding improvements in service providers' performance, taking into account factors such as availability, quality, and management responsiveness, which directly influence overall user satisfaction (Timilsena, 2024).

In this context, customer service has gained importance within organizations and is now viewed as a channel for implementing techniques to build customer loyalty. You should offer a benefit or a perk—one that builds relationships—that will attract, convert, build loyalty, and retain customers for the business.

In this context, customer service has come to be seen as a strategic channel for implementing customer loyalty strategies by building lasting relationships. The increasingly competitive market requires organizations to offer unique advantages that go beyond simply providing products, with customer service being a key factor in justifying the choice of a particular company.

Dissatisfaction with the services provided can have serious consequences, such as an increase in complaints and a loss of public trust. Investigating customer service practices and their impact is essential for identifying gaps and opportunities for improvement. Customer dissatisfaction negatively influences future consumption behavior and can result in lost revenue and damage to the organization's reputation (Lu, Chang & Zhou, 2025).

The relevance of this study stems from the fact that efficient and customer-centered service can contribute significantly to the growth of Água da Região do Norte–Nampula by fostering customer loyalty, reducing dissatisfaction, and strengthening acceptance of the services provided. Thus, this study is relevant in analyzing the importance of customer service as a factor in business growth, taking into account the specific circumstances of Água da Região do Norte – Nampula, and seeking to contribute to strengthening the relationship between the company and its customers, as well as to organizational sustainability and development.

Customer Service

Customer service refers to an organization's ability to identify and meet customer needs through an appropriate range of products and services, combined with clear, respectful, and efficient communication. This is an institutional responsibility that is reflected in the way the organization interacts with its customers at all touchpoints (Kotler & Keller, 2022).

The customer service process requires attention, active listening, and proper handling of requests, and is a key factor in perceived satisfaction. A customer feels satisfied when the performance of the service received meets or exceeds their initial expectations (Zeithaml, Bitner & Gremler, 2023).

Customer service is essential to the survival of organizations, since failures in this process create opportunities for competitors. The quality of customer service shapes the public's perception of the company, so it is essential to avoid mistakes that undermine trust and customer loyalty. Satisfied customers tend to become brand advocates, strengthening the institutional relationship.

Customers

A customer is an individual or organization that purchases products or services in exchange for value and is the primary focus of organizational strategy (Kotler & Keller, 2022). The customer is at the heart of our business philosophy, as they are the foundation of sustainability and organizational success.

To serve customers properly, professionals must know how to listen, understand their needs, and offer appropriate solutions. Organizations that have a deep understanding of their customers are able to develop products and services that meet their expectations, thereby increasing their share of the market and fostering long-lasting relationships (Zonone, 2010).

Customer loyalty depends, above all, on the quality of customer service provided. A customer who receives good service is more likely to remain loyal to the organization and less likely to seek out other suppliers.

Customer Service

Customer service is based on the ability to make each customer feel valued by building empathy and trust. Customer service representatives play a strategic role, as they represent the organization in direct contact with customers and are responsible for conveying credibility and professionalism (Kotler, Kartajaya & Setiawan, 2021).

The relationship between customers and organizations is essential in today's business environment, requiring ongoing efforts to attract, retain, and create value for customers. Satisfaction is directly related to service performance compared to consumer expectations, making customer relationship management a fundamental process for building long-term relationships.

Excellence in customer service depends on organizational commitment, employee training, and the existence of appropriate systems and procedures that promote service quality (Bee, 2000).

Business Growth

Business growth refers to the process by which an organization increases its ability to generate revenue, expand its operations, and increase its market share (Kotler & Keller, 2022). This growth can be achieved through innovation, the expansion of services, and continuous adaptation to customer needs.

Innovation is a key driver of organizational growth, enabling companies to stand out in the market and expand their competitive advantage. Understanding customer needs and continuously adapting products and services is essential for driving business growth (OECD, 2023).

Customer service is a critical step in an organizational relationship; it can either undermine or enhance the investments made in product, pricing, and marketing. Thus, customer service is not merely a differentiation strategy, but a necessary condition for the survival of organizations.

The Relationship Between Customer Service and Business Growth

Customer satisfaction is essential to organizational performance, as sales success depends both on attracting new customers and retaining existing ones (Kotler & Keller, 2022). Customer service must be aligned with organizational goals, ensuring quality, trust, and credibility.

Dissatisfied customers tend to leave the organization, reducing sales and jeopardizing business growth. On the other hand, quality customer service creates competitive advantages and contributes to organizational success.

Satisfaction

Customer satisfaction results from the assessment of perceived value, which combines tangible and intangible elements of the service. It is an essential factor for the organization's continued presence in the market, requiring an understanding of customers' expectations and needs (Zeithaml, Bitner & Gremler, 2023).

Satisfied customers tend to maintain their relationship with the organization and recommend it to other consumers. Implementing ongoing customer satisfaction assessment mechanisms makes it possible to turn complaints into opportunities for improvement.

Customer satisfaction is crucial to organizational success, and excellent customer service provides a competitive advantage over the competition. To this end, companies must establish systematic customer satisfaction survey programs and respond effectively to complaints.

General Objective

Analyze customer service as a factor in the growth of the Northern Region Water Company–Nampula.

Specific Objectives

- Identify the customer service channels at Água da Região do Norte–Nampula;
- Describe the current service models in place for Água da Região do Norte–Nampula;
- Identify and propose ways to link customer service with customer satisfaction at Água da Região do Norte–Nampula.

Methods

Description of the Research Site

The study will be conducted by Água da Região do Norte–Nampula (AdRN), a public company committed to providing high-quality drinking water to the population of northern Mozambique. As a company dedicated to providing high-quality, reliable service that is accessible to the public and committed to sustainable development, Água da Região Norte–Nampula ensures a continuous supply of drinking water in the city of Nampula, contributing to the well-being of communities and the preservation of water resources.

Drawing

In conducting this study, the approach—that is, the method chosen—was qualitative research, since this method guides research procedures for subjects that

require non-numerical descriptions and analyses of a given phenomenon. . The qualitative approach allows for the analysis of the meanings, perceptions, attitudes, and behaviors of the subjects involved in the phenomenon under study (Lakatos & Marconi, 2017).

Qualitative research focuses on interpreting deeper aspects of social reality, describing the complexity of human behavior, and providing detailed analyses of practices, habits, attitudes, and trends (Minayo, 2014). Furthermore, this type of research is characterized by the flexibility of its design, allowing the research questions to be adjusted throughout the data collection and analysis process, based on the empirical evidence found (Malhotra, 2019).

Participants

Research participants are individuals who provide information relevant to the study and are considered active participants in the research process (Caetano, 2020). The study included 15 participants, 5 of whom are AdRN customer service representatives and 10 of whom are the company's customers.

Participants were selected using non-probability, purposive sampling, based on the subjects' relevance to the research objectives and their direct experience with customer service at AdRN (Gil, 2019).

Data Collection Techniques

Data collection for this study was conducted using semi-structured interviews, questionnaires, non-participant observation, and document analysis. These techniques are widely recognized in qualitative research for enabling a deeper understanding of the phenomena under study, as well as for allowing for the triangulation of information, which strengthens the validity of the results. The choice of these techniques is justified by the fact that they allow for greater flexibility in gathering information, enabling the researcher to explore in greater depth the meanings that participants attribute to the phenomenon under study (Lakatos & Marconi, 2017).

Technical Procedures

With regard to technical procedures, this research is structured as a case study, as the aim is to conduct an in-depth, detailed, and contextualized analysis of customer service as a factor in business growth at AdRN, in the city of Nampula.

The case study allows for a holistic understanding of the reality under investigation, taking into account its multiple dimensions and relationships; it is particularly well-suited for investigating contemporary phenomena within real-world contexts (Yin, 2015).

According to Pradanov and Freitas (2013), the case study is based on the practical application of scientific knowledge to a specific reality, contributing both to an understanding of the phenomenon and to theoretical development.

Data Analysis

Data analysis is one of the most important stages of research, as it is through this process that results are organized, interpreted, and presented, thereby enabling the study's conclusions to be drawn (Lakatos & Marconi, 2017).

To analyze the collected data, a combination of techniques was used, allowing for the triangulation of information from different primary and secondary data sources. Consequently, we relied on document analysis and content analysis.

Document analysis was used to examine financial reports, regulatory documents, administrative records, and other institutional documents relevant to the study. Content analysis, on the other hand, enabled the systematic coding, categorization, and interpretation of textual data, identifying relevant themes, patterns, and meanings (Bardin, 2016).

The content analysis technique was also applied to the data from the semistructured interviews, providing insight into the different perceptions, challenges, and opportunities related to customer service at AdRN.

Result

1st question: Frequency of service use

Table 1

Describes the frequency of use of AdRN's services

Use of AdRN Services	Percentage
Every day	30%
Weekly	40
Monthly	20%
Rarely	10%

The prevalence of weekly (40%) and daily (30%) use indicates that a significant portion of customers consider AdRN's services essential to their daily routines. This suggests that the company offers a service that is perceived as necessary, especially in a sector as essential as water supply. According to the study by Kotler and Keller (2016), frequency of use is an important indicator of customer loyalty, and frequent use can lead to increased loyalty.

The 20% monthly usage rate may indicate that, while some customers rely on AdRN's services regularly, others may not need them as often. This may be due to factors such as different consumption patterns or places of residence. AdRN should investigate the reasons behind this less frequent use, which may include alternative supply options or dissatisfaction with the service.

With 10% of respondents indicating that they use the services rarely, it is important to understand who these customers are and why their usage is low. According to a McKinsey study (2017), customers who use services only occasionally may represent a growth opportunity if the company identifies and addresses their specific needs. This analysis can help AdRN develop strategies to increase the frequency of use among these customers.

The frequency of use can directly impact marketing and customer service strategies. As Solomon (2018) noted, understanding consumption patterns can help companies tailor their offerings and communications. For customers who use the services daily or weekly, AdRN can implement loyalty programs or incentives, while for those who use them rarely, the company can develop re-engagement campaigns or specific promotions.

2nd question: Service Method**Table 2***It illustrates the workflow for using customer service methods at AdRN*

<i>Methods</i>	<i>Percentages</i>
In-person	30%
Telephone	25%
Online	35%
Apps	10%

The highest percentage of customers using online customer service (35%) indicates a growing trend toward digital solutions. This is consistent with what Deloitte (2020) states about digitization, which has become a key factor in the consumer experience. AdRN should, therefore, invest in improving its digital platforms, ensuring that they are intuitive and effective in meeting customer needs.

Although online customer service is the most widely used, in-person customer service still accounts for a significant share (30%). This suggests that many customers value face-to-face interaction, which can provide a level of trust and clarity on issues they consider important. As the Harvard Business Review (2017) points out, personal interaction can be key to building relationships and brand loyalty.

The use of telephone support (25%) is also significant, indicating that many customers prefer a more traditional form of communication that offers the opportunity for direct interaction. The preference for phone support may be related to the desire for quick answers and immediate solutions. This is consistent with a 2018 PwC study, which suggests that consumers still value human interaction.

