

INFORMATION & TECHNOLOGY

Warehouse Management
Systems (WMS): Improving..

Expert Validation of an
Extended Reality
Framework...

Governance &
Observability in Finance
Data

BI Model for Food Sector
Commercial Management

Discovering Thoughts, Inventing Future

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PREFACE

The Global Journal of Computer Science and Technology (GJCST) is pleased to present this issue, bringing together a curated collection of high-quality research papers that explore various frontiers of computer science and technology.

This issue features research spanning topics including artificial intelligence, machine learning, software engineering, network security, and interdisciplinary applications of computing. Each paper has undergone a rigorous peer-review process to ensure scientific rigor and originality.

We would like to express our sincere gratitude to the authors for entrusting their research with us, to the reviewers for their thorough and constructive evaluations, and to our readers for their continued engagement with the scientific discourse.

We hope that the research presented herein inspires further inquiry and contributes meaningfully to the advancement of knowledge in computer science and technology.

The Chief Editor
Global Journal of Computer Science and Technology
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Warehouse Management Systems (WMS): Improving Warehouse Operations and Supply Chain Efficiency

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Abstract

Warehouse management plays a critical role in modern supply chain operations. With the rapid expansion of global trade, e-commerce platforms, and complex logistics networks, organizations increasingly rely on advanced technological systems to manage warehouse activities efficiently. A Warehouse Management System (WMS) is a specialized software platform designed to control, coordinate, and optimize warehouse operations such as receiving goods, inventory management, order picking, packing, and shipping. This study explores the role of warehouse management systems in improving warehouse efficiency and overall supply chain performance. The research uses a qualitative approach based on secondary data collected from academic journals, books, and industry publications. Existing literature was analyzed to identify the functions, advantages, and challenges associated with implementing WMS technologies. The findings suggest that warehouse management systems significantly improve inventory accuracy, increase operational efficiency, reduce human error, and enhance order fulfillment speed. Furthermore, modern WMS platforms integrate emerging technologies such as cloud computing, automation, artificial intelligence, and the Internet of Things to create smart warehouse environments. Despite these benefits, organizations may face several challenges during implementation, including high initial costs, employee training requirements, and system integration complexities. The study concludes that warehouse management systems are essential tools for modern logistics management and will continue to play a significant role in improving supply chain efficiency in the future.

Warehouse Management Systems

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Warehouse Management Systems (WMS): Improving Warehouse Operations and Supply Chain Efficiency

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Abstract

Warehouse management plays a critical role in modern supply chain operations. With the rapid expansion of global trade, e-commerce platforms, and complex logistics networks, organizations increasingly rely on advanced technological systems to manage warehouse activities efficiently. A Warehouse Management System (WMS) is a specialized software platform designed to control, coordinate, and optimize warehouse operations such as receiving goods, inventory management, order picking, packing, and shipping. This study explores the role of warehouse management systems in improving warehouse efficiency and overall supply chain performance. The research uses a qualitative approach based on secondary data collected from academic journals, books, and industry publications. Existing literature was analyzed to identify the functions, advantages, and challenges associated with implementing WMS technologies. The findings suggest that warehouse management systems significantly improve inventory accuracy, increase operational efficiency, reduce human error, and enhance order fulfillment speed. Furthermore, modern WMS platforms integrate emerging technologies such as cloud computing, automation, artificial intelligence, and the Internet of Things to create smart warehouse environments. Despite these benefits, organizations may face several challenges during implementation, including high initial costs, employee training requirements, and system integration complexities. The study concludes that warehouse management systems are essential tools for modern logistics management and will continue to play a significant role in improving supply chain efficiency in the future.

Keywords: Warehouse Management Systems, Supply Chain Efficiency, Inventory Management, Logistics Automation, Smart Warehousing, Order Fulfillment, E-commerce Logistics

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1. Introduction

Warehouses are essential components of supply chains because they provide storage, distribution, and inventory management services for goods moving between suppliers, manufacturers, retailers, and customers. As businesses expand globally and consumer expectations for fast delivery increase, warehouses must operate efficiently and accurately. Traditional warehouse operations that rely heavily on manual processes often struggle to meet these demands.

Warehouse Management Systems (WMS) were developed to address these challenges by automating and optimizing warehouse processes. A WMS is a computer-based system that supports the planning, execution, and monitoring of warehouse operations. These systems allow organizations to track inventory levels in real time, improve space utilization, and streamline warehouse workflows.

In the past, many warehouses relied on manual documentation and simple inventory tracking systems. Such approaches often resulted in inaccurate inventory data, delayed order processing, and inefficient warehouse layouts. With the introduction of digital technologies, warehouse operations have become more automated and data-driven. Modern WMS platforms integrate with other enterprise systems such as Enterprise Resource Planning (ERP) and Transportation Management Systems (TMS), allowing organizations to manage their supply chains more effectively.

Additionally, technological advancements such as barcode scanning, radio-frequency identification (RFID), robotics, and artificial intelligence have significantly enhanced the capabilities of warehouse management systems. These innovations enable real-time data collection, automated material handling, and intelligent decision-making.

As supply chains continue to grow in complexity, warehouse management systems are becoming increasingly important. Organizations that adopt advanced WMS technologies can improve operational efficiency, reduce costs, and provide better customer service. Therefore, studying the functions and benefits of warehouse management systems is essential for understanding how modern logistics operations can be optimized.

2. Problem Statement

Many organizations continue to face operational challenges in managing warehouse activities efficiently. Traditional warehouse operations often rely on manual record keeping, spreadsheets, or outdated inventory systems. These methods are prone to human error and may lead to inaccurate inventory records, misplaced items, and delays in order fulfillment.

Inaccurate inventory information can cause serious problems for businesses. For example, companies may experience stock shortages, overstocking, or incorrect shipments. These issues can lead to financial losses, customer dissatisfaction, and reduced competitiveness in the market.

Furthermore, inefficient warehouse layouts and poorly organized storage systems can increase the time required to locate and retrieve products. Workers may spend unnecessary time searching for items or traveling long distances within the warehouse. As a result, productivity decreases and operational costs increase.

With the growth of e-commerce and same-day delivery services, organizations must process orders quickly and accurately. Customers expect fast shipping and real-time order tracking. Without a reliable warehouse management system, it becomes difficult for businesses to meet these expectations.

Therefore, there is a need to explore how warehouse management systems can improve warehouse operations, enhance inventory accuracy, and support efficient supply chain management.

3. Research Objectives

The primary objective of this paper is to analyze the role of warehouse management systems in improving warehouse operations and supply chain efficiency.

Specific objectives include:

1. To examine the functions and features of warehouse management systems.
2. To evaluate the impact of WMS on warehouse productivity and inventory accuracy.
3. To identify the operational benefits of implementing WMS technologies.
4. To explore the challenges organizations face during WMS implementation.
5. To analyze how emerging technologies enhance warehouse management systems.

4. Literature Review

Several researchers have examined the role of warehouse management systems in improving logistics performance. Faber, De Koster, and Smids (2006) highlighted that WMS solutions improve the coordination of warehouse activities and enable better decision-making by providing real-time information about inventory levels and warehouse operations.

Gu, Goetschalckx, and McGinnis (2007) conducted a comprehensive review of warehouse operations and emphasized the importance of efficient storage policies, order picking strategies, and warehouse layout design. Their research showed that advanced information systems such as WMS can significantly enhance operational efficiency.

De Koster, Le-Duc, and Roodbergen (2007) focused on order picking processes and found that order picking is one of the most labor-intensive activities in warehouses. By optimizing picking routes and using automated systems, organizations can reduce travel time and improve productivity.

Recent studies have also explored the use of emerging technologies in warehouse management systems. For example, cloud-based WMS platforms allow organizations to access warehouse data remotely and scale their operations more easily. Similarly, IoT sensors and RFID technologies enable real-time tracking of goods within warehouses.

Minashkina and Happonen (2023) examined the sustainability benefits of modern warehouse management systems. Their research indicates that smart warehouses equipped with automation

and digital monitoring systems can reduce energy consumption and improve operational safety.

Overall, existing literature demonstrates that warehouse management systems are essential tools for improving warehouse efficiency, reducing operational costs, and supporting effective supply chain management.

5. Methodology

This research uses a qualitative methodology based on secondary data analysis. Secondary data were collected from academic books, peer-reviewed journals, logistics research publications, and reputable online sources related to warehouse management systems.

The literature review method was used to analyze previous studies on warehouse technologies and logistics management. By examining multiple sources, the study identifies common findings related to the benefits and challenges of implementing warehouse management systems.

The analysis focuses on understanding how WMS technologies influence warehouse productivity, inventory management, and supply chain performance. This approach provides a comprehensive overview of current knowledge and trends in warehouse management research.

6. Conceptual Framework

The conceptual framework illustrates the relationship between warehouse management system implementation and warehouse performance outcomes.

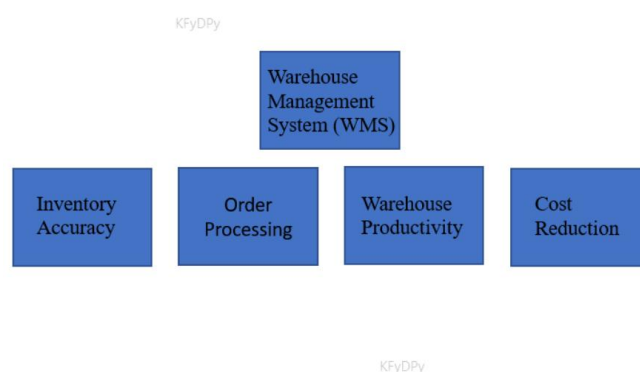


Figure 1. Relationship between WMS implementation and warehouse performance outcomes.

Implementation of a warehouse management system is expected to improve operational performance by providing accurate inventory information, optimizing warehouse workflows, and reducing operational costs.

7. Warehouse Management System Architecture

Modern warehouse management systems typically consist of several interconnected modules that manage different warehouse processes.

These modules work together to ensure efficient coordination of warehouse activities and accurate inventory tracking.



Figure 2. Interconnected modules of a modern warehouse management system (WMS).

8. Benefits of Warehouse Management Systems

Implementing a warehouse management system provides several operational advantages.

Improved Inventory Accuracy: WMS provides real-time inventory tracking, reducing errors associated with manual record keeping.

Increased Productivity: Automation and optimized workflows allow warehouse workers to perform tasks more efficiently.

Better Space Utilization: WMS systems analyze storage capacity and recommend optimal storage locations for products.

Faster Order Fulfillment: Optimized picking routes reduce the time required to locate and retrieve items.

Cost Reduction: Automation and improved efficiency reduce labor costs and minimize operational waste.

9. Challenges of Implementing wms

Despite its advantages, implementing a warehouse management system can present several challenges.

High Initial Investment: Purchasing and implementing WMS software may require significant financial investment.

System Integration Issues: Integrating WMS with existing enterprise systems may require technical expertise.

Employee Training Requirements: Staff must be trained to use the new system effectively.

Data Migration Challenges: Transferring data from legacy systems to a new WMS can be complex.

Resistance to Change: Employees may initially resist adopting new technologies or workflows.

10. Future trends in Warehouse Management

Technological innovations are transforming warehouse operations worldwide. Automation technologies such as robotic picking systems, autonomous mobile robots, and automated storage and retrieval systems are becoming increasingly common in large distribution centers.

Artificial intelligence and machine learning are also being integrated into warehouse management systems to improve demand forecasting, inventory planning, and operational decision-making.

Another emerging trend is the development of smart warehouses that use IoT sensors to monitor equipment, track inventory, and optimize energy consumption. These technologies enable warehouses to operate more efficiently and sustainably.

Cloud-based WMS solutions are also gaining popularity because they allow organizations to access warehouse data remotely and scale their operations more easily.

11. Conclusion

Warehouse management systems play a vital role in modern logistics and supply chain management. By automating warehouse processes and providing real-time visibility of inventory and operations, WMS technologies help organizations improve efficiency, reduce costs, and enhance customer satisfaction.

The literature reviewed in this study demonstrates that implementing a warehouse management system can significantly improve inventory accuracy, optimize warehouse workflows, and accelerate order fulfillment. However, successful implementation requires careful planning, adequate training, and effective integration with existing enterprise systems.

As technology continues to evolve, warehouse management systems will become even more sophisticated, incorporating advanced automation, artificial intelligence, and data analytics capabilities. Organizations that adopt these technologies will be better positioned to compete in increasingly complex global supply chains.

