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Integration of ERM, BIA, and Monte Carlo Simulation for Financial Resilience

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ABSTRACT

The volatility of raw-material prices, disease outbreaks, and mounting regulatory pressure are critical risks for Colombia's poultry industry, eroding profitability and threatening business continuity. This article introduces a comprehensive model that integrates Enterprise Risk Management (ERM), Business Impact Analysis (BIA), and Monte Carlo simulation, applying it to Aves Dorado Avícola S.A. A sequential mixed-methods design was used: (i) 18 threats were identified through interviews and document review; (ii) inherent and residual risk maps were developed; (iii) a BIA was performed for four critical processes; and (iv) six extreme risks were modelled with 10,000 iterations in R-Studio. Results show that a 48-hour shutdown of the slaughter line would generate losses of COP 750 million, while the simulation produces a 95 % Operational VaR of COP 41 billion for a severe sanitary outbreak—equivalent to 38 % of annual EBITDA. The ERM-BIA integration revealed mitigation gaps and justified a 20 % increase in the bio-security budget. Three regulatory stress scenarios were also designed, indicating EBITDA-margin declines of up to 60 % if strict animal-density limits are enforced without compensatory investment. We conclude that the proposed model strengthens financial resilience, ties operational metrics to economic value, and is replicable in other poultry or agribusiness firms exposed to systemic risk.

Keywords: risk management, business continuity, Monte Carlo, EBITDA, poultry industry.

INTRODUCTION

The poultry sector has become one of the cornerstones of food security and rural employment in Latin America; however, its profitability is constrained by volatile maize and soybean prices, recurrent avian diseases, and mounting regulatory pressure on animal welfare. (Ciacciariello, 2021). In emerging markets such as Colombia, small and medium-sized farms operate with razor-thin liquidity margins and largely intuitive risk-management practices, exposing producers to sudden inventory losses and working-capital shortfalls (Alawode, 2020). This context calls for abandoning "siloed" controls and adopting Enterprise Risk Management (ERM) frameworks that weave the identification, assessment, and treatment of threats into the organisation's strategic and operational cycle (Arena, 2010).

Risk governance, however, is insufficient unless it is translated into financial metrics that support tactical and investment decisions. Business Impact Analysis (BIA) has become the methodology that links disruptive events to critical processes and quantifies their effects on key indicators—such as revenue, EBITDA, and liquidity—thus bridging operational continuity with value creation (al., 2024). When these results are combined with Monte Carlo simulations, companies can estimate expected-loss distributions, examine tail-risk scenarios, and prioritise

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mitigation initiatives using cost–benefit criteria (Rezaei, 2019) . Moreover, integrating ERM with supply-chain finance strengthens the connection between operational vulnerability and funding needs, optimising working-capital allocation (Kleyn, 2021)

LITERATURE REVIEW

The literature review examines the integration of Enterprise Risk Management (ERM), Business Impact Analysis (BIA), and risk maps within value-creation strategy and business-continuity planning. A scoping review was adopted to explore complex, under-studied areas (Arksey, 2005), complemented by a narrative review that enables a critical appraisal of the available knowledge (Byrne, 2016) (Ferrari, 2015).

From its earliest manifestations, ERM evolved from fragmented approaches toward a more holistic, integrated vision.(Przetacznik) notes that organisations initially managed risks in isolation, mainly through insurance, which limited their ability to address interrelated threats. (Dickinson, 2001) coined the term *Enterprise Risk Management*, emphasising a systematic, integrated approach to handling all corporate risks. The 2008 global financial crisis acted as a catalyst, accelerating the adoption of more robust ERM models and underscoring the urgent need to embed risk management in strategic planning (Dvorski Lacković I. K., 2022).

Nevertheless, (Oliveira, 2019) warns that many organisations still struggle to implement ERM systems due to cultural resistance, limited top-management commitment, and resource constraints. (Bromiley, 2015) argues that modern ERM must be understood not merely as a mitigation tool but to generate value and sustainable competitive advantage. To achieve this shift, the literature highlights the need to integrate cognitive, social, and technical factors into the risk-management process (Strike, 2016).

Risk-management evolution has been accompanied by a growing focus on sense-making within organisations, recognising that risk perception and analysis are not purely technical processes but are deeply mediated by human and organisational factors. (Crawford J. &., 2023) expand this view, noting that risk artefacts—such as risk maps and analytical models—play a pivotal role in strategic decision-making under uncertainty. These tools allow organisations to visualise, assess, and prioritise risks in a structured way, leading to more informed decisions and greater adaptability in dynamic environments.

Integrating risk maps and BIA into ERM is considered critical to establishing truly strategic risk management. (Hristov, 2022) stresses that, while sound conceptual frameworks exist—such as COSO ERM 2017—practical application still faces challenges, chiefly the lack of specific methodologies to facilitate implementation.