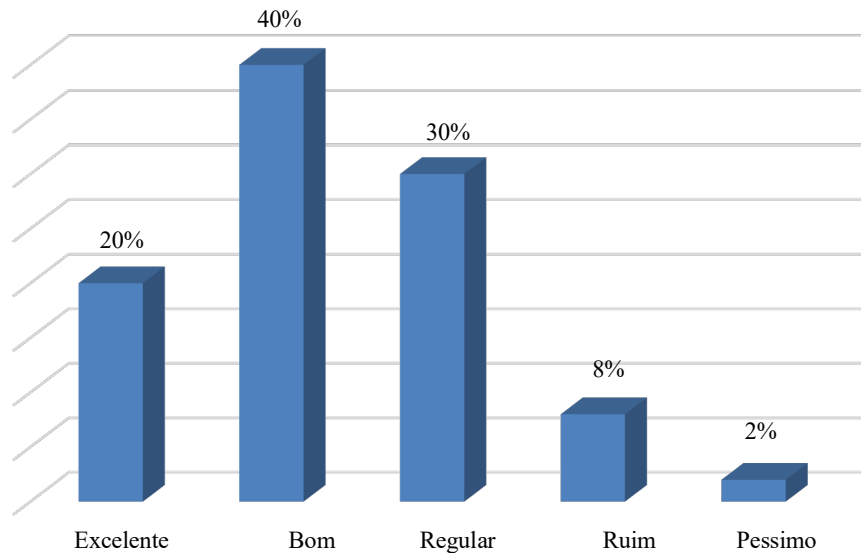
The use of customer service apps (10%) is the lowest among the methods listed. This may indicate a lower level of familiarity with or acceptance of app platforms, or it may suggest that AdRN still has room to develop its digital offerings in this channel. Nielsen (2019) points out that the user experience in apps must be optimized in order for them to become a viable and attractive option for customers.

With a diverse range of service methods, AdRN should consider a multifaceted approach that caters to the preferences of different customer groups. According to Solomon (2018), a customer service strategy that recognizes and values customer preferences can increase satisfaction and loyalty. The company can implement improvements to its online customer service channels and apps, while maintaining and enhancing the effectiveness of in-person and telephone customer service.

3rd question: Quality of service

Figure 1

It illustrates opinions regarding the quality of service provided by AdRN



The combined percentage of "Excellent" (20%) and "Good" (40%) ratings totals 60%, indicating that most customers consider the service to be satisfactory or better. This positive perception is crucial, as satisfied customers are more likely to become loyal to the brand and recommend it to others, as noted by Kotler and Keller (2016). AdRN should continue to strengthen the practices that lead to these positive results.

A significant portion of the respondents (30%) rated the service as "Fair." This suggests that, although there is satisfaction, there is considerable room for improvement. According to an Accenture survey (2016), customers who rate the service as average often feel dissatisfied with specific aspects, which can lead to a loss of loyalty if these issues are not addressed. AdRN should investigate the reasons behind this assessment and implement changes.

The negative reviews, which account for 10% (8% "Bad" and 2% "Terrible"), are a warning sign. Customers who rate customer service as poor or terrible may have had frustrating experiences that affect their perception of the brand. According to Solomon (2018), a customer's negative experience can be amplified on social media, leading to repercussions for the company's image. AdRN should monitor these situations and take steps to resolve complaints effectively and proactively.

AdRN should use this data as the basis for corrective actions. Customer feedback should be collected on an ongoing basis to identify areas for improvement, as suggested by McKinsey (2017). Implementing an effective feedback system can help you better understand your customers' needs and concerns, enabling a more responsive and accurate response.

4th question: Speed and Efficiency of Service**Table 3***Describes the speed and efficiency of customer service at AdRN*

Speed and Efficiency	Percentages
Always	25%
Most of the time	35%
Sometimes	25%
Rarely	10%
Never	5%

The combined total of the responses "Always" (25%) and "Most of the time" (35%) is 60%. This indicates that a substantial portion of customers recognize that the quality of customer service has a positive impact on their decision to continue using AdRN's services. This correlation is supported by studies showing that good customer service can be a crucial factor in building customer loyalty (Kotler & Keller, 2016).

The "Sometimes" responses (25%) are also significant, as they indicate that a considerable portion of customers may be influenced by factors other than customer service, such as price or service quality. This suggests that AdRN should continue to strive to improve its service, but also consider other factors that may influence customers' decisions.

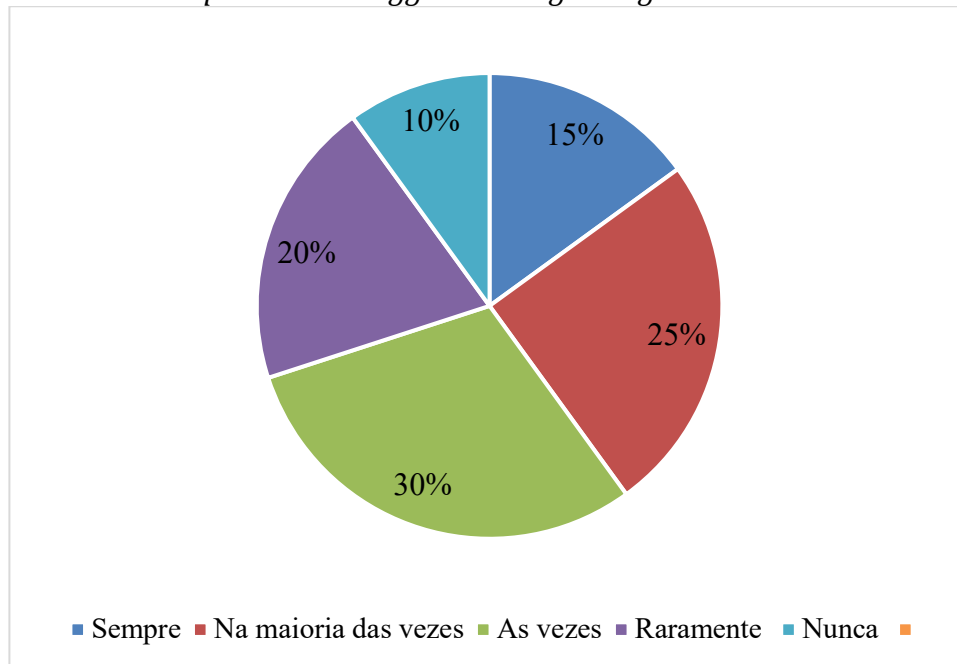
With only 10% of respondents stating that customer service is "rarely" influential and 5% stating "never," the data shows that most customers see some value in customer service. However, the fact that 15% of customers feel that customer service has little or no influence is a warning sign. This may indicate areas where AdRN can still improve or where perceptions of the service do not match reality.

AdRN should focus on maintaining and improving the high standards of service that are already recognized by a significant portion of its customers. Investing in employee training and customer service processes can have a positive impact on customer satisfaction and loyalty. In addition, the company should seek to better understand the factors that influence the 25% who answer "Sometimes" in order to tailor its offering more effectively.

5th question: Complaints or Suggestions

Figure 2

Describes customer complaints and suggestions regarding customer service at AdRN



The combined total of the responses “Always” (15%) and “Most of the time” (25%) comes to 40%, indicating that a significant number of customers believe their complaints and suggestions are, in fact, being heard. This recognition is essential, as the perception that the customer’s voice is valued can increase customer loyalty and satisfaction (Solomon, 2018).

The response “Sometimes” (30%) suggests that there is a considerable group of customers who feel that their concerns are acknowledged, but perhaps not as often as they would like. This points to an opportunity for AdRN to implement more robust customer service and feedback processes. The Accenture study (2016) highlights that companies that actively respond to feedback tend to have more engaged customers.

The combined total of the responses “Rarely” (20%) and “Never” (10%)—which amounts to 30%—is a cause for concern. This means that a significant number of customers do not feel that their complaints or suggestions are being handled properly. This lack of communication can lead to dissatisfaction and a decline in trust in the brand. As noted by McKinsey (2017), a lack of response can result in a negative perception of the service, leading to potential criticism or the loss of customers.

AdRN should consider implementing a more effective feedback system, ensuring that all complaints and suggestions are recorded, reviewed, and, whenever possible, addressed. Ongoing training for the team in communication and problem-solving can help foster a culture of active listening and responsiveness.

6th question: Overall satisfaction with AdRN's services**Table 4***Measures overall satisfaction with AdRN's services*

Very satisfied	15%
Satisfied	45%
Neutral	25%
Dissatisfied	10%
Very dissatisfied	5%

The combined percentage of "Very satisfied" (15%) and "Satisfied" (45%) responses totals 60%. This result indicates that a majority of customers view AdRN's services positively. Customer satisfaction is a critical factor for customer loyalty and business growth, as highlighted by Kotler and Keller (2016), who note that satisfied customers tend to be more loyal and to promote the brand.

The "Neutral" rating (25%) represents a significant portion of customers who do not express a clear opinion about their satisfaction. This may suggest that these customers are dissatisfied with certain aspects of the service, but have not yet reached a level of dissatisfaction high enough to classify them as "dissatisfied." According to Accenture (2016), neutral customers may be vulnerable to competition because they are not necessarily engaged. AdRN should investigate the reasons behind this neutrality in order to improve the customer experience.

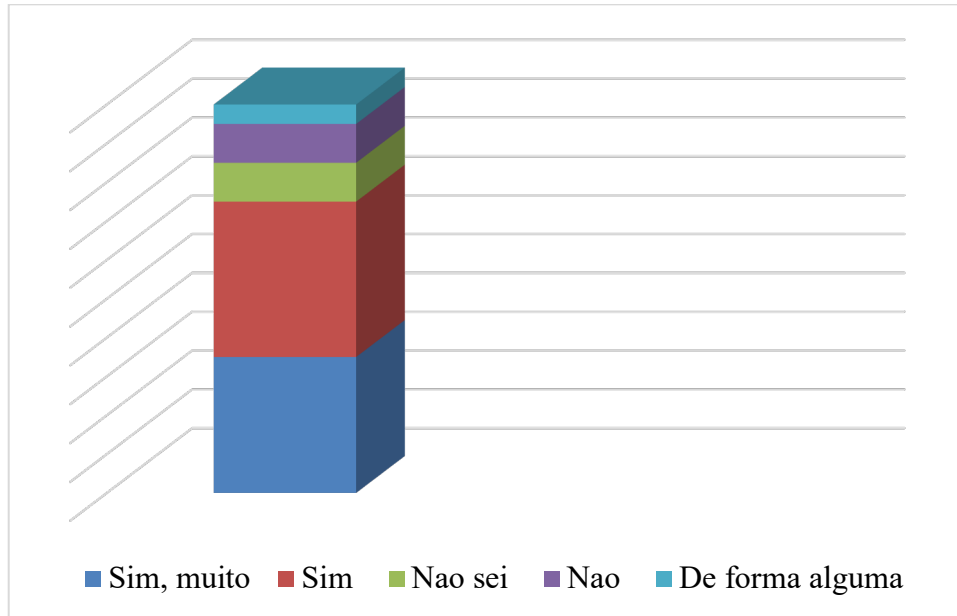
The "Dissatisfied" (10%) and "Very dissatisfied" (5%) ratings total 15%. Although this percentage is smaller, it is significant and must be addressed urgently. The presence of dissatisfied customers can negatively impact a company's reputation, as noted by Solomon (2018) and McKinsey (2017). It is essential that AdRN identify and address the causes of dissatisfaction, as reports of negative experiences can spread quickly, especially on social media.

AdRN should use this data to better understand the areas where it can improve. Implementing a feedback system that allows for the collection of additional information about the causes of dissatisfaction and neutrality can be vital to the continuous improvement of services. In addition, loyalty programs and active communication with customers can help turn neutral customers into satisfied ones.

7th question: The Influence of Customer Service on the Decision to Continue Using the Services

Figure 3

Describes the influence of customer service on the decision to continue using AdRN's services



The combined total of the responses "Yes, very much" (35%) and "Yes" (40%) is 75%. This indicates that a large majority of customers recognize that the quality of customer service has a positive impact on their decision to continue using AdRN's services. This insight reinforces the idea that good customer service is a critical factor in building customer loyalty, as noted by Kotler & Keller (2016).