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Expert Validation of an Extended Reality Framework for Outcome-based Education: A Proposed Validation Protocol

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Abstract

Extended Reality (XR) technologies, encompassing Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), hold transformative potential for Outcome-Based Education (OBE), yet frameworks to guide their systematic, outcomes-aligned integration into higher education remain scarce and insufficiently validated. Existing XR instructional design frameworks specify general pedagogical planning procedures without explicit alignment with graduate outcome accreditation regimes, such as those governing ASEAN higher education. This paper proposes an expert validation protocol for an eight-step XR-OBE integration framework spanning learning outcome identification, technology assessment, curriculum integration, pilot programme development, experiential implementation, data collection, iterative refinement, and continuous quality improvement. The proposed validation employs a mixed-methods design that combines Content Validity Index (CVI) scoring, an interrater reliability check using a modified kappa statistic, structured expert rubrics, focus group discussions, and a two-round Delphi consensus technique with seven purposively selected academic and industry experts. The paper specifies expert selection criteria, validation instruments, a six-phase protocol with explicit entry and exit criteria, and a convergent mixed-methods analytical plan grounded in established trustworthiness criteria. Anticipated outcomes include a content-validated, evidence-based framework suitable for adoption across higher education institutions (HEIs) and scalable within Malaysia's MySTIE Education and Ekonomi MADANI policy agendas, together with a reusable validation protocol transferable to other emerging educational technology frameworks.

Extended Reality (XR)

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Content Validity Index

Higher Education

Immersive Learning

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TRIAL REG.

Not applicable.

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Expert Validation of an Extended Reality Framework for Outcome-based Education: A Proposed Validation Protocol

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Abstract

Extended Reality (XR) technologies, encompassing Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), hold transformative potential for Outcome-Based Education (OBE), yet frameworks to guide their systematic, outcomes-aligned integration into higher education remain scarce and insufficiently validated. Existing XR instructional design frameworks specify general pedagogical planning procedures without explicit alignment with graduate outcome accreditation regimes, such as those governing ASEAN higher education. This paper proposes an expert validation protocol for an eight-step XR-OBE integration framework spanning learning outcome identification, technology assessment, curriculum integration, pilot programme development, experiential implementation, data collection, iterative refinement, and continuous quality improvement. The proposed validation employs a mixed-methods design that combines Content Validity Index (CVI) scoring, an interrater reliability check using a modified kappa statistic, structured expert rubrics, focus group discussions, and a two-round Delphi consensus technique with seven purposively selected academic and industry experts. The paper specifies expert selection criteria, validation instruments, a six-phase protocol with explicit entry and exit criteria, and a convergent mixed-methods analytical plan grounded in established trustworthiness criteria. Anticipated outcomes include a content-validated, evidence-based framework suitable for adoption across higher education institutions (HEIs) and scalable within Malaysia's MySTIE Education and Ekonomi MADANI policy agendas, together with a reusable validation protocol transferable to other emerging educational technology frameworks.

Keywords: *Extended Reality (XR), Outcome-Based Education (OBE), Expert Validation, Delphi Method, Content Validity Index, Higher Education, Immersive Learning, Curriculum Design*

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1. Introduction

The rapid proliferation of immersive technologies in educational settings has prompted educators and policymakers to seek structured guidance for their adoption. Extended Reality (XR) is a superset of VR, AR, and MR that has demonstrated significant promise in facilitating experiential learning, enhancing engagement, and supporting the acquisition of complex skills. A systematic review of 295 XR studies in higher education across 48 countries (Burke, Crompton, & Nickel, 2025) confirms that adoption has accelerated markedly since 2020, with a concentration in professional training, STEM education, soft skills development, general education, and assessment. Theoretically, Dede (2009) frames immersion as the subjective sense of participating in a comprehensive, realistic experience that supports multiple perspectives, situated learning, and transfer, while the Cognitive Affective Model of Immersive Learning (CAMIL; Makransky & Petersen, 2021) specifies the psychological mechanisms, such as presence, agency, and six cognitive-affective factors, through which immersive virtual reality produces knowledge acquisition and transfer. In the context of Outcome-Based Education (OBE), which foregrounds the alignment of teaching, learning, and assessment with predefined graduate competencies, integrating XR is a compelling yet methodologically complex endeavour.

Despite this growing evidence base, a notable gap persists: a few frameworks offer practitioner-ready, step-by-step guidance that is simultaneously grounded in OBE principles and empirically validated by domain experts. Even the most recent general-purpose XR instructional-design frameworks illustrate this gap. XR2Learn (Karachristos et al., 2026), for instance, extends established models such as ADDIE and ASSURE to address the spatial, embodied, and interactive characteristics of immersive environments, and was itself subjected to a thorough multi-round Delphi evaluation involving twenty specialists. However, its validation identified persistent gaps in practical performance, accessibility, and the explicit usage of XR-specific constructs such as presence and social interaction and, notably, it does not address alignment with formal graduate-outcome accreditation requirements. The eight-step XR-OBE integration framework shown in Figure 1 addresses this compound gap by providing a cyclical, continuous quality-improvement model that spans the full lifecycle of XR adoption, from identifying learning outcomes to scaling and refining the XR experience and is explicitly mapped onto OBE curriculum design logic.

However, the credibility and transferability of any educational framework rest on the rigour of its validation. Without systematic expert review, a framework risks being theoretically sound but practically unfit for diverse institutional contexts. This paper

therefore proposes a structured expert validation protocol that will focus on the XR-OBE framework to be validated by scholars and practitioners across XR technology, OBE curriculum design, educational technology, instructional design, and industry practice.

The objectives of this study are to: (1) design a expert validation protocol for the XR-OBE integration framework; (2) identify appropriate instruments and criteria for assessing content validity, OBE alignment, pedagogical soundness, feasibility, and usability, including an inter-rater reliability check that corrects for chance agreement; and (3) outline an analytical plan such as quantitative, qualitative, and trustworthiness-oriented that yields defensible evidence of the framework's validity for publication and institutional adoption.

The remainder of this paper is organised as follows. Section 2 reviews related work on XR in higher education, OBE principles, and framework-validation methodology, and positions the proposed framework relative to comparable recent work. Section 3 presents the XR-OBE framework itself. Section 4 details the proposed validation protocol, including expert panel composition, instruments, and phased procedure. Section 5 outlines the data analysis plan. Sections 6 through 9 address ethical considerations, expected outcomes and contributions, limitations and future directions, and concluding remarks, respectively.

2. Background and Related Work

2.1. XR in Higher Education

XR technologies have been studied extensively across medical education (Pottle, 2019), engineering training (Hamilton et al., 2021), and humanities learning environments (Southgate, 2020). The systematic review by Burke et al. (2025) confirms that XR adoption in higher education has grown rapidly since 2020, while a complementary review of 95 studies (Sümer & Vančec̆ek, 2024) reports that medical and health-science courses remain the dominant application context, with simulation-based pedagogy the most frequently deployed instructional strategy. Meta-analytic and narrative review evidence converges on moderate-to-large effect sizes for VR-enhanced learning on knowledge retention and engagement. At the same time, AR overlays support spatial reasoning in STEM disciplines and MR environments enable real-time collaborative problem-solving.

Beyond effect-size evidence, theoretical models increasingly explain why XR supports learning. CAMIL (Makransky & Petersen, 2021) specifies presence and agency as the core psychological affordances of immersive virtual reality, mediating six cognitive-affective factors: interest, motivation, self-efficacy, embodiment, cognitive load, and self-regulation that jointly determine knowledge acquisition and transfer. Extending this line of enquiry to adoption behaviour, Al-Adwan et al. (2023) apply an extended Technology Acceptance Model to show that perceived usefulness, personal innovativeness, and perceived enjoyment, rather than ease of use, drive students' intentions to adopt metaverse-based learning platforms, underscoring that pedagogical design, not technological novelty alone, determines uptake. The XR-OBE framework draws on this theoretical base: Step 1 (Identify Learning Outcomes) and Step 3 (Curriculum Integration) operationalise CAMIL's emphasis on aligning XR affordances with intended cognitive outcomes. In contrast, Step 4 (Pilot Programme and Training) addresses the adoption-related barriers identified in the technology-acceptance literature.

Within Malaysian higher education, initiatives aligned with MySTIE Education and the national Ekonomi MADANI agenda signal increasing institutional receptiveness to technology-enhanced learning. Nevertheless, the gap between awareness of XR's potential and systematic, outcome-aligned deployment remains wide, and practitioners continue to lack actionable frameworks validated within educational contexts.

2.2. Outcome-Based Education Principles

OBE, as conceptualised by Spady (1994) and operationalised by ASEAN higher education accreditation bodies, including the Malaysian Qualifications Agency (MQA), mandates that curriculum design begin with clearly articulated graduate attributes and work backwards through instruction and assessment. The second edition of the Malaysian Qualifications Framework (MQA, 2024) reaffirms this outcomes-first orientation, consolidating learning-outcome domains across the Academic and TVET sectors and strengthening institutional accountability for demonstrable graduate competencies. The Constructive Alignment model (Biggs & Tang, 2011) is foundational to OBE and provides the theoretical bridge between learning activities, including XR experiences and measurable learning outcomes.

Integrating XR into OBE therefore demands more than technological deployment. It requires deliberate curriculum mapping, outcome specification, and evidence-based evaluation of whether immersive experiences produce the intended competencies, a requirement that existing XR instructional-design literature rarely operationalises against formal accreditation frameworks (see Section 2.4).

2.3. Framework validation in Education research

Expert validation is an established methodology for ensuring that educational frameworks, instruments, and models have content validity prior to empirical testing. The Content Validity Index (CVI), introduced by Lawshe (1975) and refined by Lynn (1986) and Polit and Beck (2006), provides a quantitative measure of expert consensus on the relevance of each framework component. CVI scores at the item level ($I\text{-}CVI \geq 0.78$) and at the scale level ($S\text{-}CVI/\text{Ave} \geq 0.90$) are widely accepted thresholds in educational and health sciences research (Zamanzadeh et al., 2015). Polit, Beck, and Owen (2007), however, note that the raw CVI does not adjust for chance agreement among experts; they recommend supplementing CVI with a modified kappa statistic, a refinement adopted in the present protocol (Section 5.1).

The Delphi technique (Linstone & Turoff, 1975) complements CVI by iteratively polling experts until consensus is reached on the items under review, making it particularly well suited to new frameworks as existing evidence grows. Diamond et al.'s (2014) systematic review of Delphi reporting practice highlights substantial inconsistency in how consensus is defined across published studies and recommends that Delphi protocols pre-register explicit stopping rules and consensus thresholds, a recommendation incorporated into the phased protocol described in Section 4.5. Together, CVI and Delphi provide a robust, mixed-methods foundation for establishing content validity prior to empirical field trials.

2.4. Positioning Relative to Existing XR Instructional Frameworks

The most directly comparable recent work is XR2Learn (Karachristos et al., 2026), a hybrid instructional-design framework for XR-based education validated through a multi-round Delphi study involving twenty specialists in instructional design and

Table 1. Positioning of the XR-OBE Framework Relative to Comparable XR Instructional Frameworks

Framework	Primary Focus	Validation Approach	OBE / Accreditation Alignment	Panel Size
XR-OBE Framework (this paper)	Full-lifecycle XR integration mapped to graduate outcomes	CVI + modified kappa + Delphi + focus group discussion (triangulated)	Explicit (MQA/OBE-aligned)	7 experts
XR2Learn Hybrid Instructional Design Framework (Karachristos et al., 2026)	XR-specific instructional design procedure (extends ADDIE/ASSURE)	Multi-round Delphi	Not addressed	20 experts
CAMIL (Makransky & Petersen, 2021)	Theoretical model of cognitive-affective mechanisms in immersive VR learning	Conceptual synthesis of empirical literature (not an empirical validation protocol)	Not addressed	N/A

XR-enhanced education. XR2Learn extends established models such as ADDIE and ASSURE to address the spatial, embodied, and interactive characteristics of immersive environments; its validation identified persistent gaps in practical enactment, accessibility, and the explicit treatment of XR-specific constructs such as presence and social interaction. While methodologically rigorous, XR2Learn, like ADDIE- and ASSURE-derived models generally, is discipline- and outcome-agnostic: it specifies how to design XR instruction but not how that instruction maps onto predefined, accreditation-bound graduate competencies. Table 1 situates the proposed XR-OBE framework relative to XR2Learn and to CAMIL, the dominant theoretical (rather than procedural) account of XR-based learning.