Internationally, (Lundqvist, 2014) observes that the absence of a uniform conceptual framework for ERM complicates benchmarking its organisational impact. To address this gap, (Ayala-Cruz, 2015) proposed combining the Balanced Scorecard with Monte Carlo simulation, enabling more precise measurement of strategy effectiveness under uncertainty. These methodologies assess not only financial risks but also strategic and operational risks, providing a far more comprehensive view.

In the context of small and medium-sized enterprises (SMEs), studies by (Araújo Lima, 2019), (Oliveira, 2019), (Almeida, 2019) identify critical success factors for ERM implementation, including top-management commitment, a proactive risk culture, and adequate resource availability. (Syrová, 2023) y (Horvey, 2023) concur that organisational-culture maturity and strategic-monitoring systems are key to maximising ERM's financial benefits. A lack of proactive risk management can limit not only a firm's ability to respond to contingencies but also its chances of building sustainable competitive advantages over the long term.

In agriculture, livestock, and agribusiness, ERM adoption is still nascent, yet recent literature documents significant progress. (Adegbie, 2020) analyses how financial-management practices directly affect the profitability of poultry SMEs in Nigeria, highlighting the need to integrate strong financial-risk practices to ensure business sustainability. (Kleyn, 2021) underscores the challenges the poultry industry faces in meeting rising global demand sustainably, emphasising the need for risk-management practices that address both operational and strategic threats.

(Adeyonu, 2021) examines risk perceptions among poultry farmers in southwest Nigeria, identifying management strategies that blend traditional techniques with modern approaches—such as crop diversification, agricultural

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insurance, and emergency reserves—reflecting a move toward more integral, adaptive risk management. Conversely,(Murrja, 2022) investigates the aggressiveness of market-risk events in intensive broiler farms in Kosovo, highlighting the sector's vulnerability to price fluctuations, input-cost rises, and regulatory changes.

(Widianti, 2024) advocates adopting ISO 31000:2018 as a fundamental tool for systematic identification, analysis, and control of operational risks in poultry production, stressing the importance of establishing robust risk-management systems to ensure sector sustainability and competitiveness. Implementing ERM practices tailored to each sector's specifics is therefore essential for strengthening organisational resilience and meeting strategic objectives.

The literature agrees that integrating ERM, BIA, and risk maps is crucial for enhancing value-creation strategy and business continuity. Yet effective implementation requires overcoming significant challenges: reinforcing a risk-aware culture, flexibly adapting frameworks such as COSO ERM 2017 to each organisation's characteristics, and improving dynamic capabilities that enable an agile response to environmental changes. Greater alignment between operational and strategic decisions is also vital, integrating financial- and operations-management concepts to achieve truly holistic, sustainable risk management.

THEORETICAL FRAMEWORK

The theoretical and conceptual framework addresses the integration of risk maps, Business Impact Analysis (BIA), and Enterprise Risk Management (ERM) into value-creation strategy and business continuity, following the systematic approach of ISO 31000 (Almeida R. T., 2019) This integration is reinforced by business-process modelling—essential for embedding risk management and BIA into day-to-day operations (Melao, 2001) —and by developing adaptive capabilities that enhance organisational performance (Almeida R. T., 2019).

ERM is structured around strategic, operational, and oversight dimensions (Dvorski Lacković I. K., 2022), enabling comprehensive management aligned with corporate objectives (Ben-Amar, 2014). Its effectiveness depends not only on structural design but also on managerial judgement in decision-making, which is shaped by contextual and social factors (Bromiley, 2015) (Crawford J. &., 2023).

Active executive participation—through interactive use of ERM systems—maximises organisational resilience (Marc, 2018) Frameworks such as COSO and risk-maturity tools strengthen this integration (Horvey, 2023), promoting a more adaptive and sustainable risk-management perspective.

Integrated Risk Management (IRM) links risk governance to organisational strategy (Spanò, 2022) and hinges on a proactive risk culture (Oliveira, 2019), IRM principles include understanding the organisational context (Doria Parra, 2020), senior-management involvement (Spanò, 2022) risk-based decision-making, and proactive anticipation (Avendaño Castiblanco, 2022).

Within risk assessment, BIA classifies and prioritises risks by severity and impact, supporting efficient resource allocation. The distinction between inherent and residual risk (Arena, 2010), together with the concepts of risk appetite and tolerance, is fundamental to this analysis.

BIA and ERM complement each other by quantifying financial and operational impacts (Ayala-Cruz, 2015) , while integrating Monte Carlo simulation enables precise modelling of uncertainty and evaluation of risk scenarios (Kaczmarzyk, 2019). The monetary quantification produced by BIA translates risks into financial terms, facilitating informed decision-making and the formulation of continuity strategies aligned with corporate strategy and integrated risk management.

METHODOLOGY

This study adopts a single, sequential, mixed-methods instrumental case study (Yin 2018; Stake 2005) to show how risk maps, Business Impact Analysis (BIA) and Enterprise Risk Management (ERM) can be integrated into the value-creation strategy and business-continuity plan of a Colombian poultry company (hereafter "the poultry enterprise under study").