The "I don't know" response (10%) suggests that some customers may be unsure about the impact of customer service on their decision. This uncertainty may be a sign that these customers are not having a clear or impactful enough experience, which may prevent them from forming a definite opinion. According to Accenture (2016), a lack of clarity in the customer experience can lead to a decline in engagement.

The responses "No" (10%) and "Not at all" (5%) total 15%, indicating that a minority of customers do not consider customer service to be a relevant factor in their decision to remain with AdRN. The presence of customers who feel that customer service does not influence their decision may suggest that they are already dissatisfied or that they are looking for other factors, such as price or service quality. The company should investigate these opinions to identify potential areas of dissatisfaction.

AdRN should focus on further strengthening its customer service, since most customers view its influence as crucial to building customer loyalty. Implementing a regular feedback system can help the company better understand its customers' needs and expectations, allowing it to adjust its strategies. For those who do not view customer service as an important factor, AdRN can explore other elements that influence satisfaction and loyalty, such as competitive pricing or service innovation.

8th question: I would recommend AdRN's services to others**Table 5***Represents the level of recommendation for AdRN services*

Definitely	30%
Probably	40%
Maybe	20%
Probably not	5%
Not at all	5%

The combined total of the responses "Definitely" (30%) and "Probably" (40%) is 70%. This suggests that a large proportion of customers are willing to recommend AdRN's services, which is a strong indicator of satisfaction and loyalty. Studies such as those by Kotler and Keller (2016) show that recommendations are one of the best indicators of service quality and customer experience, reflecting the trust customers have in the brand.

The "Maybe" response (20%) represents a group of customers who are not entirely convinced by the recommendation, suggesting that, although they are satisfied, they may have some reservations. This uncertainty may stem from varied experiences or from expectations that have not been fully met. According to an Accenture survey (2016), customers who do not feel fully engaged may be open to alternatives, which poses a potential risk to AdRN.

The combined total of the responses "Probably not" (5%) and "Not at all" (5%) amounts to only 10%. This low percentage suggests that most customers do not have a strongly negative opinion of AdRN's services. However, it is important for the company to investigate the reasons why these customers would not recommend its services, since even a small fraction of dissatisfied customers can negatively impact the brand's reputation, especially in a world where word of mouth and online reviews are increasingly influential.

AdRN should focus on strengthening the areas that are already leading to a high recommendation rate and addressing the concerns of customers who express uncertainty. Implementing loyalty programs and soliciting ongoing feedback can help identify and resolve issues that could affect customers' willingness to recommend the company.

Discussions

1st question: Position and Responsibilities

Answer: I am the Director of Operations at AdRN. My main responsibilities include overseeing daily operations, implementing customer service policies, ensuring the quality of the services provided, and leading the team in the pursuit of continuous improvement.

The fact that the interviewee is the Director of Operations indicates a leadership position that shapes the quality of customer service. This responsibility suggests that he is directly involved in defining policies and strategies, reflecting the importance the company places on the customer experience. According to Kotler and Keller (2016),

leadership plays a vital role in defining a company's service culture, suggesting that effective management is essential to shaping the customer experience.

2nd question: Experience at the company

Answer: I've been working at AdRN for seven years. My experience has been very rewarding; I've seen the company grow and improve, but I've also faced significant challenges, especially during periods of high demand.

In this case, seven years of experience suggests a deep understanding of the inner workings of AdRN. The mention of challenges and growth reflects a journey of learning and adaptation, which may indicate an organizational culture that values progress and resilience. According to Senge (2006), "organizational learning intensifies with experience," suggesting that long-tenured employees can contribute significantly to continuous improvement.

3rd question: Quality of service

Answer: I rate the quality of service as good, but there is room for improvement. We have a dedicated team, but there are times when the workload can affect the quality of our service.

Rating the quality of service as "good, but with room for improvement" reflects a realistic view of the situation. This suggests that, while the team's efforts are recognized, there is also an awareness of the areas that need attention, reflecting a commitment to continuous improvement. The "SER-QUAL" service quality model, developed by Parasuraman, Zeithaml, and Barry (1988), suggests that the perception of quality can be improved by identifying gaps between expectations and actual service delivery.

4th question: Challenges in Customer Service

Answer: The main challenges include managing customer expectations, dealing with pressure during peak periods, and the need for quick solutions to complex problems. In addition, effective communication among the team is crucial.

Identifying challenges such as managing expectations and communication demonstrates a critical awareness of the customer service environment. As Zeithaml and Bitner (2016) state, "Effective management of customer expectations is essential to preventing dissatisfaction," highlighting the importance of clear communication.

5th question: Service Methods

Answer: I believe that in-person and online consultations are the most effective. In-person service allows for a more personal interaction, while online service offers convenience. Telephone support, while useful, often results in long wait times.

The preference for in-person and online service reflects an understanding of customers' needs for convenience and personalization. Recognizing the limitations of phone support suggests an opportunity for the company to innovate in its customer service channels. The McKinsey study (2017) emphasizes that "the customer experience is enhanced when a variety of service channels are offered," corroborating the interviewee's view.

6th question: Customer Service Processes That Can Be Improved

Answer: Yes, I believe the phone support process could be improved. Implementing a more efficient triage system would help reduce wait times and direct customers to the most appropriate staff members.

The suggestion to optimize telephone customer service reflects a proactive approach to improving efficiency. Screening can improve the customer experience, highlighting the importance of call flow management and prioritizing needs. According to Blazevic and Lievens (2008), "operational efficiency in customer service can lead to greater customer satisfaction," suggesting that process improvements can have a positive impact.

7th question: Training and Development

Answer: I received initial training on customer service policies and conflict resolution. However, the training was limited to a single session, which could be improved through ongoing training.

Criticism of the inadequacy of training points to a gap in the ongoing professional development of employees. A lack of regular training can affect the quality of service, indicating that the company should invest more in professional development. According to Brinkerhoff (2003), regular training is crucial for retaining knowledge and improving skills, which can be essential to the effectiveness of customer service.

8th question: Receiving and Handling Feedback

Answer: We receive feedback from customers on a regular basis, mainly through satisfaction surveys. This feedback is reviewed monthly during meetings, but I feel we could act more quickly in the areas that need attention.

The frequency of customer feedback suggests that AdRN is attentive to users' opinions. However, the perception that the team could act more quickly reveals a possible disconnect between gathering feedback and implementing improvements, which could impact customer satisfaction. According to McKinsey (2016), "customer feedback should be a driver of continuous improvement," emphasizing the importance of swift and targeted actions based on customer feedback.

9th question: The Relationship Between Customer Service and Growth

Answer: I believe there is a strong correlation. Good customer service not only builds loyalty among existing customers but also attracts new ones. Satisfied customers tend to recommend AdRN, which is essential to our growth.

The belief in the correlation between quality service and company growth reflects a strategic understanding of the importance of the customer experience. This is consistent with marketing theories that argue that customer satisfaction is essential for building customer loyalty and expanding the customer base. Oliver's (1999) theory of customer satisfaction argues that high satisfaction leads to loyalty, which is essential for the sustainable growth of companies.

10th question: Organizational Culture

Answer: AdRN's organizational culture regarding customer service is focused on enhancing the customer experience, but it is still evolving. There is a clear understanding of the importance of quality service, and the team is committed to providing service that meets customers' expectations.

The description of the organizational culture indicates a recognition of the value of customer service, but it also suggests that there is still room for improvement. The transition to a customer-centric mindset requires deliberate efforts to integrate this vision at all levels of the organization. According to Heskett et al. (1994), "organizational

culture is a key determinant of service quality," indicating that cultural changes are necessary to achieve excellence in customer service.

11th question: Inspiring Practices from Other Companies

Answer: Yes, companies that use real-time feedback platforms, such as chatbots for initial customer service, are inspiring. In addition, some companies implement recognition programs for employees who excel in customer service, which could be a best practice for us.

The mention of practices used by other companies, such as chatbots and recognition software, indicates a willingness to embrace innovation. This suggests that the interviewee is aware of market trends and believes in the importance of learning from others to improve AdRN's performance. According to Christensen (2003), "innovation is vital to the survival and growth of companies," which suggests that AdRN could benefit from adopting successful practices from other organizations.

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DIGITIZATION, SUSTAINABILITY, AND COST-EFFECTIVENESS IN EUROPEAN UNIVERSITY BUSINESS EDUCATION: THE START DSP PROJECT

DIGITALIZACIÓN, SOSTENIBILIDAD Y RENTABILIDAD EN LA EDUCACIÓN EMPRESARIAL UNIVERSITARIA EUROPEA: EL PROYECTO START DSP

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RESUMEN

Keywords:

sustainability, digitization, profitability, entrepreneurship

This research aims to know the level of use and application of the concepts of sustainability, digitalization and profitability as a triad - according to the principles of the European Union- for the development of business plans in the entrepreneurship professorship of different universities and countries, specifically by educators from Germany, Spain, Greece and Ireland. This study was carried out within the framework of the European START DSP project, funded by the European Union. The ultimate goal of this project is to develop a training platform for the acquisition of competencies in the field of entrepreneurship in relation to sustainability, digitalization and profitability, which is fully congruent with the existing and analyzed literature on the subject. The methodology used was qualitative, and the data were collected using an interview guide validated by expert criteria. Inclusion and exclusion criteria were applied to select only those educators who have real contact with real entrepreneurship and in academia. Among the main results of the research, it can be summarized that educators give more emphasis to the issue of sustainability than to that of digitalization because, the latter is something that is interpreted as a logical consequence of the growth of a business, therefore, the concept of profitability is something that is taken for granted because, in itself, it is the objective of any company in the capitalist system, but the difficulty is to develop ideas and business models that achieve the triad sustainability-digitization-profitability.

RESUMEN

Palabras clave:

sostenibilidad, digitalización, rentabilidad, espíritu empresarial

Esta investigación pretende conocer el nivel de uso y aplicación de los conceptos de sostenibilidad, digitalización y rentabilidad como tríada - según los principios de la Unión Europea- para el desarrollo de planes de empresa en la cátedra de emprendimiento de diferentes universidades y países, concretamente por educadores de Alemania, España, Grecia e Irlanda. Este estudio se ha realizado en el marco del proyecto europeo START DSP, financiado por la Unión Europea. El objetivo último de este

proyecto es desarrollar una plataforma formativa para la adquisición de competencias en el ámbito del emprendimiento en relación con la sostenibilidad, la digitalización y la rentabilidad, que sea plenamente congruente con la literatura existente y analizada sobre el tema. La metodología empleada ha sido cualitativa y la recogida de datos se ha realizado mediante una guía de entrevista validada por criterios de expertos. Se aplicaron criterios de inclusión y exclusión para seleccionar sólo a aquellos educadores que tienen contacto real con el emprendimiento real y en el ámbito académico. Entre los principales resultados de la investigación, se puede resumir que los educadores dan más énfasis al tema de la sostenibilidad que al de la digitalización porque, este último es algo que se interpreta como una consecuencia lógica del crecimiento de un negocio, por lo tanto, el concepto de rentabilidad es algo que se da por sentado porque, en sí, es el objetivo de cualquier empresa del sistema capitalista, pero la dificultad es desarrollar ideas y modelos de negocio que logren la tríada sostenibilidad-digitalización-rentabilidad.

Introducción

European higher education faces several significant challenges related to entrepreneurship, particularly in its promotion. These challenges are compounded by a rapidly evolving labor market, ongoing digital transformation, increasingly specific customer demands, and the need to comply with legislation; above all, they involve guiding the European business ecosystem toward a vision that embraces sustainability, digitization, and profitability simultaneously.