This positioning clarifies the paper's contribution: rather than proposing a new theory of XR-based learning or a generic XR instructional-design procedure, the XR-OBE framework operationalises existing theoretical and procedural knowledge into an OBE-accreditation-aligned, cyclically self-improving protocol, validated through a triangulated CVI-Delphi-focus-group design that additionally corrects for chance agreement via modified kappa, a methodological refinement absent from the single-method Delphi validation reported for XR2Learn.

3. The Proposed XR-OBE Integration framework

The framework under validation comprises eight sequential, cyclical steps designed to guide higher education practitioners through the full lifecycle of XR integration within an OBE context, illustrated in Figure 1. Grounded in the theoretical constructs reviewed in Section 2.1, the framework treats learning-outcome specification (Step 1) and outcome-mapped content selection (Step 3) as prerequisites for meaningful immersion, consistent with CAMIL's emphasis on aligning technological affordances with intended cognitive outcomes rather than deploying XR for novelty alone. The steps are:

1. Identify Learning Outcomes: Define pedagogical objectives and target engagement levels, ensuring alignment with programme-level graduate attributes.
2. Assess Available XR Technologies: Evaluate the spectrum of XR options (VR, AR, MR) against institutional budget and infrastructure resources.
3. Curriculum Integration: Map selected XR experiences to existing curriculum units, selecting content most appropriately delivered through immersive modalities.
4. Develop a Pilot Programme and Training: Select a student cohort, co-design realistic scenarios, establish resource-sharing

protocols, and provide professional development for educators.

5. Implement the XR Experience: Schedule and facilitate XR sessions with attention to safety, inclusivity, and technical contingency.
6. Data Collection and Analysis: Systematically collect engagement data, learner feedback, and performance metrics to identify areas for improvement.
7. Refine and Scale: Adjust content and delivery based on evidence, then scale successful interventions across cohorts or disciplines.
8. Continuous Quality Improvement: Institute updates and long-term evaluation cycles to ensure sustained effectiveness and relevance.

The cyclical design of the framework reflects the iterative nature of OBE quality assurance and mirrors established continuous-improvement cycles such as Plan-Do-Study-Act (PDSA) and Deming's PDCA. Each step interlocks with adjacent steps through feedback mechanisms, ensuring that insights from data collection (Step 6) inform both immediate refinement (Step 7) and long-term quality improvement (Step 8), which in turn re-triggers outcome identification (Step 1) for subsequent cohorts or disciplines.

Integrating extended reality (XR) into outcome-based education

A step-by-step guideline

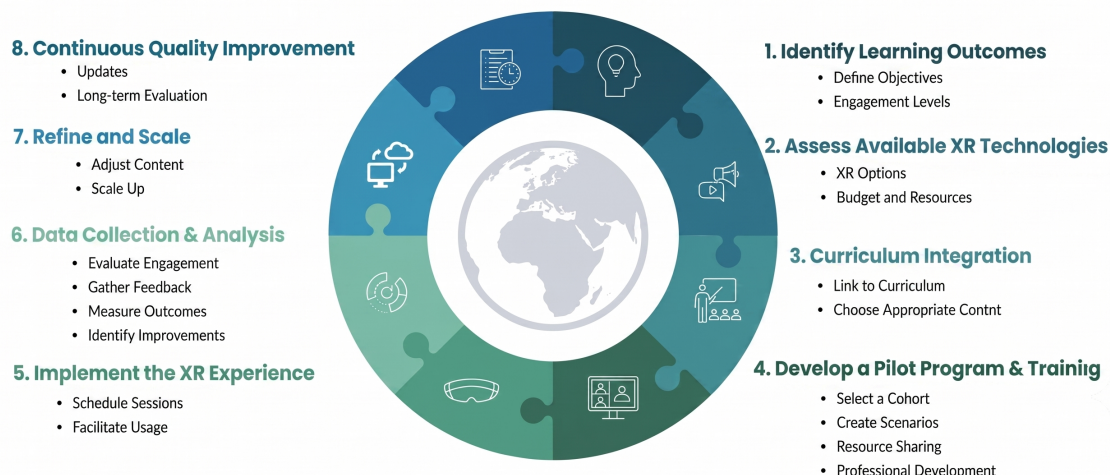


Figure 1. The Eight-Step XR-OBE Integration Framework (Sofiadin, 2025)

Table 2. Expert Panel Profile and Qualification Criteria

Expert	Designation	Institution	Domain	Years Exp.
E1	Professor / XR Researcher	Public University	XR & Immersive Learning	18
E2	Associate Professor	Public University	OBE & Curriculum Design	14
E3	Senior Lecturer	Public University	Educational Technology	7
E4	Instructional Designer	Higher Ed Institution	VR/AR Content Design	16
E5	Curriculum Specialist	Public University	OBE Policy & Quality	8
E6	XR Solutions Architect	Industry (XR Technology Firm)	XR Product Development & Deployment	10
E7	Professor	Public University	Instructional Design & Curriculum Evaluation	20

4. Proposed Expert validation Protocol

4.1. Research design

A mixed-methods validation design is proposed that combines quantitative CVI scoring with qualitative expert feedback and Delphi consensus rounds. This approach reflects best practices in educational framework validation (Grant & Davis, 1997; Yusoff, 2019) and ensures that both the statistical rigour of content validity measurement and the rich contextual insight of expert judgement are captured. To address a recognised weakness of CVI — its failure to adjust for chance agreement (Polit, Beck, & Owen, 2007), the design additionally incorporates a modified kappa statistic as a secondary reliability check (Section 5.1).

4.2. Expert Panel Composition

A panel of seven experts will be recruited through purposive sampling to ensure representation across the key domains relevant to the framework: XR technology, OBE curriculum design, educational technology, instructional design, and industry practice. The recommended expert profile is described in Table 2. Seven experts are consistent with Polit and Beck's (2006) recommendation for novel frameworks and provide statistical adequacy for CVI calculation; recruitment will draw on professional networks, relevant conference communities, and industry partners to ensure the panel spans both academic and applied XR expertise.

4.3. Inclusion Criteria for Expert Selection

To be included in the expert panel, candidates must satisfy a minimum of three of the following criteria:

- Holds a doctoral degree in a relevant field (Educational Technology, Computer Science, Curriculum Studies, or a related discipline)
- Has a minimum of five years of experience in XR development, XR research, or OBE implementation
- Has published at least two peer-reviewed articles in XR, immersive learning, or OBE within the past five years
- Has held a leadership role in curriculum design or technology integration at a recognised higher education institution
- Has demonstrable industry experience in XR product development for educational applications

Candidates with an unresolved conflict of interest with the research team (e.g., direct supervisory or co-authorship relationships within the preceding two years) will be excluded, consistent with the independence requirements typically expected of content-validity expert panels.

Table 3. Validation Instruments and Their Purposes

Instrument	Purpose	Key Criteria
Content Validity Index (CVI)	Measure relevance and clarity of each framework component	Item-CVI ≥ 0.78 ; Scale-CVI/Ave ≥ 0.90 ; modified kappa ≥ 0.74 (excellent)
Expert Judgement Rubric	Assess completeness and coherence of the 8-step guideline	Accuracy, Comprehensiveness, Feasibility, Alignment
Open-Ended Feedback Form	Capture qualitative suggestions and improvements	Thematic analysis via NVivo
Delphi Consensus Round	Achieve consensus on ambiguous or debated items	Consensus $\geq 70\%$; IQR < 1.5

Table 4. Expert Validation Protocol Phases

Phase	Activity	Description	Output
Phase 1	Expert Recruitment	Purposive sampling of 7 experts across XR, OBE, and EdTech domains	Expert Panel Confirmed
Phase 2	Document Review	Experts review framework document, background literature, and visual guideline (Figure 1)	Annotated Feedback
Phase 3	Structured Validation Survey	Likert-scale rating (1–5) on content validity, clarity, feasibility, and OBE alignment	CVI Scores, Modified Kappa, and Ratings
Phase 4	Focus Group Discussion	Online FGD to discuss findings, resolve ambiguities, and refine components	Consensus Minutes
Phase 5	Delphi Round (if needed)	Second-round survey for items with low consensus ($< 70\%$)	Final Consensus Data
Phase 6	Framework Refinement	Revise framework based on expert input; produce validated version	Validated XR-OBE Framework

4.4. Validation Instruments

Four complementary instruments will be deployed across the validation phases to ensure comprehensive triangulation of expert judgement. These are summarised in Table 3.

The primary instrument is a structured validation survey comprising: (a) a five-point Likert scale rating each framework component on relevance, clarity, completeness, and feasibility; (b) a CVI rating question (relevant / not relevant) for each of the 8 steps and their sub-components; and (c) open-ended fields for elaborative comments and suggestions. Prior to full deployment, the survey will be piloted with two experts outside the main panel to assess item clarity and completion time, consistent with recommended instrument development practices (Grant & Davis, 1997). The survey will be administered digitally via a secure, purpose-built form and, if Delphi iteration is required, in two rounds.

4.5. Validation Phases

The validation process is structured across six phases to ensure systematic, traceable, and defensible evidence generation, with an indicative overall duration of four to six months. The phased protocol is outlined in Table 4.

Each phase is designed with explicit entry and exit criteria, following Diamond et al.'s (2014) recommendation that Delphi protocols pre-register stopping rules. For instance, Phase 3 proceeds only after all seven experts have confirmed receipt of the framework document; Phase 5 (Delphi) is triggered only if any item achieves fewer than 70% expert agreement in Phase 3. This conditional logic minimises unnecessary burden on experts while ensuring rigour.

4.6. Evaluation Criteria and Dimensions

The validation process will assess the framework across six core dimensions, as detailed in Table 5. These dimensions collectively address the intellectual rigour, practical applicability, and pedagogical grounding of the XR-OBE framework.

Table 5. Validation Dimensions, Indicators, and Methods

Dimension	Indicators	Validation Method
Content Validity	Relevance, accuracy, and completeness of each step	CVI rating per item
OBE Alignment	Mapping of XR activities to learning outcomes and competencies	Expert rubric scoring
Technological Feasibility	Practicability of XR options given typical HEI resource constraints	Open-ended feedback + FGD
Pedagogical Soundness	Grounding in constructivist, experiential, and cognitive-affective (CAMIL) learning theory	Expert judgement rubric
Scalability & Sustainability	Potential for long-term adoption across disciplines	Delphi consensus
Clarity & Usability	Comprehensibility of the step-by-step guideline for practitioners	Cognitive walkthrough + FGD

5. Data Analysis Plan

5.1. Quantitative analysis

Item-level CVI (I-CVI) scores will be computed for each of the 8 framework steps and their constituent sub-components by dividing the number of experts rating an item as relevant (4 or 5 on the Likert scale) by the total number of experts. Items with I-CVI below 0.78 will be flagged for revision or elimination. The Scale-level CVI averaging method (S-CVI/Ave) will be computed as the mean of all I-CVI scores; a threshold of ≥ 0.90 will be required for the overall framework to be considered content-valid (Polit & Beck, 2006). Because raw CVI does not correct for the probability that experts agree by chance, each I-CVI will additionally be converted to a modified kappa statistic (κ^*) following Polit, Beck, and Owen (2007), with $\kappa^* \geq 0.74$ interpreted as excellent agreement, 0.60–0.73 as good, and 0.40–0.59 as fair.

Descriptive statistics (mean, standard deviation, interquartile range) will be reported for all Likert-scale ratings across the six

validation dimensions. Where Delphi rounds are conducted, convergence will be assessed using the interquartile range (IQR); consensus is defined as $IQR < 1.5$ with $\geq 70\%$ of experts in agreement, consistent with the stopping-rule pre-registration recommended by Diamond et al. (2014).

5.2. Qualitative analysis

Open-ended feedback from the expert survey and FGD transcript data will be subjected to thematic analysis following Braun and Clarke's (2006) six-phase framework, facilitated by NVivo software. Initial codes will be generated inductively, then organised into themes that map to the six validation dimensions. Member-checking will be conducted by sharing thematic summaries with expert panellists before finalisation.

The integration of quantitative CVI/kappa scores and qualitative thematic findings will follow a convergent mixed-methods design (Creswell & Plano Clark, 2018), with quantitative results prioritised for decisions on framework retention, revision, or elimination of components, and qualitative findings used to contextualise and enrich the rationale for revisions.

5.3. Trustworthiness and Rigour

Because the protocol combines quantitative content-validity indices with qualitative expert judgement, trustworthiness will also be assessed against Lincoln and Guba's (1985) four naturalistic inquiry criteria. Credibility is addressed through methodological triangulation across CVI, Delphi, and FGD data sources, as well as through member checking of thematic summaries. Transferability is supported by a thick description of the Malaysian HEI, MQA accreditation, and the MySTIE/Ekonomi MADANI policy context in which the framework is situated, enabling readers in other jurisdictions to assess its applicability to their own settings. Dependability is established through an auditable trail of Delphi-round data, survey versions, and a documented revision log linking each framework change to its supporting evidence. Confirmability is supported by involving researchers not directly engaged in framework development in the coding of open-ended responses, reducing the risk that thematic interpretation is shaped solely by the framework's original authors.

6. Ethical Considerations

All expert participants will provide written informed consent before participation. Participation is voluntary, with the right to withdraw at any stage without consequence. Expert identities will be anonymised in publications, and individual responses will be reported only in aggregate; identifiable data will be stored on access-controlled institutional servers for the duration required by IIUM data-retention policy and then securely destroyed. The study will seek ethical clearance from the IIUM Institutional Research Ethics Committee (IREC) before data collection. Expert panel members with prior working relationships with the research team will be identified through a conflict-of-interest declaration, and their data will be analysed separately to assess any influence on the results.

7. Expected Outcomes and Contributions

Upon completion of the validation protocol, the study anticipates the following outcomes:

- A validated, eight-step XR-OBE integration framework with documented CVI and modified-kappa scores, expert consensus data, and a detailed revision log.

- A reusable, open-access expert validation protocol that can be adapted for validation of other educational-technology frameworks in the Malaysian and broader ASEAN higher education context.
- A peer-reviewed publication presenting validation evidence to the academic community, contributing to the nascent literature on XR framework development and validation, and to the emerging comparative literature exemplified by XR2Learn (Karachristos et al., 2026).
- Practical guidelines for higher education practitioners seeking to adopt the framework, informed by expert-identified implementation considerations and feasibility caveats.

Theoretically, this study contributes to the field of Educational Technology by demonstrating how triangulated, chance-corrected expert validation can be applied systematically to immersive learning frameworks, and by explicitly connecting procedural framework design to cognitive-affective learning theory (CAMIL) and outcomes-based accreditation logic (MQA, 2024). In practice, it provides IIUM's FRGS-EC research project (Reference: FRGS-EC/1/2024/ICT09/UIAM/03/1) with a validated instrument, ready for subsequent empirical field trials in collaboration with industry partners such as GamesMy.

8. Limitations and Future Directions

The proposed validation protocol has several acknowledged limitations. First, the expert panel of seven, while statistically adequate for CVI computation, limits the breadth of perspectives that may be captured compared with larger panels, such as XR2Learn's 20 specialists (Karachristos et al., 2026); future work may employ a larger, internationally representative panel. Second, content validity, while necessary, is not sufficient to establish construct or predictive validity; this paper therefore positions expert validation as a precursor to a full empirical field trial with student participants, mirroring the transitional conceptual-to-classroom trajectory that XR2Learn itself is only beginning to undertake. Third, the cultural and institutional specificity of the Malaysian HEI context, including MQA accreditation requirements and MySTIE Education mandates, means that direct transferability to other national contexts must be approached with caution, notwithstanding the transferability safeguards outlined in Section 5.3.

Future research directions include: (1) empirical field testing of the validated framework in multiple IIUM faculties; (2) co-development of XR content aligned with the framework in partnership with GamesMy; (3) longitudinal evaluation of the framework's impact on graduate-attribute achievement; and (4) adaptation of the framework for secondary education and vocational training contexts under the Ekonomi MADANI human-capital development agenda.

9. Conclusion

This paper has presented a structured expert validation protocol for an eight-step XR-OBE integration framework, addressing a critical methodological gap in the literature on immersive technologies in higher education, a gap that persists even in the most recent general-purpose XR instructional-design frameworks such as XR2Learn. By combining Content Validity Index measurement with a chance-corrected modified kappa check, expert judgement rubrics, focus group discussions, and Delphi consensus methodology, and by grounding the analytical plan in established

trustworthiness criteria, the proposed protocol offers a rigorous, transparent, and reproducible approach to framework validation. The resulting validated framework will provide higher education institutions with an evidence-based, practitioner-ready roadmap for systematically integrating XR technologies into OBE curricula, with the potential to enhance graduate competency attainment in the digital era meaningfully.

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The Silent Architects: Governance, Observability, and Trust in Finance Digital Data Foundations

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Abstract

Modern financial systems depend on complex digital data pipelines that support regulatory reporting, enterprise analytics, and AI-driven decision-making. However, trust in these systems cannot be achieved through policy and audit alone, particularly in environments characterised by automated transformations, distributed ownership, and high-velocity data movement. This paper introduces a governance-embedded finance digital data foundation that unifies stewardship, privacy-by-design, lineage, and data observability as core architectural capabilities. The proposed framework shifts governance from static oversight to continuous verification by making control effectiveness observable at runtime. Using enterprise-scale case evidence from real-world financial data ecosystems, the paper demonstrates how observable governance improves audit readiness, strengthens provenance for explainable analytics, reduces time-to-detect and time-to-remediate data issues, and increases stakeholder confidence in AI-driven insights. The paper concludes by outlining research directions for real-time governance observability, AI-assisted stewardship, cross-domain validation, and standardised governance maturity models.

Data Governance

Data Observability

Financial Data Foundations

Data Stewardship

Privacy-by-Design

Data Lineage

AI Trustworthiness

AI USE STATEMENT

No generative AI was used for analysis or results.

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The Silent Architects: Governance, Observability, and Trust in Finance Digital Data Foundations

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Abstract

Modern financial systems depend on complex digital data pipelines that support regulatory reporting, enterprise analytics, and AI-driven decision-making. However, trust in these systems cannot be achieved through policy and audit alone, particularly in environments characterised by automated transformations, distributed ownership, and high-velocity data movement. This paper introduces a governance-embedded finance digital data foundation that unifies stewardship, privacy-by-design, lineage, and data observability as core architectural capabilities. The proposed framework shifts governance from static oversight to continuous verification by making control effectiveness observable at runtime. Using enterprise-scale case evidence from real-world financial data ecosystems, the paper demonstrates how observable governance improves audit readiness, strengthens provenance for explainable analytics, reduces time-to-detect and time-to-remediate data issues, and increases stakeholder confidence in AI-driven insights. The paper concludes by outlining research directions for real-time governance observability, AI-assisted stewardship, cross-domain validation, and standardised governance maturity models.

Keywords: *Data Governance, Data Observability, Financial Data Foundations, Data Stewardship, Privacy-by-Design, Data Lineage, AI Trustworthiness, Regulatory Compliance*

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1. Introduction

In modern financial ecosystems, the credibility of analytics, regulatory reporting, and AI-driven decision-making depends less on algorithmic sophistication than on the trustworthiness of the data foundations beneath them. Yet the work that sustains this trust—data stewardship, governance engineering, lineage design, privacy-by-design enforcement, and data observability—often remains invisible to decision makers until failure occurs. Reconciliation discrepancies, audit findings, consent violations, and unexplainable AI outputs typically expose weaknesses that originate not in analytical models, but in inadequately governed data foundations.

This paper argues that these “silent architects” fundamentally shape the reliability of enterprise intelligence. It further contends that governance must evolve from a retrospective compliance overlay into a continuously verifiable system capability. To this end, the paper proposes a governance-embedded framework for finance digital data foundations that integrates stewardship, privacy, lineage, and data observability as first-class architectural properties. Using enterprise-scale case evidence, the study demonstrates how observable governance improves auditability, strengthens explainability, and enhances organisational trust while enabling scalable analytics and responsible AI.

1.1. Background and Motivation

Modern financial systems operate at unprecedented scale, velocity, and complexity. Trillions of dollars in transactions flow through digital pipelines spanning cloud platforms, distributed data stores, streaming architectures, and AI-enabled analytics layers. These systems no longer support internal reporting alone; they increasingly underpin regulatory filings, tax remittance, consumer protection programmes, and automated financial decision-making with material economic and societal impact.

As financial data ecosystems expand, expectations for trust, transparency, and accountability have intensified. Regulators require end-to-end traceability of financial records, demonstrable internal controls, and verifiable enforcement of privacy and consent obligations. At the same time, organisations rely on advanced analytics and machine learning to improve forecasting accuracy, fraud detection, and operational efficiency.

These dual pressures—regulatory rigour and analytical ambition—have exposed a persistent weakness in many data architectures. Governance is frequently implemented as an external overlay rather than as an intrinsic system capability. Traditional governance approaches emphasise policies, periodic controls testing, and retrospective audits. While necessary, these mechanisms prove insufficient in environments where data pipelines evolve continuously, transformations occur automatically, and decision-making increasingly happens in near real time.

In such contexts, governance must shift from static assurance to continuous, observable control that operates alongside the data itself. This paper argues that data observability, when integrated with governance and stewardship, constitutes the critical missing pillar that enables continuous verification of trust in finance digital data foundations.

1.2. Problem Statement

Despite sustained investment in modern data platforms, many organisations continue to experience governance failures that manifest across four interrelated dimensions.

First, reference data governance remains fragile. Inconsistent definitions, uncontrolled change processes, and unclear ownership propagate errors into downstream reconciliation, reporting, and analytics pipelines. Without real-time visibility into dependency impacts, reference data drift becomes a systemic risk.

Second, lineage and auditability frequently remain incomplete or retrospective. Organisations often maintain static lineage documentation that fails to reflect runtime execution. When auditors request evidence explaining how a financial figure was produced, teams must reconstruct provenance manually. This process increases cost, delay, and operational risk.

Third, consent and privacy controls are often enforced only at access boundaries. Once data enters complex pipelines, organisations struggle to demonstrate that privacy-by-design requirements remain intact across the full lifecycle, particularly as data is transformed, aggregated, and reused.

Fourth, AI explainability and trust deteriorate when data foundations lack transparency. Models trained or evaluated on inadequately governed pipelines inherit ambiguity that cannot be resolved at the model layer alone. In many cases, explainability failures originate upstream, in undocumented transformations, ambiguous definitions, or unmonitored drift.

These failures share a common root cause: governance intent remains disconnected from operational reality. Without continuous visibility into data health, lineage execution, and control effectiveness, governance remains aspirational rather than enforceable.

1.3. Research Objectives and Contributions

This paper advances a governance-embedded finance digital data foundation that unifies stewardship, privacy-by-design, lineage, and observability.

The primary contributions are as follows:

1. A formal definition of **Finance Digital Data Foundations** as governed, observable, and audit-ready architectures that support regulatory compliance and enterprise intelligence.
2. A layered **Governance and Observability Framework** that embeds controls directly into data pipelines and makes control effectiveness continuously observable.
3. An evaluation methodology with explicit metrics spanning audit readiness, data quality, consent enforcement, and explainability outcomes.
4. Enterprise-scale case evidence demonstrating how observable governance improves trust, reduces risk, and strengthens analytical credibility.

2. Related Work and Literature Review

2.1. Governance in Financial Systems

Data governance literature has traditionally emphasised organisational roles, stewardship operating models, and policy frameworks. In regulated financial contexts, governance is closely associated with internal controls, auditability, and risk management. However, much of the literature remains policy-centric and struggles to address operational challenges in distributed, high-velocity data ecosystems.

Recent approaches advocate governance-by-design and metadata-driven enforcement. Nevertheless, these efforts often underemphasise runtime verification and continuous monitoring. As a result, they provide limited capability to detect drift or degradation in control effectiveness.

2.2. Lineage, Provenance, and Auditability

Lineage is central to auditability in financial systems. Prior research distinguishes between design-time lineage and operational (runtime) lineage. In practice, organisations frequently rely on design-time artefacts that become outdated as pipelines evolve.

Auditors increasingly require evidence of actual execution paths rather than conceptual diagrams. This requirement motivates lineage as a continuously captured system capability rather than a static documentation exercise.

2.3. Privacy-by-Design and Consent Artefacts

Privacy engineering literature highlights principles such as data minimisation, purpose limitation, and consent-driven processing. However, consent is often treated as a static ingestion attribute rather than a lifecycle constraint that must be enforced across transformations and downstream use.

Without observable consent propagation, organisations cannot convincingly demonstrate compliance across complex data pipelines.

2.4. Data Observability and Enterprise Intelligence

Data Observability, originating in systems engineering, focuses on inferring internal system state through telemetry such as metrics, logs, and traces. Applied to data systems, observability encompasses freshness, completeness, schema change, distribution drift, and pipeline performance.

Although observability has gained traction for operational reliability, its integration with governance and regulatory assurance remains underexplored. This paper positions observability as the mechanism that closes the loop between governance intent and verifiable system behaviour.