In response to these challenges, the European project Start DSP was initiated to enhance the effectiveness of entrepreneurship education in higher education institutions. By offering innovative teaching materials and emphasizing digital, sustainable, and ethical business practices, the project seeks to better equip educators and, in turn, empower students to tackle contemporary global challenges through entrepreneurship. During its diagnostic phase, the Start DSP project will assess how well the concepts of digitization, sustainability, and profitability are integrated into business plans—the primary outputs of entrepreneurship courses—in order to develop a platform that reinforces these ideas and improves the quality of business proposals.

Business plans have changed over time. Historically, equal emphasis was placed on the details of every section—strategic, operational, administrative, financial, and marketing. Over the years, this approach has evolved toward more concise and streamlined documents, acknowledging that numerous variables and factors can alter the original plans once a business is launched. This evolution has led to the development of models that are as succinct and strategic as the CANVAS framework. However, it is concerning that in university business education, beyond the natural evolution of business proposal models, insufficient emphasis is placed on treating digitization, sustainability, and profitability as an integrated triad. Instead, these concepts are often addressed as isolated elements, with sustainability and digitization sometimes being misapplied.

Therefore, this research examines how educators in European universities use and apply the concepts of digitization, sustainability, and profitability in business education. Initially, the research will assess educators' familiarity with these concepts in their teaching practices, followed by an evaluation of how these concepts are applied in the business models of their students.

In today's world, business digitization has become imperative, fundamentally transforming how organizations operate and compete. The benefits of digitization include increased efficiency, improved customer experiences, enhanced competitiveness, reduced costs, and greater adaptability.

Conversely, prioritizing sustainability in companies is no longer just a trend—it is an essential requirement. Organizations that emphasize sustainability contribute to a more sustainable future while also reaping several competitive benefits. Sustainability is associated with critical factors such as enhanced reputation, cost reduction, innovation, talent attraction and retention, regulatory compliance, resilience, and access to new markets.

Profitability is the engine that drives the growth and survival of any company. It results from efficient management, resource optimization, and the ability to generate revenue that exceeds costs. Profitability is directly linked to survival, growth, attracting investment, financial stability, debt repayment, company valuation, and social responsibility.

According to the news portal Euronews, the more than 32 million companies in the European Union—which form the complete business fabric and are the project’s target audience—have an opportunity to enhance their sustainability, digitization, or profitability processes, especially small and medium-sized enterprises. Although the project is funded by the European Union for European companies, its potential application may extend to companies located outside Europe.

The medium-term repercussions of not implementing this project relate to two critical aspects that must be highlighted. The first aspect involves environmental care and sustainable economic development, focusing on managing resources for future generations. The second aspect concerns helping companies achieve competitiveness through digitization and a dedicated focus on profitability. Both aspects align with the strategic objectives set by the European Union.

The study’s feasibility is based on the assumption that, using the resources granted for the StartDSP project, a survey was developed to collect information on how professors in entrepreneurship courses use the concepts of sustainability, profitability, and digitization.

Literature Review

Existing literature suggests that sustainability—defined as the responsible management of production and resources—is a widely discussed topic in business start-up education, alongside business digitalization, a relatively new term driven by disruptive technologies, and profitability, a cornerstone guiding strategic decisions. The integration of these three concepts forms an ideal triad that should be achieved, rather than treating each as an isolated factor without social significance.

In principle, incorporating sustainability into higher education is radically transforming how new businesses are conceptualized. Universities are increasingly training conscious entrepreneurs committed to building a more sustainable future (Enri-Peiró et al., 2024). Today’s graduates are tomorrow’s leaders. According to Arias-Valle (2024), by incorporating sustainability into the curriculum, universities are equipping students to tackle global challenges and create businesses that positively impact society and the environment. Conversely, Arrollo et al. (2023) argue that sustainability demands a multidisciplinary approach encompassing environmental, social, and economic aspects. Studying sustainability helps students develop essential skills such as critical thinking, problem-solving, creativity, and collaboration, which are crucial for entrepreneurial success. Similarly, Martínez-Martínez et al. (2024) note that companies increasingly value professionals with sustainability expertise because such insight influences business decisions at all levels and offers a competitive advantage as well as training efficiencies. Entrepreneurs who incorporate sustainable practices into their businesses are more likely to attract socially conscious investors and consumers. Likewise, Herce Lezeta (2024) states that sustainability fosters innovation by challenging entrepreneurs to find creative solutions to environmental and social problems. This can lead to the development of new products, services, and business models. Finally, de Oliveira Santos (2024) identifies four fields of application for sustainability in business creation: integration in curricula, business incubators and accelerators, research projects, and partnerships with companies. In short, sustainability has become a fundamental pillar of higher education, driving the emergence of a new kind of entrepreneur—one who combines a passion for business success with a commitment to building a more

sustainable future. By integrating sustainability into the curriculum, universities are preparing students to lead the transition toward a greener and more equitable economy.

Conversely, the inclusion of digitization in European education is relatively novel compared to sustainability, due to its recent emergence and rapid evolution. Existing literature indicates that digitization has revolutionized all sectors, including higher education. Its impact on business creation is increasingly evident, as it equips students with the tools and knowledge needed to succeed in an increasingly connected world. Digitalization is transforming higher education and creating an environment that encourages the emergence of new businesses. By providing students with the tools and knowledge required for entrepreneurship in a digital world, universities are fostering innovation and economic development. In this regard, Ndour & Alexandre (2020) emphasize that digitization in higher education for entrepreneurship is essential because it provides access to information and resources, develops digital skills, promotes personalized learning, encourages collaboration and networking, and simulates real-life scenarios. According to Medfouni et al. (2024), digitization is applied through online courses and programs, learning platforms, digital incubators and accelerators, hackathons and competitions, and virtual communities.

Profitability, unlike the other two concepts, has been inherent since the establishment of the capitalist system with private sector companies, and its teaching in higher education serves as the guiding maxim for all undertakings. In isolation, the concept of profitability does not differ from what common sense already indicates. The challenge lies in achieving profitability while complying with sustainability and digitalization standards as outlined by the European Union. Enri-Peiró et al. (2024) assert that the integration of profitability, sustainability, and digitalization in higher education is creating a new paradigm for business creation. Each concept individually drives transformation, but their combined synergy is leading to more resilient, innovative business models that are aligned with global challenges. Marín-García et al. (2023) explain that the pursuit of long-term profitability compels companies to adopt sustainable practices, which in turn generate cost savings, enhance reputation, and attract socially conscious investors. Similarly, digitalization optimizes processes, reduces resource consumption, improves efficiency, and expands market reach, thereby translating into higher profitability and a reduced environmental impact. Universities have the power to train entrepreneurs who merge the pursuit of profitability with a commitment to sustainability and digital innovation (Solaja et al., 2025).

Method

The methodology is qualitative, following the paradigm and assumptions established by Jiménez Mora et al. (2023), and is used to interpret responses and capture results. In-depth interviews were conducted with educators using open and exploratory questions designed to collect information without presupposed answers (Ignacio Berredy & Fernández Guillermet, 2024), focusing on their knowledge and use of the concepts of sustainability, digitalization, and profitability in teaching and in their students' enterprise creation. The interviewees were 18 educators from four countries: Germany, Spain, Greece, and Ireland. The results were obtained in the native languages of each country and were later translated into English. The interview guide was validated by expert consensus using a simple Likert scale for each response until all items received a positive score. Informed and signed consent was requested from all participants. The

questionnaires were structured around six topics covering a wide range of business aspects:

- 1) Familiarity of the interviewee,
- 2) Priority areas to focus on,
- 3) Challenges and gaps,
- 4) Good practices,
- 5) Impact on society and the environment,
- 6) Key points of GreenComp.

The interviews were conducted over a period of two months and served as the diagnostic phase of the project. The interviews included open-ended, non-directional, and flexible questions designed to provide a comprehensive view of the study's subject (Jiménez Mora et al., 2023).

The selection method was non-random purposive sampling, guided by specific inclusion and exclusion criteria.

- a) Inclusion criteria:
 - Professors who have previously taught entrepreneurship
 - University professors (from both public and private institutions) with a current contract
 - Professors of any nationality, provided they reside in one of the countries involved in the project
- b) Exclusion criteria
 - Professors without formal business training.
 - Professors lacking positive recognition from the educational community, as evidenced by evaluations or public opinion.

For the overall analysis, responses were first analyzed by country and then categorized by the type of interviewee, acknowledging that some interviews were extensive while others were shorter. Interview transcripts were coded inductively and deductively to identify recurring patterns related to the integration of sustainability, digitalization, and profitability in entrepreneurship education. The analysis followed three stages: open coding, category development, and thematic interpretation.

Results and discussion

The present study used in-depth interviews to explore educators' perceptions regarding the integration of digitization, sustainability, and profitability in university entrepreneurship courses. The findings reveal a complex interrelationship between these concepts, alongside challenges and opportunities for their effective implementation in entrepreneurship training.

All interviews were transcribed and reviewed by two researchers independently. Codes were generated from the interview data and subsequently grouped into broader analytical categories. Discrepancies in coding were discussed until consensus was reached. This process enhanced the credibility and trustworthiness of the findings.

Many educators possess strong academic backgrounds in fields related to business, economics, and entrepreneurship. For instance, one interviewee holds a degree in IT and Economics, while others have earned PhDs in Business Administration, Environmental Science, or Economics. These details indicate that educators share a common academic foundation, particularly in disciplines connected to entrepreneurship. Moreover, the fact that several participants hold PhD degrees underscores the necessity, in some cases, of advanced education across various fields. Bonilla and Gutiérrez (2024)

suggest that a solid theoretical background in business and entrepreneurship is linked to improved learning outcomes in areas such as sustainability and competitiveness.

In addition to academic credentials, practical entrepreneurial experience emerges as an important theme among the educators. For instance, one participant founded his own agency and now applies his entrepreneurial experience in coaching. Another respondent co-owns an IT company. Yet another interviewee has developed personal entrepreneurship projects. These examples illustrate the connection between academic knowledge and real-world entrepreneurial practice. In fact, Vélez Falcones et. al. (2025) indicate that entrepreneurship teachers with real-life business experience tend to be better evaluated than those without such experience. Many respondents have engaged in or led entrepreneurial ventures—whether through personal initiatives, like founding agencies, or through university programs designed to foster startup growth.

Most respondents are involved in teaching entrepreneurship or related subjects. One respondent teaches courses related to IT and entrepreneurship. Another integrates entrepreneurship into courses on digital fluency. A respondent from the University of Halle works on raising entrepreneurial awareness through curricular modules and workshops. This demonstrates a shared commitment to fostering entrepreneurship through both formal curriculum settings and additional programs or workshops. This observation aligns with Vélez Falcones et al. (2025), which highlights a strong correlation between studying technology careers and the propensity to start one's own business.

Lastly, innovation is considered a key point by respondents and is seen as the pinnacle of entrepreneurship. Some educators support innovative research-based start-ups, while others attempt to integrate sustainability into business practices. Innovation and competitiveness are terms that, according to Sobko et. al. (2023) are highly correlated, although innovation is not always profitable in the long term.

The results are organized by analytical categories (Mendoza Ruiz et al., 2024), and the discussion follows the interpretation framework of Jiménez Mora et al. (2023) to highlight and contrast key literature aspects, thereby generating valid conclusions. Interview results are presented in detail and contrasted with available literature to facilitate an in-depth analysis of the responses.