3. Finance Digital Data Foundations

3.1. Definition and Scope

A **Finance Digital Data Foundation** is the integrated architectural layer that ensures financial data is accurate, traceable, privacy-compliant, and continuously observable from source systems through analytical and AI consumption layers. It supports core financial domains, including transactions, subledgers, payment processing, reference data, and regulatory reporting datasets.

3.2. Foundational Design Principles

Effective finance digital data foundations are guided by five principles:

- **Accuracy:** Data must reflect transactional reality through controlled transformations.
- **Traceability:** Each data element must possess defensible provenance and lineage.
- **Privacy-by-Design:** Consent and protection mechanisms must be embedded and enforceable.
- **Observability:** Data health and control effectiveness must remain continuously visible.
- **Intelligence Enablement:** Governed data must support analytics and AI without compromising trust.

3.3. The “Silent Architects”

The integrity of finance digital data foundations depends on professionals whose work remains largely invisible in dashboards and reports. These include data stewards, governance engineers, privacy architects, and observability designers.

Their contribution does not lie in producing insights directly. Instead, they ensure that insights remain auditable, explainable, and compliant.

4. Governance and Observability Framework

4.1. Framework Overview

The proposed **Governance and Observability Framework** integrates governance intent, architectural enforcement, and continuous verification. It comprises three tightly coupled layers:

- **Policy and Control Layer:** Defines requirements and accountability.
- **Architecture and Enforcement Layer:** Embeds controls into pipelines and access paths.
- **Observability and Stewardship Layer:** Monitors data behaviour and control effectiveness at runtime.

This structure shifts governance from retrospective validation to continuous assurance.

4.2. Policy and Control Layer

The policy layer translates regulatory and business requirements into enforceable control objectives. It includes reference data standards, traceability obligations, consent and privacy constraints, and stewardship ownership mappings.

Importantly, policies are designed to be operationalised. They are expressed in forms that systems can enforce and observability mechanisms can verify.

4.3. Architecture and Enforcement Layer

4.3.1. Reference Data Governance

Reference data is treated as a governed product. Publishing workflows include validation checkpoints, versioning controls, and dependency-aware change impact analysis.

4.3.2. Lineage as an Executable Capability

Lineage is captured as runtime evidence rather than static diagrams. Each transformation emits metadata that records source dependencies, execution context, and derivation logic. This approach enables audit-ready provenance reconstruction and strengthens explainability.

4.3.3. Consent and Privacy Enforcement

Consent and privacy constraints are enforced across lifecycle stages: ingestion, transformation, consumption, and AI workflows. This ensures that privacy-by-design principles remain intact throughout data use.

4.4. Observability and Stewardship Layer

4.4.1. Observability Dimensions

Observability spans five dimensions: data quality, lineage execution, control effectiveness, drift detection, and usage transparency.

4.4.2. Stewardship as a Control-Response System

Stewardship operates as an active control-response system. Observability signals trigger detection, triage, remediation, and verification workflows. Each remediation action generates auditable evidence, enabling governance to function as a closed-loop control system.

5. Methodology

5.1. Research Design

This study follows a design science research approach that combines framework development with enterprise-scale application and evaluation.

5.2. Context

The framework was applied in large financial data ecosystems characterised by high transaction volumes, multi-domain datasets, regulatory reporting requirements, and advanced analytics and AI consumption patterns.

5.3. Procedure

The research followed four stages: baseline assessment, framework embedding, operationalisation, and evaluation.

5.4. Evaluation Metrics

Metrics assessed governance coverage, audit readiness, data quality, privacy enforcement, and analytics and AI trust.

6. Enterprise-Scale Case Evidence

The framework was deployed iteratively across high-risk financial domains. Observed outcomes included reduced audit preparation effort, faster detection of data issues, improved remediation cycles, and increased confidence in analytical and AI outputs.

7. Discussion

7.1. Governance as an Enabler of Enterprise Intelligence

The results suggest governance is not inherently a constraint. When embedded and observable, governance becomes an enabling foundation that supports scalable analytics, reduces operational risk, and increases organizational trust in decision outputs.

7.2. Observability and Explainable AI

This study reinforces that explainability is inseparable from data provenance. Where data foundations are opaque, model-level explainability techniques cannot fully satisfy auditability or trust requirements. Observability provides the empirical grounding that makes explainability defensible.

7.3. Organizational Adoption

Operationalizing governance requires elevating stewardship as a design discipline and integrating governance responsibilities into engineering workflows. Observability helps sustain adoption by making control effectiveness measurable, enabling performance management and continuous improvement.

7.4. Limitations

Implementation complexity varies with platform maturity, organizational structure, and regulatory scope. While the framework is tool-agnostic, adoption requires cross-functional alignment and disciplined operational practices. Additional multi-industry validation would strengthen generalizability.

8. Future Research Directions

Several research directions emerge from this work.

First, **AI-assisted stewardship** warrants systematic investigation. Governance agents could monitor observability telemetry, detect anomalies, generate impact analyses, and recommend remediation—improving response consistency while preserving human accountability for decisions.

Second, **real-time governance observability** in streaming architectures is increasingly necessary. As financial decisioning shifts toward real-time risk scoring and event-driven compliance, research into low-latency lineage capture, streaming consent enforcement, and continuous compliance validation becomes essential.

Third, **cross-domain comparative studies** could test generalizability in healthcare, public sector, and critical infrastructure—domains that share regulatory and ethical constraints but differ in data semantics and operational rhythms.

Finally, the field needs **standardized maturity models and benchmarks** for governance observability. Future research should formalize measurable readiness standards that allow organizations to assess observability coverage, governance effectiveness, and AI trustworthiness consistently across institutions.

9. Conclusion

This paper reframes data governance from a retrospective compliance obligation into a proactive architectural capability that underpins trustworthy financial intelligence. By integrating governance, stewardship, privacy-by-design, and data observability into a unified finance digital data foundation, organizations can achieve continuous assurance, regulatory readiness, and analytical credibility at scale.

The evidence indicates that many failures attributed to analytics or AI originate upstream—in data foundations lacking traceability, visibility, and enforceable controls. Observability emerges as the mechanism that transforms governance intent into verifiable system behavior, enabling earlier detection of drift, validation of control effectiveness, and proactive remediation before issues escalate into audit findings or operational failures.

Equally important is recognition of the “silent architects” whose work makes enterprise intelligence trustworthy. Elevating governance and stewardship to first-class system design disciplines is not merely an operational refinement; it is a strategic requirement for institutions that seek to responsibly harness advanced analytics and AI in regulated environments. As financial systems grow in complexity and societal importance, the capacity to build **observable, governed, and ethically grounded data foundations** will define not only technical excellence but institutional trust itself.

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Desarrollo de un Modelo de Inteligencia de Negocio para la Gestion Comercial en una Empresa del Sector Alimenticio

Development of a Business Intelligence Model for Commercial Management in a Food Sector Company

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Abstract

Companies generate large volumes of data through transactional systems, but they are not always able to centralize and analyze them effectively for strategic decision-making. In the mass consumption food industry, and particularly in the coffee sector in Ecuador, the market and competition demand a data-driven approach to identify trends, growth opportunities, and more accurately analyze consumer behavior. In this context, a company dedicated to the production and marketing of coffee faces the need to improve its commercial management through the use of business intelligence. The main problem lies in the dispersion of information from various sources, which makes it difficult to access up-to-date and understandable reports. Therefore, this research develops a business intelligence model that facilitates data consolidation and optimizes commercial management. Finally, when evaluating its implementation with the company's strategic commercial area, it was confirmed that this solution contributes to more secure, agile, and reliable decision-making based on accurate and timely information.

analysis

Data

decision

modeling

visualization

AI USE STATEMENT

No generative AI was used for analysis or results.

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Abstract

Las empresas generan grandes volúmenes de datos a través de sistemas transaccionales, pero no siempre logran centralizarlos ni analizarlos de manera efectiva para la toma de decisiones estratégicas. En la industria alimentaria del consumo masivo, y particularmente en el sector del café en Ecuador, el mercado y la competencia exigen un enfoque basado en datos para identificar tendencias, oportunidades de crecimiento y analizar con mayor precisión el comportamiento del consumidor. En este contexto, una empresa dedicada a la producción y comercialización de café enfrenta la necesidad de mejorar su gestión comercial mediante el uso de la inteligencia de negocios. El principal problema radica en la dispersión de información proveniente de diversas fuentes, lo que dificulta el acceso a informes actualizados y comprensibles. Por ello en esta investigación se desarrolla un modelo de inteligencia de negocios que facilite la consolidación de datos y optimice la gestión comercial. Finalmente, al evaluar su implementación con el área estratégica comercial de la empresa, se validó que esta solución contribuye a la toma de decisiones más seguras, ágiles y confiables basadas en información precisa y oportuna.

Keywords: Datos, visualización, decisión, análisis, modelado

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1. Introducción

En la actualidad, las organizaciones producen una gran cantidad de datos que son administrados mediante distintos sistemas transaccionales. La capacidad de recolectar, procesar y aprovechar esta información de manera eficiente constituye una ventaja competitiva para las empresas en un entorno cada vez más dinámico y orientado por los datos (Niu et al., 2021). La integración de los datos y su evaluación desde múltiples enfoques son fundamentales para la toma de decisiones estratégicas, permitiendo abordar cuestiones clave como las preferencias de los consumidores, las tendencias del mercado y las estrategias de la competencia (Ramírez et al., 2021). Negro (2020) evidencia la importancia de la recopilación de datos internos y externos, que, tras un proceso de evaluación y validación, se convierte en información especializada que se integra como conocimiento e influye en la toma de decisiones.

En este contexto, se considera la inteligencia de negocios como un sistema integral en una organización que oferta una variedad de servicios y funciones para ayudar al entendimiento y comprensión de lo que ocurre por medio de los datos, a través de informes o tableros, evaluando y controlando a través de indicadores que ayuden a tomar decisiones oportunas (Slusarczyk, 2024). La analítica empresarial, un término acuñado originalmente por la industria, es la síntesis de aquellas herramientas destinadas a convertir datos (grandes o pequeños, estructurados o no estructurados) en información procesable mediante un proceso científico, matemático e inteligente (Delen y Ram, 2018).

El uso de una herramienta de inteligencia de negocio ofrece múltiples beneficios para los negocios, otorgando un panorama amplio en el entendimiento y la trazabilidad de la empresa, así como la obtención inmediata de conclusiones al momento de hacer un análisis. El éxito de su implementación depende de la extracción de los datos, arquitectura de las bases de datos, y carga de información, así como del diseño de los reportes y cuadros de mando. El uso rutinario e innovador de sistemas de inteligencia empresarial (BI) impulsa el marketing, ventas, gestión, operaciones y compras en las PYMEs, generando un valor tangible y mejorando significativamente el rendimiento empresarial (Popovič et al., 2019).

Particularmente, la industria alimenticia ha evolucionado con rapidez gracias a la tecnología y herramientas estratégicas que facilitan la negociación y la adaptabilidad ante un mercado competitivo. Esta evolución ha sido impulsada por el cambio constante, repetitivo y veloz en los patrones de consumo, con una creciente inclinación hacia opciones saludables y sostenibles, y la aplicación de inteligencia de negocios permite tomar decisiones estratégicas en alimenticio mediante el análisis de las preferencias, ventas y comportamiento del cliente (Uribe, 2024). Asimismo, la adecuada explotación de la información permite a las empresas identificar necesidades comunes, como conocer a los distintos perfiles de clientes, a la competencia, a los proveedores y a los consumidores (Olayinka, 2021). Por ello, es fundamental que la empresa objeto de esta investigación mantenga su liderazgo, crecimiento y desarrollo sostenido en el mercado ecuatoriano, con miras a superar las barreras nacionales mediante el uso estratégico de la inteligencia de negocios. El sector del café en

el Ecuador sufre altos costos, baja productividad y escaso apoyo a pequeños productores, afectando su participación internacional y contribuyendo solo con el 0.7% al PIB nacional (Buri et al., 2023). Pese a ello, debido a los altos precios del café a nivel mundial, se prevé que el mercado del café alcance los 96,450 millones de dólares estadounidenses en 2025 en términos de consumo en el hogar (PROECUADOR, 2025).

El presente proyecto de investigación se aplica a una empresa ecuatoriana dedicada a la producción y comercialización de café tostado y molido, con más de 60 años de trayectoria, que enfrenta el reto de mejorar su gestión comercial. Actualmente, la información generada por las diferentes áreas operativas se encuentra dispersa en múltiples fuentes y formatos, lo que limita su análisis oportuno y dificulta la toma de decisiones basada en datos, y se carece de un sistema de seguimiento a los indicadores de desempeño. Para ello, se plantea la implementación de un modelo de inteligencia de negocios que permita integrar, transformar y visualizar la información relevante de manera sistemática. La aplicación de la inteligencia de negocios contribuirá a que la empresa pueda mantener su liderazgo en el mercado nacional del café y explorar oportunidades de expansión incluyendo a nivel internacional.

Con este fin, se propone desarrollar un modelo de inteligencia de negocio para la gestión comercial y la toma de decisiones para el área estratégica, explicando los fundamentos teóricos aplicados a la gestión comercial y su contribución en la toma de decisiones estratégicas, diseñando una herramienta informática de negocios, implementándola en la empresa y validando su efectividad para facilitar la toma de decisiones estratégicas.

2. Metodología

La presente investigación busca desarrollar e implementar un modelo de Inteligencia de Negocios en una empresa del sector alimenticio ecuatoriana, con el propósito de mejorar la toma de decisiones comerciales estratégicas. Para ello, se adopta un enfoque cualitativo, basado en la retroalimentación de los líderes estratégicos de la empresa. El estudio es de tipo aplicado, ya que se orienta a la creación de una herramienta informática que optimice la gestión comercial mediante el análisis y procesamiento de datos clave.

La población de estudio está conformada por los 117 colaboradores de la empresa al cierre del 2024. la naturaleza del estudio exige trabajar específicamente con informantes clave que posean conocimiento especializado sobre los procesos comerciales y la toma de decisiones. Por ello, en lugar de considerar a toda la población general, se define una población experta, conformada por los líderes del área comercial estratégica. Dentro de esta población experta se selecciona una muestra intencional de 11 participantes, incluyendo gerencia, jefaturas y responsables de planificación comercial. La selección responde a criterios de experiencia, rol estratégico e intervención directa en el uso y gestión de información para la toma de decisiones, lo cual garantiza la pertinencia del análisis cualitativo.

La recopilación de información se llevará a cabo a través de encuestas dirigidas a estos líderes, las cuales estarán estructuradas en cinco categorías y contendrán 25 preguntas, evaluadas mediante la escala de Likert con rangos de 1 a 5. Este instrumento permitirá obtener datos relevantes sobre la situación actual de la gestión y almacenamiento de información en la empresa.

Las variables de estudio incluyen aspectos como la estrategia organizacional, la gestión de datos, la aplicación de Inteligencia de Negocios, el uso de tecnologías para la gestión de procesos y

la identificación de indicadores comerciales. Estas variables han sido definidas con base en el marco teórico de la investigación y permitirán evaluar el impacto de la herramienta informática en la optimización de la toma de decisiones dentro de la empresa.

Para garantizar la validez del instrumento de medición, se aplicará el coeficiente V de Aiken. Este método evaluará la pertinencia de cada pregunta dentro de la encuesta, asegurando que los datos recopilados sean confiables y reflejen con precisión la realidad de la empresa. Un resultado próximo a 1 indicará una alta validez de las preguntas, mientras que valores cercanos a 0 señalarán la necesidad de ajustes en su formulación.

La adecuada gestión de datos es fundamental para que la empresa pueda desarrollar estrategias basadas en información precisa y actualizada. Un modelo eficiente de Inteligencia de Negocios permitirá analizar la evolución comercial, predecir tendencias y mejorar la toma de decisiones en tiempo real. Con la correcta selección de indicadores comerciales y el uso de herramientas tecnológicas adecuadas, la empresa podrá fortalecer su competitividad y alcanzar un crecimiento sostenible en su sector.

3. Resultados

Para desarrollar el modelo de inteligencia de negocios, es necesario contar con objetivos claros. Los resultados de la encuesta aplicada evidencian que la empresa cuenta con necesidades en torno al análisis de los datos comerciales. El coeficiente V de Aiken es de 0.92, lo que indica un alto nivel de validez de contenido según la evaluación de los expertos. La tabla 1 incluye los promedios para cada dimensión medida en la encuesta.

La primera dimensión evaluada se enfoca en cómo la empresa integra el uso de los datos en su estrategia comercial para lograr sus objetivos y evalúa si la información histórica es parte de la planificación estratégica. De forma detallada, la mayoría de los encuestados (81,82%) reconoce que los datos de clientes, así como de los productos que compran y/o consumen son fundamentales para la toma de decisiones estratégicas. La inteligencia de negocios está alineada con los objetivos organizacionales, lo que refuerza la importancia de la tecnología en la gestión comercial. El uso de herramientas informáticas es ampliamente valorado, con un 72,73% de encuestados indicando que siempre contribuye al cumplimiento de objetivos estratégicos. No obstante, aunque el análisis de datos en la planificación estratégica es una práctica frecuente, aún el 9,09% menciona no considerarlo, lo que representa una oportunidad de mejora en la integración de herramientas analíticas.

La segunda dimensión, gestión de los datos, analiza cómo la empresa administra, almacena y gestiona sus datos. Aunque el 45,45% indica que los datos se almacenan de forma centralizada y existe cierta claridad sobre sus fuentes, aún persiste una gestión dispersa y poco estructurada. Solo el 18,18% afirma que existen políticas claras de calidad de datos y que los análisis se realizan de manera oportuna. El uso de herramientas avanzadas como análisis predictivo y aprendizaje automático es limitado, lo que resalta la necesidad de fortalecer la infraestructura analítica y la cultura de datos.

La importancia de la inteligencia de negocios en la toma de decisiones evalúa si la empresa considera a la inteligencia de negocios como un elemento importante al momento de tomar decisiones en el área comercial. La inteligencia de negocios es considerada un elemento clave en la toma de decisiones dentro de la empresa, especialmente en el área comercial. El 72,73% de los encuestados afirma que siempre genera un impacto positivo.

Table 1. Respuestas a la encuesta de diagnóstico

Dimensión	Siempre (%)	Casi Siempre (%)	Frecuentemente (%)	Algunas veces (%)	Nunca (%)
Estrategia organizacional	50.91	38.18	9.09	0.00	1.82
Gestión de los datos	20.00	40.00	21.82	14.55	3.64
Importancia del BI para la toma de decisiones	50.91	32.73	10.91	5.45	0.00
Uso de las tecnologías para la gestión de los procesos	16.36	34.55	27.27	10.91	10.91
Identificación de indicadores comerciales	47.27	45.45	7.27	0.00	0.00

Fuente: Abad y Desfrancois, (2025).

Un 81,82 % reconoce que los datos son un activo estratégico para el crecimiento organizacional, pero su aplicación práctica aún presenta limitaciones: solo el 36,36 % indica que se utilizan datos históricos para analizar tendencias de mercado y apenas un 27,27 % afirma que los líderes basan siempre sus decisiones en análisis de datos. Además, ante interrogantes complejas del negocio, el uso del análisis de datos no está plenamente consolidado, lo que evidencia que, aunque se valora la BI, su integración en la toma de decisiones aún es parcial y requiere fortalecimiento. Estos resultados reflejan que, aunque la empresa reconoce la importancia de la inteligencia de negocios y el valor estratégico de los datos, aún existen oportunidades de mejora para fortalecer su integración en la toma de decisiones diarias y en el uso de análisis avanzados para resolver problemáticas comerciales complejas.

La dimensión tecnológica examina si la empresa invierte y utiliza tecnologías informáticas para incrementar la eficiencia en sus procesos internos. Los resultados destacan que la empresa está comprometida con la modernización tecnológica, aunque los encuestados varían en su percepción sobre la frecuencia de las inversiones. Si bien el 54,55 % señala que se utilizan herramientas para generar visualizaciones como dashboards, solo el 27,27 % considera que la tecnología ha contribuido de forma constante a mejorar la eficiencia y productividad. La inversión en nuevas tecnologías es percibida como poco frecuente, ya que únicamente el 36,36 % indica que “frecuentemente” se realizan estas inversiones, y solo un 18,18 % afirma que se contempla de manera permanente en el presupuesto. El 9,09 % considera que la empresa cuenta siempre con tecnología actualizada. Estos datos evidencian que, aunque hay avances en visualización y ciertos procesos, aún es limitada la planificación tecnológica a largo plazo, lo que restringe el potencial transformador de la tecnología en la organización.

El monitoreo y actualización de estos indicadores es clave. Solo el 9,09% de los encuestados indica que los supervisa frecuentemente, el 54,55% casi siempre y el 36,36% lo hace de manera constante. La disponibilidad de la información comercial es alta: el 63,64% señala que siempre está accesible y actualizada. Respecto a la toma de decisiones, el 9,09% de los gerentes usa indicadores frecuentemente, el 54,55% casi siempre y el 36,36% siempre. También, el análisis de datos en el tiempo es una práctica común, con un 63,64% de encuestados que lo realizan regularmente. Aunque la empresa dispone de herramientas comerciales valiosas, su efectividad depende de su monitoreo y actualización continua para mejorar la toma de decisiones.

Identificación de las necesidades de la organización

Los resultados del diagnóstico concluyen que existen tres requerimientos principales que justifican la adopción del modelo de inteligencia de negocios. En primer lugar, la necesidad de centralizar la información, ya que los datos provienen de diversas fuentes y actualmente los procesos de consolidación son manuales, repetitivos y demandan tiempo, lo que limita la disponibilidad inmediata de información útil para la toma de decisiones. En

segundo lugar, se requiere automatizar los tableros de información comercial mediante la creación de dashboards dinámicos y comprensibles, que se actualicen automáticamente y faciliten el análisis, considerando que los miembros del área estratégica-comercial no siempre disponen del tiempo o conocimiento técnico para generar reportes individuales. Por otra parte, se busca mejorar la eficiencia operativa mediante la integración de la información centralizada con otras áreas de soporte como marketing, trade marketing y cobranzas, lo que permitirá atender oportunamente las demandas del negocio, identificar oportunidades de crecimiento y descubrir tendencias de mercado.

Fuentes de información y proceso ETL

Actualmente la información de la empresa reposa en diferentes fuentes de datos que incluyen el sistema de contabilidad, el sistema de monitoreo y gestión de personal de campo (impulsadoras y fuerza de ventas), sell out e inventarios de los diferentes sistemas de facturación de los clientes, diversas fuentes de participación, precios, descuentos, alcances de determinados clientes estratégicos y reportes de otras áreas y/o departamentos que son soporte para el área comercial. Se debe considerar que los datos procedentes de las diferentes fuentes mencionadas no son normalizados, por lo que necesita un tratamiento previo, validación y comprobación antes de cargarlos al depósito de datos que reposa en la nube de datos de Google Drive.

En la actualidad, es necesario para las organizaciones contar con un Data cuya función es almacenar datos sea de modo físico en servidores locales o en la nube. Esta segunda, es la más destacada ya que brinda mayor seguridad en la información, así como la reducción de espacios físicos que incluye infraestructura y demás equipos especializados, por lo que permite tener siempre respaldada la información ante cualquier adversidad. En este sentido, es la base de un sistema de información de una organización y en donde se almacenan los datos que requieren ser analizados y permite extraer de diferentes fuentes, limpiarlos y prepararlos para la generación de información así se podrá tener mayor confiabilidad a la hora de implementarlo en un proyecto de BI.

El modelo de inteligencia de negocios es fundamental para lograr el objetivo principal de esta empresa, por lo que se debe considerar el tipo o clase de datos que se almacenan. Para este caso, son estructurados y semi estructurados por lo que puede ajustarse con una combinación de modelos normalizado y no normalizado. Con esto, permitirá reducir la capacidad de almacenamiento, así como evitar la necesidad de relacionar muchas uniones entre tablas, reduciendo costos y tiempos respectivamente. La capacitación a los usuarios y clientes para el manejo del sistema y tableros de control es necesario ya que permite familiarizarlos con los ambientes que puedan encontrar, así como la interpretación y entendimiento de los resultados obtenidos. Por lo tanto, el éxito depende de la herramienta implementada que permita tomar decisiones en la empresa como lo considera. El modelo de inteligencia de negocios se realiza con el software Power BI,

que tiene las ventajas de permitir una integración profunda con el ambiente de Microsoft, realizar un modelado de datos avanzado y análisis predictivo y ampliar la compatibilidad con conexión a diversas fuentes de datos. El modelo de datos se representa en la figura 1.