Theme 1. Sustainability as the dominant dimension of entrepreneurship education

The interviews revealed that sustainability occupies a central position in entrepreneurship education across all participating countries. Educators consistently reported incorporating sustainability principles into their teaching through dedicated courses, case studies, project-based learning activities, and the use of international frameworks such as the Sustainable Development Goals (SDGs). Sustainability was not perceived merely as an environmental concern but increasingly as a strategic dimension encompassing social responsibility, ethical business conduct, and long-term value creation.

Several educators described sustainability as a transversal concept integrated into multiple courses rather than a standalone topic. This finding suggests that sustainability has achieved a relatively high level of institutional acceptance within entrepreneurship curricula. Participants emphasized that students are encouraged to consider environmental and social consequences when developing business ideas and business models.

These findings support previous research indicating that higher education institutions are increasingly adopting sustainability as a core educational objective (Arias-Valle et al., 2024; Falcão et al., 2024). The results also reinforce the argument of Arroyo et al. (2023), who maintain that sustainability education requires a

multidisciplinary perspective capable of integrating economic, social, and environmental considerations. In this regard, the participating educators appear to be moving beyond traditional profit-centered entrepreneurship education toward a more holistic understanding of entrepreneurial responsibility.

However, despite the widespread incorporation of sustainability into teaching practices, the interviews also revealed important conceptual limitations. Many participants associated sustainability primarily with environmental protection and resource conservation, while fewer explicitly referred to broader social and governance dimensions. This finding suggests that sustainability remains partially interpreted through a narrow ecological lens, indicating opportunities for a more comprehensive application of the concept in entrepreneurship education.

Theme 2. Digitalization as an implicit rather than strategic competency

Unlike sustainability, digitalization was often perceived by educators as a natural consequence of business development rather than a strategic entrepreneurial competence requiring explicit instruction. While participants frequently reported using digital tools in their teaching activities, digitalization itself was rarely described as a central objective during business model development.

Educators highlighted the extensive use of digital platforms and technologies, including Learning Management Systems, business analytics software, enterprise resource planning systems, prototyping tools, and artificial intelligence applications. These technologies were generally viewed as instruments that facilitate business operations, improve efficiency, and support innovation.

The findings suggest a distinction between technological usage and digital transformation. Participants demonstrated familiarity with digital tools but less emphasis on teaching students how digitalization fundamentally reshapes business models, value propositions, customer relationships, and competitive strategies. Consequently, digitalization appears to be treated more as an operational resource than as a transformative entrepreneurial capability.

This result partially contrasts with the literature on digital entrepreneurship, which positions digital competencies as critical drivers of innovation and competitiveness (Ndour & Alexandre, 2020; Medfouni et al., 2024). While educators recognize the practical importance of technology, the interviews indicate that digital transformation is not always systematically integrated into entrepreneurial thinking.

A possible explanation is that digitalization has become so embedded in contemporary business practices that educators assume students will naturally acquire these competencies. However, such an assumption may create educational gaps, particularly in relation to emerging technologies and digital business innovation. The findings therefore suggest a need to move beyond teaching digital tools toward teaching digital transformation as a strategic process.

Theme 3. Profitability as an assumed outcome rather than a teaching priority

One of the most significant findings of the study concerns educators' treatment of profitability. Across the interviews, profitability was generally regarded as a self-evident objective of entrepreneurship and therefore received less explicit attention than sustainability or digitalization.

Participants frequently described profitability as an inherent characteristic of any viable business venture. Consequently, profitability was often taken for granted during entrepreneurship education, under the assumption that entrepreneurs naturally seek

economic returns. This perspective differs from the treatment of sustainability, which educators considered necessary to teach deliberately and explicitly.

The findings reveal an interesting paradox. Although profitability remains the ultimate objective of most business activities, it is not always approached as a competence requiring systematic development. Instead, educators focus on teaching business planning, innovation, sustainability, and digital tools, expecting profitability to emerge as a consequence of successful implementation.

This observation aligns with Marín-García et al. (2023), who argue that long-term profitability increasingly depends on sustainability and innovation capabilities. However, the interviews suggest that educators rarely frame profitability as the outcome of strategic integration among multiple dimensions. Rather, it is frequently treated as an independent and almost automatic result.

The limited emphasis on profitability may create challenges for students attempting to balance economic viability with environmental and social objectives. Future entrepreneurship education may benefit from explicitly addressing the tensions and synergies among these dimensions rather than assuming that profitability will naturally follow from business success.

Theme 4. The challenge of integrating the sustainability–digitalization–profitability triad

The most important finding emerging from the interviews is that educators do not view sustainability, digitalization, and profitability as separate concepts but recognize the difficulty of integrating them simultaneously within entrepreneurial projects.

Participants consistently acknowledged that achieving balance among these dimensions represents one of the greatest challenges facing contemporary entrepreneurs. While sustainability initiatives may increase costs in the short term, digitalization often requires significant investments in technology and training. Consequently, educators recognize the need for business models capable of reconciling social responsibility, technological innovation, and economic viability.

This challenge reflects broader transformations occurring within the European business ecosystem. Entrepreneurship is no longer evaluated exclusively according to financial performance but increasingly according to its environmental and social contributions. At the same time, organizations must adapt to rapid technological changes to remain competitive.

The findings support the arguments of Enri-Peiró et al. (2024), who propose that sustainability, profitability, and digitalization should be understood as mutually reinforcing dimensions rather than competing objectives. Nevertheless, the interviews indicate that educators still struggle to operationalize this integration within teaching practices and business plan development.

The Start DSP project emerges as a direct response to this challenge. The project seeks to provide educational resources and tools capable of supporting entrepreneurship educators in fostering business proposals that simultaneously address digital transformation, sustainable development, and economic performance.

Theme 5. Educational innovation and the transformation of entrepreneurship teaching

A final theme emerging from the interviews concerns the significant transformation of entrepreneurship education itself. Educators reported extensive use of digital technologies, simulation tools, collaborative platforms, and experiential learning methodologies. Compared with traditional approaches based primarily on lectures and

business plan writing, contemporary entrepreneurship education appears considerably more interactive and technology-driven.

Participants emphasized the importance of real-world projects, internships, industry collaboration, mentoring programs, and interdisciplinary teamwork. These approaches aim to bridge the persistent gap between theoretical knowledge and practical entrepreneurial experience.

The findings suggest that entrepreneurship education is evolving from knowledge transmission toward competence development. This evolution reflects broader educational trends emphasizing experiential learning, problem-solving, innovation, and adaptability. As noted by Schlüter et al. (2024), digital technologies are increasingly becoming essential components of educational innovation.

Nevertheless, educators also identified persistent barriers, including resource limitations, unequal access to technology, difficulties maintaining curricular relevance, and challenges engaging students from non-business disciplines. These obstacles indicate that educational transformation remains an ongoing process requiring institutional support and continuous adaptation.

Integrative discussion

Taken together, the findings reveal an asymmetrical relationship among the three dimensions examined. Sustainability occupies a prominent and explicit role within entrepreneurship education, digitalization is widely practiced but often implicitly understood, and profitability remains largely assumed rather than systematically taught. The principal challenge identified by educators is not understanding these concepts individually but integrating them into coherent entrepreneurial models.

This finding constitutes the study's main contribution. Rather than demonstrating a lack of awareness regarding sustainability, digitalization, or profitability, the results indicate the existence of a pedagogical integration gap. Future entrepreneurship education should therefore move beyond teaching these concepts independently and focus on developing frameworks, methodologies, and learning experiences that enable students to simultaneously achieve sustainability, digital transformation, and economic viability.

Conclusions

The Start DSP project has illuminated the intricate relationship between digitalization, sustainability, and cost-effectiveness in European university business education, specifically regarding the use and application of these concepts in teaching. The findings reveal that effective integration of these three concepts is not only possible but also essential to prepare future business leaders for the challenges and opportunities of the 21st century. Digitalization is presented as a catalyst for innovation and efficiency in teaching and learning processes, providing access to cutting-edge resources and tools. Sustainability emerges as a fundamental value that should permeate the entire curriculum, fostering social and environmental awareness in students. Profitability, understood not only in economic terms but also in social and environmental terms, is the logical outcome of a business education focused on long-term value creation.

Among the main research results, educators place more emphasis on sustainability than on digitalization because digitalization is often interpreted as a logical consequence of business growth; therefore, it receives less focus during the development of business plans, even though it plays a crucial role in scaling and customer attraction. The concept

of profitability is generally taken for granted since it is the primary objective of any company in a capitalist system; however, the challenge lies in developing ideas and business models that achieve the sustainability–digitalization–profitability triad.

A novel aspect of this research is the evidence of the large number of computer tools and information technologies used by educators in their teaching practice. What used to be flat drafts and calculations on paper have now largely been replaced by simulators and educational technologies that enable extensive calculations even for less ambitious business proposals.

The relevance of these results lies in the fact that, although professors are familiar with the concepts of sustainability, digitalization, and profitability, there is a significant opportunity to enhance their application in higher education. This opportunity involves deepening and understanding the concept of sustainability, incorporating new technologies and applications for business and innovative models, and integrating these with profitability. In the area of sustainability, gaps exist in its interpretation, often limiting it to environmental issues; in digitalization, innovative business transformation methods are not yet fully considered by educators; and profitability is frequently treated as an isolated concept, disconnected from the other two.

On the other hand, some limitations of the study are related to the wide dispersion in teaching styles, despite operating within a common European framework. Additionally, the interviews varied in depth—some were very long and in-depth, while others were shorter, even though more detailed responses were encouraged.

The practical implications of this research include the need to develop platforms that assess the integrated application and compliance of concepts such as sustainability, digitization, and cost-effectiveness in higher education projects that adhere to European regulations.

Lastly, potential future research avenues could include: conducting similar studies focused on students as active participants in the teaching-learning process of entrepreneurship in European higher education; investigating the application of other concepts related to European regulations—such as inclusion and migration—that are closely linked to profitability training.

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**CHALLENGES AND OPPORTUNITIES: A MULTIDIMENSIONAL ANALYSIS
OF THE ENERGY CRISIS IN THE DOMINICAN REPUBLIC
DESAFÍOS Y OPORTUNIDADES: UN ANÁLISIS MULTIDIMENSIONAL DE LA CRISIS
ENERGÉTICA EN LA REPÚBLICA DOMINICANA**

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ABSTRACT

Keywords:

electrical networks, sustainable system, wellbeing, quality of service, energy efficiency.

The present investigation presents an analysis of the current state of the electricity distribution network in the Dominican Republic, revealing a state of crisis mainly due to technical and financial factors that maintain the instability in the power supply. The main findings of the report by the Regional Centre for Sustainable Economic Strategies (CREES), based on data from the Ministry of Energy and Mines, indicate that the Electricity Distribution Companies (EDE) of the Dominican Republic recorded total energy losses of 41.7% until May 2025 (Daily List, 2025, August 20). These losses are made up of 38.3% of unbilled energy and 3.4% of unbilled energy (Daily List, 2025, 20 August). This is reflected in a tax burden with subsidies of more than 1,769 million dollars for 2024, which were implemented to solve operational deficiencies and not in strategic investments such as the exploitation of new technologies for better community service (CREES, 2025). The present work reflects a technical crisis reflected in obsolete infrastructure, a financial crisis to be remedied and not to solve in full the electrical problem facing the Dominican Republic and as a consequence of the previous crises reflects a governance crisis in which it is evident the replacement of strategic planning with surface solutions and that Consequently, the declaration of national emergency was made by Decree 517-25 in September 2025 (Invertix, 2025, consulted on 8 September). This diagnosis is a tool for key decision makers and stakeholders to justify and design viable and sustainable rehabilitation proposals for the Dominican Republic.

RESUMEN

Palabras clave:

La presente investigación presenta el análisis del estado actual de la red de distribución eléctrica en República Dominicana, revelando un estado de crisis principalmente por factores técnicos y financieros

redes eléctricas, sistema sostenible, bienestar, calidad del servicio, eficiencia energética.

que mantienen la inestabilidad en el suministro eléctrico. Los resultados se obtuvieron mediante el análisis de recursos bibliográficos, reportes e informes de instituciones gubernamentales públicas y privadas durante los periodos de 2020 y septiembre de 2025. Los principales resultados obtenidos del informe del Centro Regional de Estrategias Económicas Sostenibles (CREES), basado en datos del Ministerio de Energía y Minas, indican que las Empresas Distribuidoras de Electricidad (EDE) de la República Dominicana registraron pérdidas totales de energía del 41.7% hasta mayo de 2025 (Listín Diario, 2025, 20 de agosto). Estas pérdidas se componen de un 38,3% de energía no facturada y un 3,4% de energía facturada pero no cobrada (Listín Diario, 2025, 20 de agosto). Lo anterior reflejado en una carga fiscal con subsidios de más de 1.769 millones de dólares para el 2024, que fueron implementados para solventar deficiencias operativas y no en inversiones estratégicas como el aprovechamiento de nuevas tecnologías para un mejor servicio a la comunidad (CREES, 2025). El presente trabajo presenta una crisis técnica reflejada en infraestructura obsoleta, una crisis financiera en consecuencia por remediar y no por resolver de lleno la problemática eléctrica que enfrenta la República Dominicana y como consecuencia de las crisis anteriores se refleja una crisis de gobernanza en la que se evidencia el reemplazo de la planificación estratégica con soluciones superficiales y que, se ha realizado la declaratoria de emergencia nacional mediante el Decreto 517-25 en septiembre de 2025 (Invertix, 2025, 8 de septiembre). Este diagnóstico es un instrumento para los principales tomadores de decisiones para justificar y diseñar propuestas de rehabilitación viables y sostenibles para República Dominicana.

Introduction

According to the World Bank Group's report on cleaner and more diversified energy sources (2024), universal access to a stable, reliable, and affordable electricity supply is an essential pillar of economic development, industrial competitiveness, and improved quality of life in any nation. Consequently, the development of a robust electricity system with a balance between supply and demand, as well as a stable energy supply, is critical to building investor confidence and fostering a competitive and sustainable economic environment (OLADE, 2023).

The Dominican Republic shares the island of Hispaniola with Haiti. This island, considered the second-largest in the Greater Antilles archipelago, has a total area of 77,914 km², of which 48,442 km² is Dominican territory. The country has a coastline of 1,500 km and is geographically located between 18°20' north latitude and 68°30' west longitude. Its natural boundaries include: the Atlantic Ocean to the north, the Caribbean Sea to the south, the Mona Channel to the east, and the Republic of Haiti to the west (OHADAC, 2023, August 2025). In the case of the Dominican Republic, the resilience and efficiency of the electricity system are crucial to ensuring continued growth in gross domestic product (GDP) and to strengthening productivity in strategic sectors, ranging from micro and small businesses to large industrial corporations (Mercado, 2021, August 2025).

One of the most pressing challenges in the Dominican Republic is the instability of the electrical grid, which is characterized by extreme fluctuations in power supply. These variations, caused by geographic and political factors, pose significant risks, ranging from power surges that threaten real estate to prolonged power outages that can last for days (IDB, 2023). The root of the problem lies in the poor condition of the electrical infrastructure, whose obsolescence causes voltage fluctuations due to a lack of proper grounding, as well as physical damage to property caused by deteriorating utility poles and conductor supports. This situation not only jeopardizes public safety but also increases the risk of lawsuits against the authorities for mismanagement of the electrical system.

Another important issue is that power grids are vulnerable to illegal connections, which result in significant financial losses for electricity distribution companies (EDES), since only a fraction of the distributed energy is billed. To mitigate this financial impact, the EDES are implementing rationing plans, resulting in power outages of up to 12 hours a day in some areas, which exacerbates social unrest and limits economic development (Prensa Latina, 2025, September 2025).

As a result of the above, Citrus Circuit 701 stands out as a prime example of the crisis. Their networks, installed decades ago (1896, Milton Morrison, 2018) by the residents themselves, lack the technical capacity to meet current demand. The outdated infrastructure forces users to rely on voltage regulators to operate basic household appliances, while exposed wires, damaged insulation, and recurring failures point to an imminent collapse. Given this reality, there is an urgent need for a comprehensive assessment that will enable the design of a sustainable rehabilitation strategy focused on improving the system's resilience, energy efficiency, and safety.

This study presents an assessment of the current state of the energy sector in the Dominican Republic, with the aim of providing a tool that can serve as both a basis for justification and an incentive to develop strategies for the rehabilitation of power lines for the benefit of the entire nation. The assessment concludes that the sector faces

structural obstacles that jeopardize its long-term sustainability and profitability, as evidenced by technical and commercial inefficiencies, chronic financial fragility, and governance deficiencies.

Records from the National Energy Commission (2025), the Dominican energy sector has proven capable of sustaining foreign direct investment (FDI), as it has absorbed 25.7% of the total \$2,892.8 million received by the country, which has been directed toward clean energy projects (National Energy Commission, 2025, September 2025). However, this stands in contrast to the critical and persistent shortcomings in energy distribution, which have led to mistrust among users and continue to jeopardize the financial sustainability of the country's energy system (United Nations, Climate Action, 2023, August 2025).

The main objective of this research is to assess the current state of energy shortages in the Dominican Republic, specifically in the community of Básima, in order to encourage key decision-makers—such as the Ministers of Energy and Mines—to develop comprehensive tools that promote innovative programs to improve the quality of electricity service and ensure a stable supply. The analysis presented here is objective and is based on evidence from institutions, reports, and published technical manuals, which provide a solid foundation for future renovations or strategies to improve energy efficiency in the Dominican Republic.

Method

This article is classified as a critical-selective systematic review, as it integrates key evidence on issues in electrical grids in local contexts (Vera, 2009) from a holistic perspective. Although there are previous studies that address the central topic, this paper stands out for synthesizing relevant findings on power line failures in a specific community, with a focus on the case of Básima. To reach the above conclusion, it was necessary to integrate official data from the Ministry of Energy and Mines (MEM), which provides the most up-to-date figures on generation, demand, and distribution system losses through July 2025 (Energy and Mines, 2025, September 2025). Based on the above data, it was possible to numerically quantify the current state of the energy crisis in the Dominican Republic.

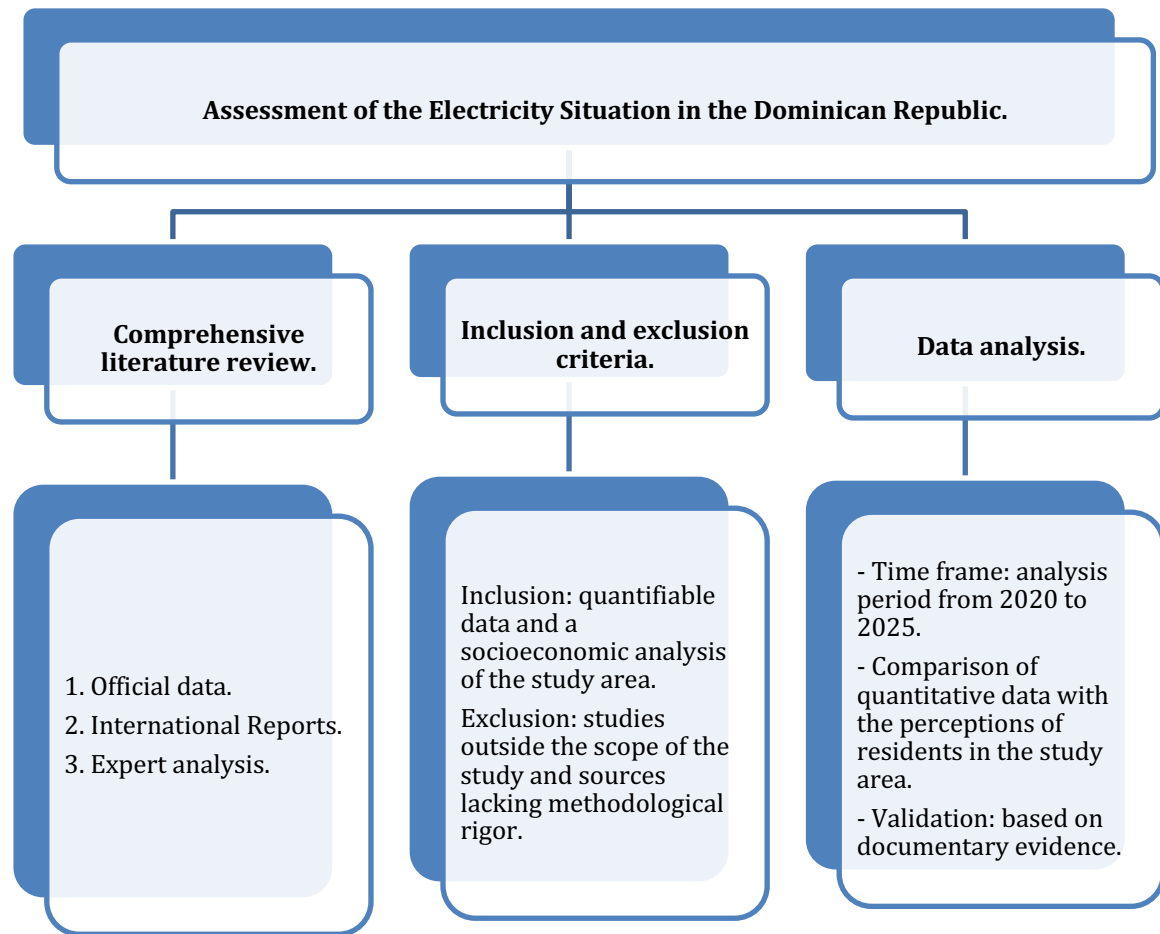
It is important to note that an analysis was also conducted based on reports from international organizations, such as those published by the Inter-American Development Bank (IDB), which have financed projects in the country and, in those reports, validate the projections and challenges facing the country in its energy transition (IDB Group, 2025).

To develop a critical perspective on the causes of the energy crisis, poor or non-existent planning, and inefficient management, reports from specialized centers such as the Regional Center for Sustainable Economic Strategies (CREES) and the Technological Institute of Santo Domingo (INTEC) were also analyzed, as were the opinions of public experts from prestigious media outlets such as *Diario Libre* and *El Dinero* (INTEC, 2015, August 2025).

By integrating these three main sources of information (Figure 1), this study presents a critical and comprehensive perspective that highlights technical instability, financial fragility, and governance deficits, with the aim of providing insights into and further examining the system's structural vulnerabilities.

Figure 1

Methodology used to assess the electrical service in the study area.



To review the resources identified, selection and exclusion criteria were applied, such as the year of the incident, the type of electricity service provided, and the geographic area under study. To explain the inclusion criteria in greater detail, they refer to documents containing quantifiable data (operating costs, efficiency metrics) and information that reflects the socioeconomic reality of the Dominican Republic. Another inclusion criterion is the analysis of time-series data, with priority given to sources published between 2000 and 2025 in order to capture historical and current trends. The exclusion criteria selected were studies focused on locations not related to the geographic or demographic context of interest, and sources lacking methodological rigor or practical applicability.

The diagnosis was validated through a critical analysis of the documented findings.