Figure 1. Modelo de datos comerciales

Nota. La figura representa el modelo de datos en Power BI de la empresa comercial

Con respecto a la arquitectura actual de datos, se recomienda contar con los datos idóneos, con buena arquitectura, de calidad y centralizados, respondiendo las inquietudes que pueda tener una empresa dentro de la industria del café. Por lo tanto, es necesario que se defina un modelo que permita ajustarse considerando las necesidades o demanda por parte de la empresa y también considerando su volumen de datos. El análisis realizado destaca desafíos en términos de gestión y análisis de la información, y la oportunidad de implementar servicios más especializados de Google, debido a que en la actualidad se cuenta con varias fuentes de datos el cual empieza a generar inconvenientes por el volumen de información. Así también, en la ingesta y/o actualización de los datos se lo realiza de manera manual siendo la gran mayoría en formatos xls, csv y json entre otros, reemplazando ciertas bases de datos en determinados momentos especificados en el día o semana dependiendo de los reportes solicitados por el área estratégica comercial. La figura 2 representa la arquitectura actual de los datos, mientras que la figura 3 evidencia la propuesta del presente trabajo de investigación.

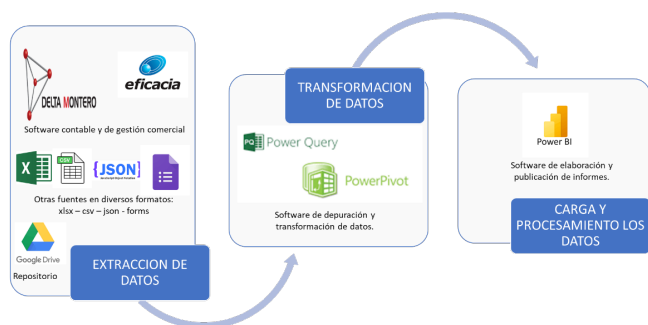


Figure 2. Arquitectura de datos actuales

Nota. La figura representa la arquitectura del modelo de inteligencia de negocios

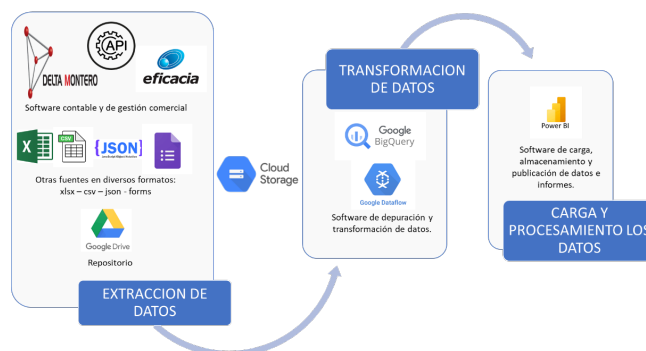


Figure 3. Propuesta de arquitectura de datos actuales

Nota. La figura representa la propuesta de arquitectura del modelo de inteligencia de negocios

Considerando la situación presente de la empresa, se recomienda implementar Google Cloud Platform considerando las necesidades y objetivos de la compañía, así como su volumen de datos y los costos para realizar el cambio en la infraestructura tecnológica. En cuanto a la integración, al reposar las bases de datos en Google Drive, permite una conexión directa sin cambios complejos en los procesos. Mediante Google BigQuery y Google apps script se podría analizar datos sin descargar ni actualizar manualmente los archivos de Excel permitiendo automatizar las tareas sin infraestructura adicional. En esta propuesta, la transformación ya no depende exclusivamente de herramientas locales como Power Query, sino que se apoya en capacidades avanzadas de procesamiento de datos en la nube, favoreciendo una mayor eficiencia, limpieza y velocidad en el tratamiento de grandes volúmenes de información. Así también en los costos es más accesible Google Cloud tomando en cuenta el tamaño de empresa y no se necesitaría servidores físicos, pagando solamente por el uso específico al que se le dé. Así también Power BI tiene la ventaja de poder conectarse a múltiples fuentes de datos en este caso con Google BigQuery. Además, en el componente de carga y visualización, la propuesta contempla el uso de Power BI con funcionalidades extendidas para el almacenamiento y publicación de datos, lo que mejora la gobernanza y seguridad de la información. Este enfoque permite no solo visualizar los datos, sino también almacenarlos de manera estructurada para consultas futuras, incrementando así el valor estratégico del sistema.

Creación del cuadro de mando de la organización

Como producto o resultado del modelo de Inteligencia de Negocios aplicado a la organización, se presenta a continuación la herramienta tecnológica desarrollada a través del software de Power BI, el cual se denomina como “Dashboard Comercial 2025” como se puede observar en la Figura 4.

Nota. El modelo fue realizado con el software Power BI.

Entre las principales páginas o apartados se destaca la importancia del cuadro de mando integral donde se puede observar que con los indicadores o KPI requeridos por el área estratégica comercial pueden obtener de forma dinámica, el estatus resumido dependiendo del canal de ventas, temporalidad, categoría de productos, etc. El modelo permite mejorar la visualización del presupuesto, se puede brindar información desde lo macro hasta lo micro mediante gráficas, indicadores, y tablas donde se puede indagar por estructura comercial, así como la distribución por portafolio de productos de la empresa. Dentro de los apartados más relevantes se puede compartir el análisis de las ventas entre periodos de tiempo brindando al área comercial un vistazo de las

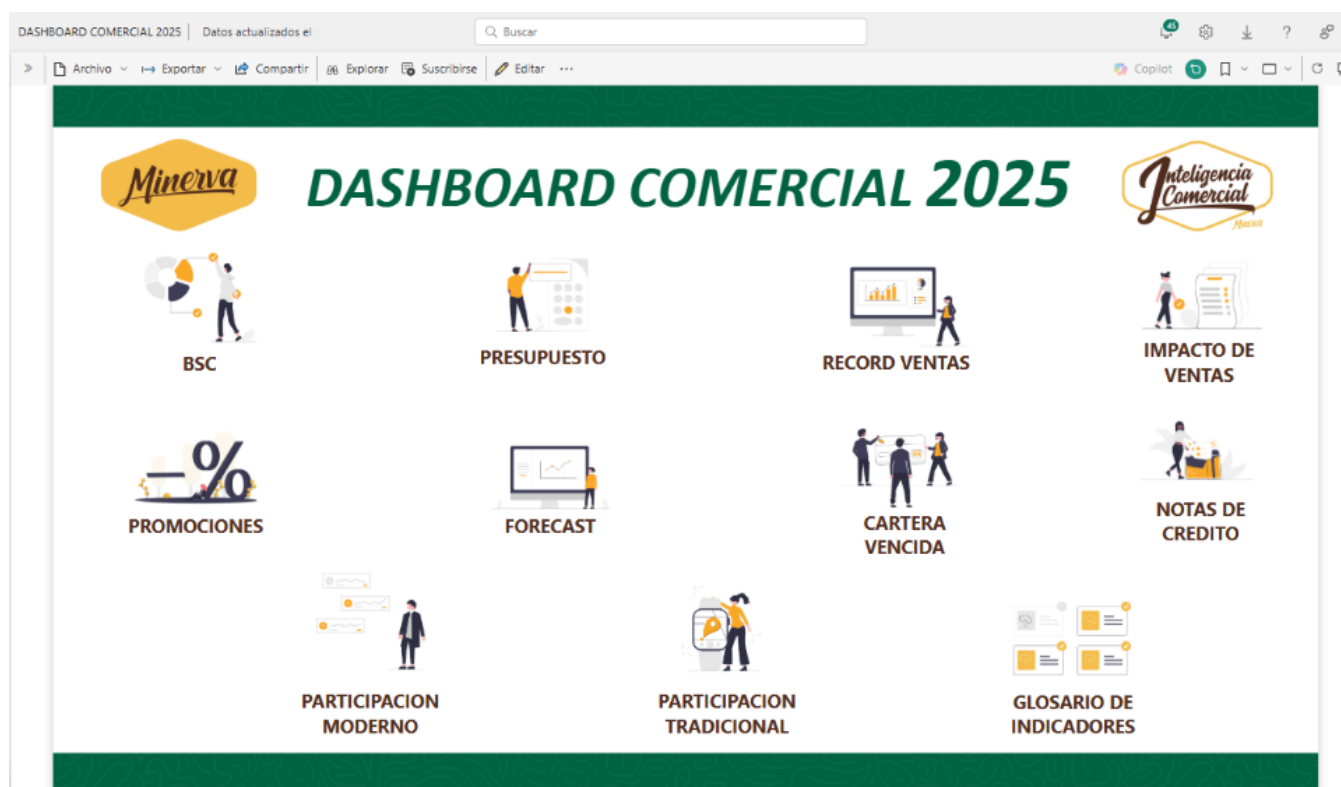


Figure 4. Modelo de Inteligencia de Negocios

variaciones que pueden darse ya sea por la estructura comercial, así como el portafolio de productos de un modo bastante comprensible el cual le ayude a analizar y tomar decisiones de manera inmediata. El resumen de los principales paneles se evidencia en la figura 5.

Nota. El modelo fue realizado con el software Power BI.

se presenta un conjunto de indicadores clave de desempeño (KPI) comerciales estratégicos que se utilizan de manera cotidiana para la toma de decisiones en el área comercial de la empresa. Estos indicadores miden y evalúan de forma precisa el comportamiento de las ventas y la gestión financiera, facilitando la identificación de tendencias, brechas y oportunidades de mejora. Entre los KPI destacan el crecimiento mensual y anual de las ventas (sell in) tanto en valor monetario (USD) como en volumen (kilogramos), los cuales reflejan la variación relativa respecto a períodos anteriores y sirven para monitorear el desempeño comercial a corto y mediano plazo. Adicionalmente, se consideran indicadores promedio como el promedio mensual de ventas y el precio unitario promedio de venta, que aportan información relevante sobre la estabilidad y rentabilidad del negocio. La efectividad de las ventas se evalúa mediante el cumplimiento del presupuesto en dólares y kilogramos, complementado con el análisis de las brechas o gaps que indican la distancia entre las ventas reales y las metas propuestas. Por otro lado, indicadores como el tamaño promedio del ticket (drop size), la frecuencia de compra y el porcentaje de clientes nuevos y de recompra permiten analizar el comportamiento y fidelización de los clientes. La diversidad de productos adquiridos por cliente (mix SKU) es otro KPI que facilita entender la penetración de portafolio en el mercado. Finalmente, la gestión financiera se monitorea a través de indicadores como el vencimiento de cartera, días de mora y la tasa de representación de notas de crédito, que reflejan la salud financiera y la eficiencia en la cobranza. Cada uno de estos indicadores está definido con

una fórmula específica y cuenta con metas claras que orientan la gestión comercial, contribuyendo a la mejora continua y al logro de los objetivos estratégicos de la empresa.