Characterization of the Study Area

The Dominican Republic occupies two-thirds of the island of Hispaniola, the second-largest island in the Greater Antilles archipelago after Cuba. It is bordered to the north by the Atlantic Ocean (586 km), to the south by the Caribbean Sea (545 km), to the east by the Mona Channel, which separates it from Puerto Rico, and to the west by Haiti, with a land border of 376 km (Figure 2). Its population (2025) is 11.5 million; its population density is: 225 (inhabitants per km²) with a total of 6.5 million tourists (worldometers.info, 2025, September 2025). Major cities: Santo Domingo (population 5.2 million), Santiago de los Caballeros (population 1.4 million), San Francisco de Macorís (population 338,900), and Barahona (population 138,470). The predominant language is Spanish, and English is widely spoken. Near the border with Haiti, people speak Haitian

Creole, a dialect of French. Its currency: Dominican peso (DOP). Exchange rate (approximate): 1 euro = 58 Dominican pesos; 1 U.S. dollar = 55 pesos (General Directorate of Communication, Public Diplomacy, and Networks, 2022).

Figure 2

Location of the Dominican Republic



Note. Taken from https://mapcarta.com/es/19369472#google_vignette, 2024.

Major Cities Analyzed

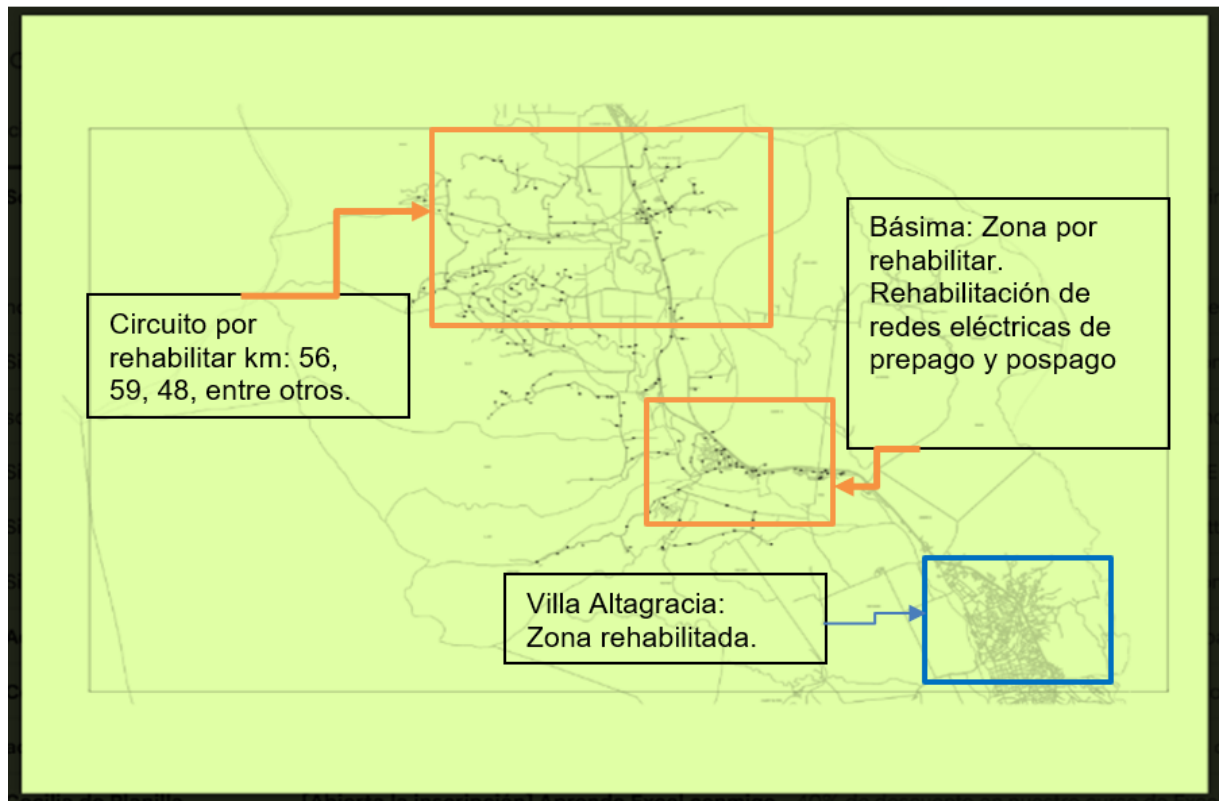
Very basic

Básima is a rural community located in the municipality of San José del Puerto, Villa Altagracia, in the province of San Cristóbal, in the northern region of the country; it is situated in a mountainous area, surrounded by natural landscapes and the lush vegetation typical of the central mountainous region of the Dominican Republic. Básima's economy is primarily based on agriculture, with crops such as coffee, cacao, plantains, and vegetables. It also has livestock operations and other small local businesses.

Básima is connected to other parts of the province of San Cristóbal, but because of its rural location, access roads can be difficult, especially during the rainy season. Transportation is often limited to two-wheel-drive vehicles or trucks. Culturally speaking, the traditions and customs of the residents of Básima are tied to rural life, with religious festivals and community events typical of mountainous regions.

Figure 3 shows the study area covered by this research. The document was generated based on surveys conducted by the author and illustrates the spatial distribution of power lines. It is proposed that the image quality be improved and that a Geographic Information System (GIS) be used to properly analyze the strategies and results expected from this research.

Figure 3
Distribution of Básima, Dominican Republic



Results

The analysis of the cross-referenced data reveals an inefficient electricity system in the Dominican Republic, primarily due to poor stability and quality of supply resulting from mismanagement and ineffective administration in providing service to the entire country. The following sections will describe the main expected results, concluding with our own perspective on the current assessment of the analyzed energy situation.

Stability of the Electricity Supply

According to Zoraima Cuello (Vanguardia del Pueblo, September 2025), the electricity sector in the Dominican Republic has been weakened by improvisation, a lack of continuity in established plans, and failure to fulfill the national commitments already made in the electricity pact. The chaotic situation is primarily affecting households, businesses, and industries, exposing the vulnerability of the National Interconnected Electric System (SENI) (Invertix, 2025, September 8). As a result, the Executive Branch issued Decree 517-25 on September 8, 2025, declaring a national state of emergency in the electricity sector for one year (Invertix, 2025, September 8).

The statement notes that the crisis had been denied because the scale of the problem was not understood and because the (Vanguardia del Pueblo, 2025, September 2025) were downplayed. However, this measure was prompted by insufficient power generation capacity, as a record high of 4,038 MW was reached in August 2025 (Invertix, 2025, September 8). This increase in demand was caused by a heat wave and the resulting rise in the use of air conditioning systems, which exceeded the operational capacity of the electrical grid—already weakened by the temporary unavailability of several power

plants undergoing maintenance and by the delay in adding an additional 600 MW intended to strengthen the grid (Invertix, 2025, September 8).

Expert analysts such as engineer José Luis Moreno San Juan, director of the Energy Institute at the Autonomous University of Santo Domingo (UASD), note that the current crisis is the result of “delays in investment” and the “lack of expansion plans that are carried out regardless of which government is in power” (CDN, 2025). Furthermore, Jaime Aristy Escuder, a mathematical economist at the University of Barcelona, pointed out that the authorities ignored experts’ recommendations to increase power generation by 150 MW per year in order to avoid critical outages; instead, they issued calls for bids with extended delivery deadlines and contracted inefficient power plants (Diario Libre, 2025).

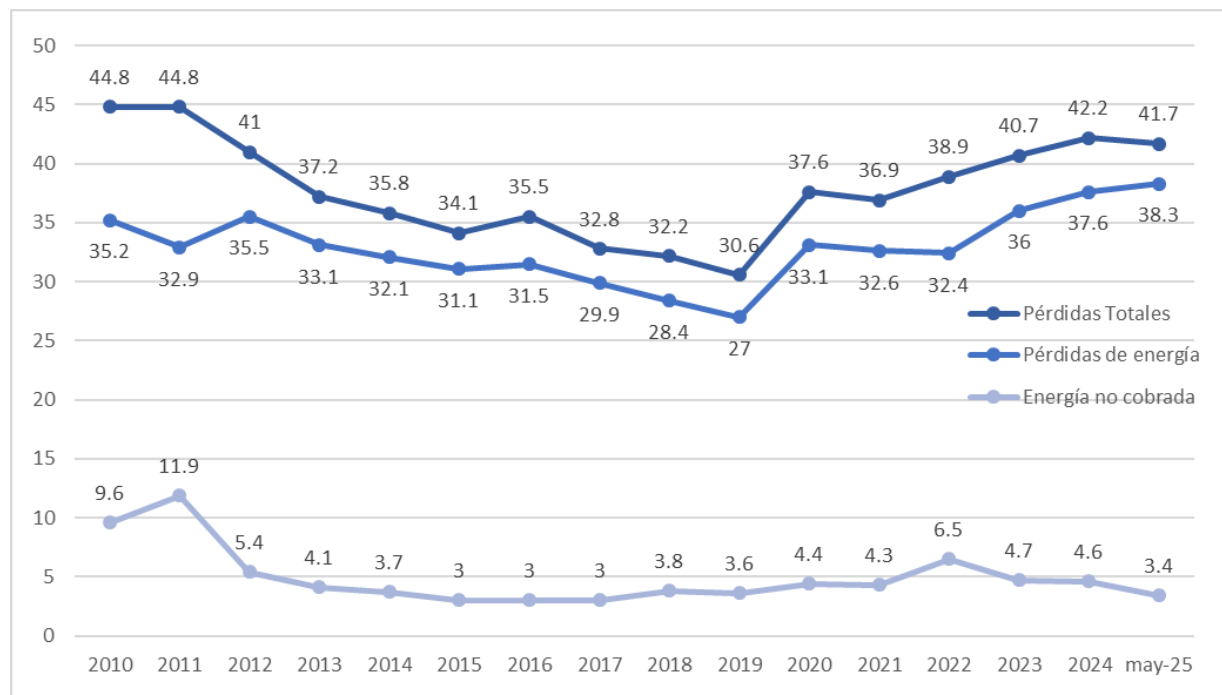
Therefore, the declaration of a state of emergency was predictable and directly linked to poor governance in the sector. Furthermore, the need to provide rapid solutions—such as contracting power plants—has caused the energy system to operate at its limits, leading to instability and system failures.

Quantification of Energy Losses in the Grid

The issue of energy losses in the Dominican Republic’s distribution system is persistent, and according to the findings, it is on an alarming upward trend. To corroborate this, reports from the Ministry of Energy and Mines indicate that energy losses stood at 37.4% in January (Ministry of Energy and Mines, 2025), rose to 40.4% in April (Diario Libre, 2025), and surged to 41.7% in May 2025 (Listín Diario, 2025). According to the Regional Center for Sustainable Economic Strategies (CREES), nearly 4 out of every 10 kWh generated and supplied to the energy system are neither billed nor collected (CREES, 2025).

After analyzing the reports from the Ministry of Energy and Mines and CREES, two types of losses were identified: technical and non-technical. The first ones are caused by heat dissipation in old transformers, overloaded transmission lines, and poor infrastructure. Igor Melo, an engineer specializing in the diagnosis of electrical energy losses, has referred to this type of loss as an “energy toll” because they operate and record data using obsolete hardware (Bridge 360, 2025).

The volatility of these losses directly affects users who do pay for electricity. Voltage drops and power surges damage industrial machinery, bring production to a standstill, and drive up electricity bills (Bridge 360, 2025). The following chart shows the trend in energy losses in the Dominican Republic from 2010 through May 2025. It illustrates the rapid deterioration in the efficiency of the electric power system, with energy losses reaching 41.7% in May 2025. Figure 4 also includes energy losses plus billed but uncollected energy.

Figure 4*Power Distribution Losses in the Dominican Republic in the First Months of 2025*

Note. Adapted from CREES, 2025, using data from the Ministry of Energy and Mines' May Energy Sector Performance Report.

Losses in the electricity sector should not be viewed solely as an indicator of operational inefficiency, but rather as the structural factor that explains the system's persistent financial deficit. Unbilled or wasted energy creates a significant revenue shortfall for electricity distribution companies (EDEs), which is repeatedly offset through fiscal transfers. Persistently high levels of losses undermine incentives to modernize business management and technical infrastructure, perpetuating dependence on state subsidies and reinforcing a pattern of chronic inefficiency. In this regard, the vicious cycle linking losses, deficits, and subsidies is the main obstacle to the economic and institutional sustainability of the electricity system.

Financial Condition and Market Distortions

The structural inefficiency of the electricity distribution system has led to a growing and increasingly unsustainable fiscal burden for the Dominican government. In 2024, government transfers intended to cover the operating deficit of the Electricity Distribution Companies (EDE) reached a record high of 1,769 million dollars (CREES, 2025). Far from being a strategic investment aimed at modernizing or expanding the system, this subsidy represents a reallocation of fiscal resources that, in practice, subsidizes both technical and non-technical losses as well as the distributors' inability to cover their operating costs through their own revenues (CREES, 2025).

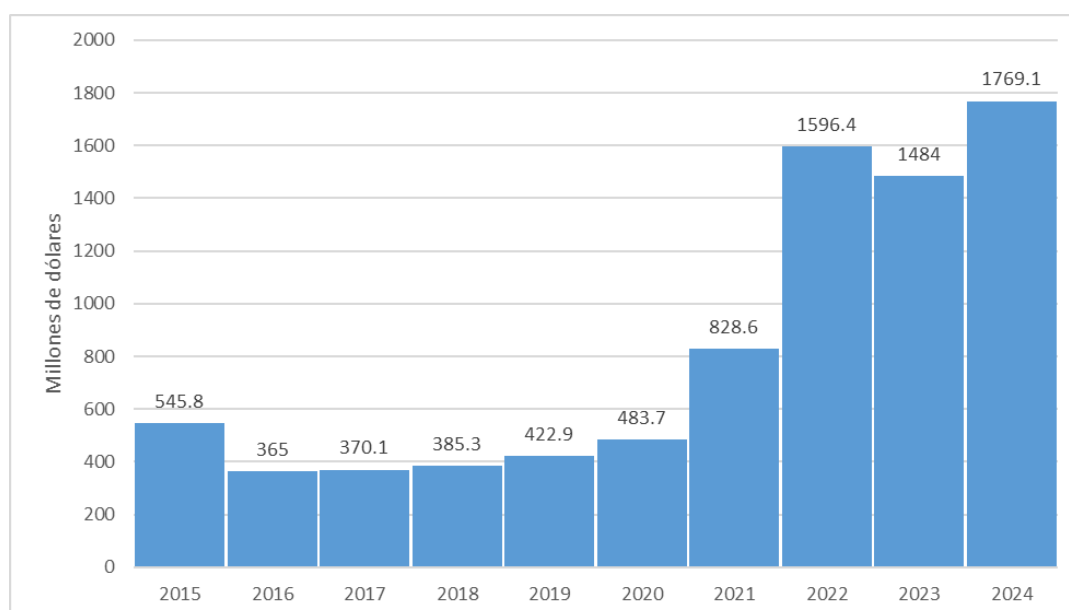
The financial fragility of the Dominican electricity system has been exacerbated by the adoption of fast-track contracting mechanisms. Decree 517-25, by declaring a state of emergency in the sector, authorizes the use of exceptional procurement procedures to expedite the purchase of equipment, which allows for the bypassing of standard bidding processes in situations that require immediate action (Invertix, 2025). While this measure aims to address the urgent need to mitigate power outages, comparative literature on public policy shows that relaxing contractual frameworks in emergency contexts—as has

occurred in Latin American and African countries in the infrastructure and health sectors—is often associated with risks of corruption, cost overruns, and lower quality in procurement (Diario Libre, 2025). In this regard, various sectors have warned that the effectiveness of these procedures depends on their integration with robust oversight and accountability mechanisms; without them, the exceptional nature of these procedures could reinforce discretionary practices and further erode the system’s sustainability (Diario Libre, 2025).

Exception-based procurement processes not only result in higher fiscal costs for the government, but also introduce market distortions by prioritizing short-term solutions at the expense of strategic planning. The long-standing lack of investment and expansion in the electricity infrastructure led to the crisis of 2025, creating an environment in which high-cost stopgap measures—such as contracting emergency power plants—are presented as “unavoidable” to prevent a collapse of the power supply (Aristy Escuder, 2025). This pattern traps the government in a reactive cycle that perpetuates the sector’s financial fragility and shifts the burden of structural inefficiency onto taxpayers. Figure 5 shows the magnitude of the fiscal burden associated with this management model, revealing an increase of more than 280 million dollars from 2023 to 2024 and indicating that the service is inefficient.

Figure 5

Trends in Transfers to the Electricity Sector in the Dominican Republic



Note. Compiled using data from the General Directorate of the Budget (DIGEPRES) and the Central Bank of the Dominican Republic, adapted from CREES, 2025.

Key Components of the Energy Sector

The energy mix in the Dominican Republic has historically been characterized by a heavy reliance on fossil fuels, which in 2025 still account for more than 70% of electricity generation (Ministry of Energy and Mines, 2025). Within this mix, natural gas is the main source (42%), followed by coal (24%) and fuel oil (4%). Despite this significant dependence, the government has expressed its commitment to an energy transition aimed at increasing the share of renewable energy sources to 25% of total electricity generation by 2025 (Ministry of Energy and Mines, 2025). In this context, solar and wind energy projects have played a central role in diversifying the energy mix, with projections estimating that solar energy’s share will increase from 8% to 17% and wind

energy's share from 6% to 7% (Ministry of Energy and Mines, 2025). However, the controversy surrounding the Punta Catalina Thermal Power Plant (CTPC)—which is the country's largest coal-fired power generation facility—argues that its advanced fluidized-bed technology makes it more efficient and less polluting than the older plants from the 1980s (UASD, 2023). For example, its CO₂ emissions (789 grams per kWh) are below the international guideline (807–907 grams per kWh), and its contribution to total global emissions is negligible (less than 0.2%) (UASD, 2023).

Some evidence against it, such as that compiled by the International Institute for Law and the Environment (IIDMA) (2022), calls for its immediate closure due to the severity of its environmental and human health impacts (IIDMA, 2022). These studies project an increase in premature deaths and illnesses among the most vulnerable populations, with an estimated economic cost of up to \$7.5 million USD per year in the Dominican Republic alone (IIDMA, 2022).

The coexistence of the push toward renewable energy and the continued operational reliance on a highly controversial power plant such as Punta Catalina demonstrates that the so-called energy transition in the Dominican Republic is, in practice, a process of gradual diversification rather than a structural transformation of the system. The continued predominant use of fossil fuels stands as a critical obstacle to long-term sustainability and undermines the internal coherence of national energy policy.

Governance and Noncompliance with the Electricity Pact

The current crisis in the Dominican electricity sector cannot be understood without considering the problems associated with its governance. The National Pact for Electricity Sector Reform (2021) was conceived as a government agreement intended to transcend political cycles and ensure regulatory predictability, legal certainty, and the sustainability of the system through 2030 (CES, 2021). However, the oversight reports prepared by the Economic and Social Council (CES) reveal systemic noncompliance, the magnitude of which plays a decisive role in explaining the crisis currently affecting the sector.

Although the 2024 oversight report indicates an overall compliance rate of 88.6% for the 167 commitments made by the 11 signatory actors (Nación Logística, 2024), a detailed examination of the obligations assigned to the Executive Branch reveals a critical failure to comply. Of the nine strategic commitments under its purview, only one has been fulfilled, three are in progress, and five have not even been started, which amounts to an 89% failure to meet the most critical objectives for the structural reform of the electricity sector.

This systematic failure reflects a lack of political will to carry out the fundamental reforms that the Electricity Pact set out to ensure. Failure to meet the deadlines for reducing losses, modernizing infrastructure, and strengthening institutions has precipitated the technical and financial collapse that the Pact itself sought to prevent. In this regard, the 2025 power outage crisis is not a random event, but rather the foreseeable consequence of a failure in governance linked to the abandonment of agreed-upon commitments. The declaration of a state of emergency, rather than a solution, appears to be an expression of a model that prioritizes short-term palliative measures over the development of a sustainable, long-term energy policy.

Electrical System Inspection in Bálsima, Dominican Republic

The circuits designated as priorities for rehabilitation are in critical condition, with direct impacts on the population's quality of life and social stability. According to data

from the 2023 Management Report of the Distribution Companies (EDEs), 68% of users in underserved areas receive less than 14 hours of power per day, a situation exacerbated by:

- Recurring outages due to demand management (up to 10 hours a day during peak season).
- Unplanned outages due to infrastructure deterioration (exposed cables, overloaded transformers).
- Media and social pressure, with an average of 15 reports per week in the press and on social media regarding electrical hazards.

This situation calls for immediate action to restore basic 24-hour service, mitigate security risks, and rebuild public trust. As outlined in the “Improvement of Medium- and Low-Voltage Networks” initiative, which the Dominican government should classify as a national priority, this project aims to protect citizens by eliminating the risks of electrocution and fires caused by network failures.

Energy companies and suppliers are expected to demonstrate operational excellence that will ensure a reduction in technical losses from 22% to 12% over the next five years. The purpose of this is to ensure service continuity ($\geq 99\%$ availability in the areas where work is being carried out).

Within the electricity distribution companies (EDEs) and for the benefit of customers, establish financial sustainability by reducing non-technical losses (currently 34% of distributed energy) through anti-fraud technology and the optimization of operating costs with automated networks. This initiative is in line with the 2025–2040 National Energy Transition Plan, which includes an investment of USD 1.2 billion to modernize 8,000 km of power grids.

Discussion and Conclusions

The electricity distribution system in the Dominican Republic is facing a deep crisis resulting from a combination of technical, financial, and governance issues. The technical crisis is reflected in an outdated infrastructure that causes significant energy losses. This not only affects the quality and stability of the service, but also has a direct impact on the sector's finances. This technical shortcoming is fueling the financial crisis. The system operates with a chronic deficit that the government covers with massive subsidies. However, instead of allocating those funds to modernize the network, they are used to maintain an unsustainable model, thereby perpetuating the problem.

The governance crisis is at the root of the problem. The failure to comply with the Electricity Pact has replaced long-term strategic planning with reactive emergency solutions. This lack of vision and leadership has prevented the necessary reforms from being implemented.

Temporary or stopgap measures are not enough to restore the system. The solution requires a profound and systemic reform that addresses the underlying causes. The path toward a sustainable and profitable electricity sector involves implementing the postponed reforms—particularly those under the Electricity Pact—as well as reducing energy losses to acceptable levels and restructuring the sector's finances to relieve the government of the burden of subsidies.

Only through bold and transparent reform will the Dominican electricity system be able to overcome the crisis and move toward a sustainable development model. Electricity service in the Dominican Republic has improved in recent decades; however, it still faces significant challenges related to aging infrastructure, energy losses, theft,

frequent outages, and production capacity during periods of high demand. Nevertheless, efforts toward modernization, growth, and the transition to renewable energy point to a promising path toward a more robust and sustainable grid. It is essential to address structural challenges and strengthen infrastructure in order to improve the quality of service nationwide.

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