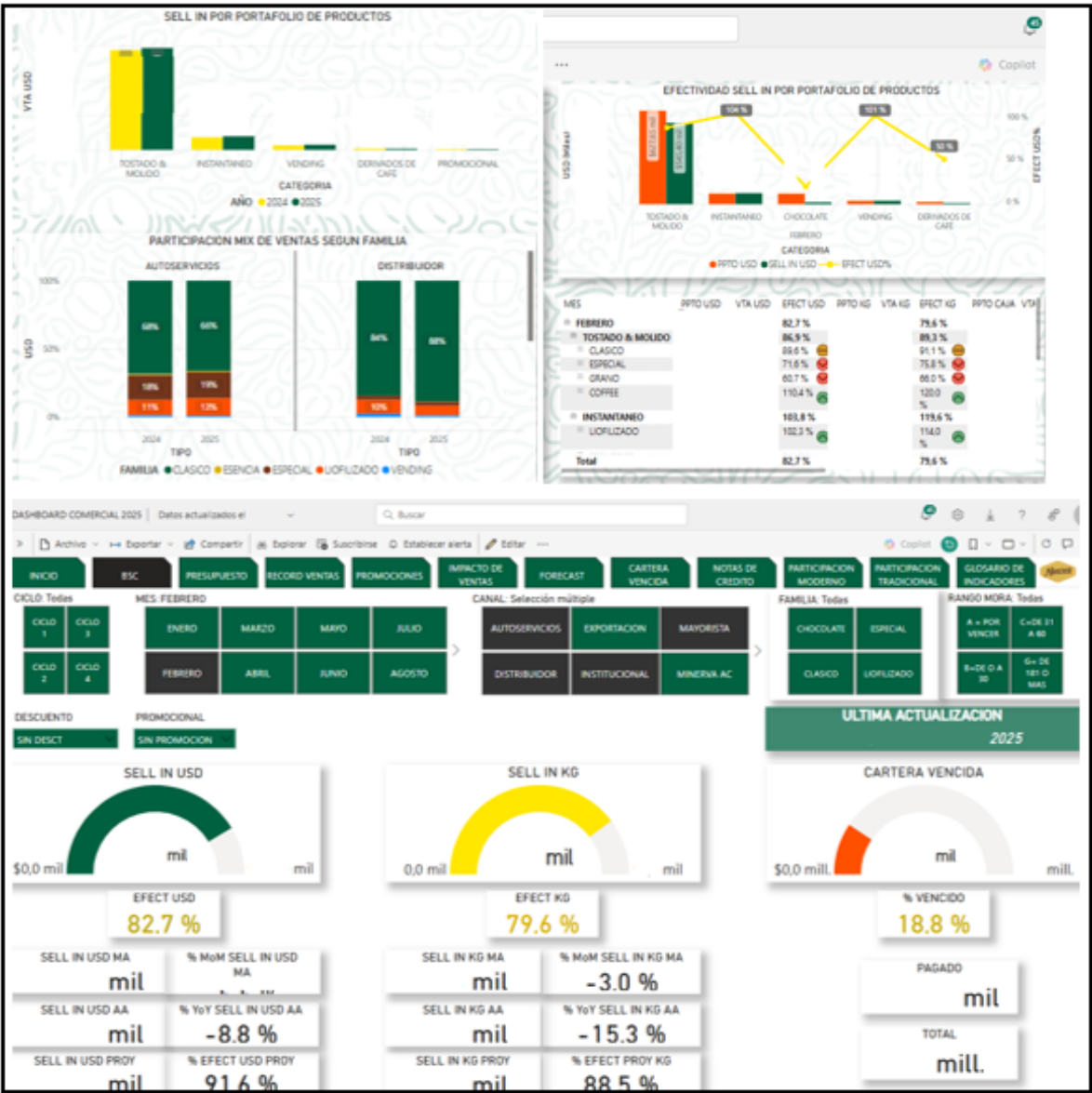


Figure 5. Visualizaciones del dashboard comercial

4. Discusión

Las Pymes enfrentan desafíos que la inteligencia empresarial y minería de datos ayudan a superar, mejorando la toma de decisiones y competitividad. Sin embargo, enfrentan barreras tecnológicas y económicas que requieren soluciones accesibles y capacitación adecuada (Tsiu et al., 2025). El desarrollo del modelo de inteligencia de negocios (BI) propuesto para una empresa del sector alimenticio, responde a necesidades operativas y estratégicas concretas, detectadas mediante un diagnóstico integral. Osorio et al. (2022) subrayan que la inteligencia de negocio facilita el análisis ágil y preciso de datos, mejorando la toma de decisiones estratégicas en las organizaciones. El diagnóstico realizado mediante la encuesta evidencia una limitada explotación de la información, debido a la dispersión de los datos y a la dependencia de procesos manuales. Esta situación no solo afecta la eficiencia operativa, sino que también limita la capacidad analítica y la toma de decisiones basadas en datos, especialmente en el área comercial. Fuentes Adrianzén (2021) demuestra que, sin uso de

herramientas de inteligencia de negocios en las Pymes, la toma de decisiones es limitada, y que su implementación mejora la gestión comercial y la eficiencia en tiempo, costo y funcionalidad hasta en un 22.6%. La necesidad de centralizar la información se presenta como un eje fundamental para superar las barreras actuales. La existencia de múltiples fuentes, como sistemas contables, reportes de ventas, monitoreo de personal de campo e información de clientes estratégicos, justifica la implementación de un proceso ETL automatizado y flexible, ya que permite extraer, transformar y cargar datos de manera eficiente, integrando fuentes heterogéneas en un repositorio común, preferiblemente en la nube. Esto garantiza datos actualizados, confiables y accesibles, mejorando la calidad del análisis y facilitando la toma de decisiones oportunas en la organización. Seenivasan (2023) concluye que la implementación de procesos ETL en tiempo real optimiza la gestión de datos, garantiza información actualizada, reduce latencia y mejora la toma de decisiones rápida y confiable en las organizaciones.

La automatización de tableros de control se identifica como una necesidad urgente para empoderar al área estratégico-comercial con herramientas visuales, dinámicas y de fácil interpretación. Singh et al. (2023) concluyen que Power BI facilita la visualización interactiva y eficiente de grandes conjuntos de datos, permitiendo un análisis claro y dinámico. Es especialmente útil para representar información compleja, apoyando la toma de decisiones en diversos sectores. Actualmente, la generación de reportes depende de la disponibilidad y conocimientos técnicos de los colaboradores, lo que dificulta el acceso oportuno a información clave. Al implementar dashboards automatizados mediante plataformas como Power BI, se promueve no solo la eficiencia en la generación de reportes, sino también una cultura organizacional basada en la toma de decisiones informadas. Almazmomi (2021) analizan que, en el entorno empresarial actual, la capacidad analítica de negocios, la cultura basada en datos y las características de desarrollo de productos son muy importantes para la ventaja competitiva de la empresa.

El modelo de inteligencia de negocios diseñado contempla la mejora de la eficiencia operativa mediante la sincronización de datos entre áreas comerciales y de soporte, como marketing, trade marketing y cobranzas. Las herramientas de visualización de datos mejoran el rendimiento empresarial, pero su eficacia está limitada por la falta de definición clara de KPIs que midan la eficiencia. Establecer y mantener KPIs adecuados es clave para optimizar la gestión basada en datos y la toma de decisiones (Siddharth et al., 2023). Esta integración horizontal de la información permite una visión más holística del negocio, identificando tendencias, oportunidades de crecimiento y posibles alertas en tiempo real. Además, el uso de modelos híbridos (normalizados y no normalizados) dentro del esquema de datos propuesto permite optimizar recursos técnicos, reduciendo tiempos de consulta y costos de almacenamiento.

En este contexto, el modelo de inteligencia de negocios no solo resuelve una problemática técnica, sino que se convierte en una herramienta estratégica clave para la transformación digital de la empresa. Espinoza-Mina et al. (2022) demuestran los beneficios de aplicar inteligencia de negocios y Balanced Scorecard en una PYME ecuatoriana, mejorando la toma de decisiones estratégicas, acceso a información clave y visualización de indicadores mediante Power BI. Permite avanzar hacia una gestión comercial más eficiente, proactiva y basada en datos, alineando los procesos operativos con los objetivos estratégicos de la organización.

Estos hallazgos coinciden con estudios previos que destacan la importancia de la gobernanza de datos, la automatización de reportes y la integración interdepartamental como pilares esenciales en la implementación exitosa de sistemas BI en entornos empresariales altamente competitivos, especialmente en sectores como el alimenticio donde los tiempos de respuesta y la comprensión del comportamiento del consumidor son factores críticos para la sostenibilidad del negocio. Un proceso facilitado de gestión del conocimiento con big data mejora el acceso, comprensión y uso de datos en PYMEs agroalimentarias, aumentando su competitividad al superar barreras relacionadas con recursos y relaciones en la red (O'Connor y Kelly, 2017). Ganeshkumar et al. (2023) evidencian que la adopción del big data en la industria alimentaria mejora el rendimiento financiero y de mercado, influida por variables como capacidad de prueba, observabilidad, complejidad, apoyo directivo, apoyo externo, incertidumbre, inseguridad y preparación organizacional.

El modelo también presenta limitaciones que deben ser consideradas. En primer lugar, su sostenibilidad depende de la

capacidad tecnológica y financiera de la empresa para mantener la infraestructura en la nube y actualizar las licencias de software por lo que, del total de los encuestados, aproximadamente la tercera parte (36,36%) consideran que casi siempre la empresa contempla dentro del presupuesto para inversiones en nuevas tecnologías. En segundo lugar, la adopción de estas herramientas implica un cambio cultural que podría enfrentar resistencia por parte de los colaboradores, especialmente en contextos donde prevalece la dependencia de procesos manuales, es así que un poco más de la cuarta parte de los encuestados (27,27%) usan la tecnología de manera frecuente para la gestión y toma de decisiones de sus procesos, mientras que una décima parte (10,91%) utilizan algunas veces, así como también una segunda décima parte (10,91%) nunca lo hacen por lo que en estos dos casos sostiene la resistencia al uso de las nuevas tecnologías. Adicionalmente, la efectividad de los tableros de control puede verse restringida si no se establecen de manera clara y consensuada los indicadores clave de desempeño (KPIs), lo que podría derivar en interpretaciones parciales o poco útiles para la gestión por cuanto un pequeño (7,27%) grupo de los encuestados consideran de manera general que los indicadores utilizados no les permiten tomar decisiones de manera oportuna, así como la falta de monitoreo y actualización continua y tampoco respaldan su gestión con métricas. Shaikh et al. (2021) señalan que los desafíos más importantes en la adopción de tecnología son el costo de la tecnología y la infraestructura, las habilidades técnicas y la eficiencia, los desafíos de adopción, la falta de apoyo organizacional y el apoyo gubernamental. Otro aspecto relevante es la escalabilidad del modelo. Si bien resulta adecuado para resolver las necesidades actuales de la empresa, su eficacia a largo plazo dependerá de la capacidad de la organización para incorporar nuevas fuentes de datos y ampliar su alcance a otras áreas, como producción o logística. Es así que dentro de la planificación estratégica para la empresa, cerca de la décima parte de los encuestados (9,09%) consideran de manera frecuente la relevancia para implementar otras áreas, y también una segunda décima parte (9,09%) consideran que nunca sería importante dicha implementación de manera integral a largo plazo. La transformación digital en Pymes enfrenta obstáculos de adopción y escalabilidad, requiriendo integración tecnológica, estrategia empresarial y expansión hacia áreas como producción y logística (Bhuiyan et al., 2024). En consecuencia, el modelo debe entenderse como un punto de partida que impulsa la transformación digital, pero no como una solución definitiva. Su éxito dependerá de la definición clara de objetivos estratégicos, la capacitación constante del personal, el diseño de políticas de gobernanza de datos y la integración gradual de las herramientas en la cultura organizacional. Solo bajo estas condiciones, la inteligencia de negocios podrá trascender su papel técnico y consolidarse como un recurso estratégico que aumente la competitividad y sostenibilidad de la empresa en un entorno altamente dinámico y competitivo.

5. Conclusión

El desarrollo de un modelo de inteligencia de negocios para la gestión comercial y la toma de decisiones en la empresa permitió integrar el uso de datos en la planificación estratégica, mejorando la capacidad de análisis y anticipación del mercado. Si bien la empresa reconoce el valor de los datos como un activo estratégico, aún existen oportunidades para fortalecer su aplicación en todos los niveles de la organización, optimizando el uso de las herramientas analíticas y asegurando que la toma de decisiones se base consistentemente en información confiable y actual. Los resultados

de la investigación demuestran que la inteligencia de negocios es un elemento clave en la gestión comercial, facilita el análisis de los datos históricos, así como el monitoreo de indicadores y tendencias para la toma de decisiones informadas y seguras. La mayoría de los encuestados reconoce su impacto positivo en la estrategia organizacional, aunque todavía existe un grupo que o la utiliza de manera constante. Esto resalta la necesidad de fomentar una cultura organizacional basada en datos, asegurando que la información sea accesible, comprensible y utilizada. El uso de las herramientas informáticas dentro de la empresa es ampliamente valorado, ya que contribuye al cumplimiento de los objetivos estratégicos y mejora la eficiencia en la toma de decisiones. Sin embargo, se ha identificado que no todos los encuestados tienen un conocimiento uniforme sobre las fuentes de datos ni la calidad de la información utilizada. Esto refuerza la importancia de diseñar una herramienta informática que integre datos de manera centralizada, facilite su análisis y garantice que todos los usuarios accedan a información de manera confiable y oportuna. La implementación de una herramienta de inteligencia de negocios debe enfocarse en mejorar la integración de la tecnología con los procesos comerciales, asegurando que la infraestructura tecnológica esté actualizada y que las inversiones en este ámbito sean constantes. Si bien los encuestados perciben que la tecnología ha optimizado la productividad, aún existen diferencias en cuanto a la percepción de su actualización y accesibilidad. La implementación exitosa de la herramienta requiere una planificación adecuada, capacitación del personal y una infraestructura tecnológica sólida que garantice su funcionamiento óptimo. Los resultados reflejan que la inteligencia de negocios es un pilar fundamental en la toma de decisiones estratégicas dentro de la empresa, aunque su uso aún no está completamente consolidado en todos los niveles. La mayoría de los encuestados, utilizan datos para la toma de decisiones, pero un porcentaje significativo lo hace de manera ocasional. Esto sugiere que la herramienta informática implementada debe reforzar la accesibilidad y usabilidad de los datos para facilitar su adopción en toda la organización. Asimismo, es esencial garantizar un monitoreo y actualización constante de los indicadores comerciales para mejorar su precisión y contribuir eficazmente a la gestión comercial

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