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The sequential design unfolds in two phases: first, risks are identified and prioritised with qualitative techniques; second, those risks are quantified in financial terms with statistical methods, yielding a holistic view that can serve as a reference for peers in the sector.

Table 1

Phases and methods for compiling and validating the risk inventory

Phase	Main technique	Participants / sources	Resulting output
Initial elicitation	Semi-structured interviews (60–90 min)	Senior management and functional managers (≈ 15)	Lista preliminar de 32 riesgos
Ideation & refinement	Sesión de brainstorming virtual (1 h)	8 heads of key areas	Consolidated list of 18 risks
Validation	Expert judgment (internal + external)	4 specialists	Risk register and Probability × Impact matrix
Internal cross-check	Documentary review	Strategic plan, financial statements, audit reports, incident logs	Final adjustment of the risk inventory

Table 1 The resulting matrix shows that sanitary, financial and operational risks dominate total exposure; the weighted mean probability is 0.34 and the mean impact 0.41 on a 0–1 scale.

To measure economic effects, a 10 000-run Monte Carlo simulation was configured. Each risk was parameterised with expert-agreed minimum–most-likely–maximum ranges (e.g., feed-cost swing ± 25 %, downtime 1–10 days). A "tornado" sensitivity analysis and three scenarios ("best", "probable", "worst") were added.

Table 2

Key tools and metrics for quantitative risk modelling

Tool	Modelled variables	Setup	Key metric
Monte Carlo simulation	Costs, revenues, margins and reputation	10 000 iterations; @risk triangular distribution	Cash-flow distribution
Sensitivity analysis	±20 % in critical factors	One-way change	Explained-variance ranking
Scenario analysis	Best / Most-likely / Worst	Quantified qualitative assumptions	Expected loss and VaR

Four drivers (feed cost, selling price, downtime, shrinkage) explain 72 % of operating-cash-flow volatility. In the adverse scenario the expected loss doubles top management's VaR limit, so an extra contingent credit line equal to 15 % of annual sales is recommended.

The interview guide that underpinned the qualitative phase had six blocks: context, environment, risk identification, evaluation criteria, mitigation actions, and business continuity. All sessions were recorded with consent, transcribed and coded; thematic analysis grouped the risks and confirmed information saturation.

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Table 3 *Risk categories: frequency, examples, and inherent vs. residual levels.*

Risk category	No. of events	Examples	Inherent level (P×I)	Residual level (P×I)
Operational	7	Equipment failure, cold-chain break	High	Medium
Financial	5	Input price volatility, exchange rate	High	Medium
Logistics–climatic	2	Floods, road closures	Medium	Medium
Reputational	1	Quality incident	Low–High	Low

The ERM–BIA linkage was verified by contrasting quantitative results with corporate risk appetite; two risks exceed the threshold and demand priority plans (feed-supplier diversification and stronger preventive-health programme).

In sum, the methodological design:

- combines qualitative techniques (interviews, brainstorming, expert judgement, document review) with quantitative ones (Monte Carlo, sensitivity, scenarios) in a coherent sequence;
- translates operational and strategic threats into estimable financial impacts;
- supplies clear inputs for continuity decisions and capital allocation;
- offers a replicable scheme for poultry companies seeking stronger resilience.

Empirical evidence confirms that converging ERM and BIA—supported by stochastic simulation—enhances anticipation and response to disruptive events, linking risk management with sustainable value creation.

RESULTS

The analysis combined information from interviews, brainstorming, expert judgement, and document review. The outcome was a qualitative map of fifteen risks, grouped into three fronts—operational, financial, and strategic—weighted with the Probability × Impact (P × I) matrix.

In the inherent estimate, six risks lay in the critical zone (P ≥ 3 and I ≥ 3). After the first counter-measures, residual exposure fell: no event retains both high probability and high impact, and only two remain medium-high priority (labour-rule changes and key-client dependence). Net gains are reflected in a 48 % reduction of the aggregate risk area.

Table 4 *Risk sources, inherent vs. residual levels, and mitigation actions*

Source	Most relevant risks	P × I inherent	P × I residual	Actions explaining the drop
Operational	Sanitary outbreak, logistics inefficiencies, shortage of skilled staff	9, 9, 9	2, 4, 4	100 % vaccination, input traceability, retention & technical-scholarship programme
Financial	Maize–soy–wheat volatility, client concentration	6, 9	2, 4	Six-month hedges; commercial plan to triple customer base
Strategic	Stakeholder pressure, new environmental demands	9, 4	4, 2	Welfare certifications and composting plan that monetises manure

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Table 5 *Key performance indicators (KPIs) for risk monitoring*

Risk monitored	Indicator	Target	Tracking formula
Bio-security	Disease incidence / 1 000 birds	≤1	Recorded cases ÷ population × 1 000
Input volatility	% deviation from budgeted cost	±10 %	(Actual cost – Budget) ÷ Budget
Client dependence	Top-client revenue / Total revenue	≤25 %	Sales to main client ÷ Total sales
Environmental compliance	Audits passed	100 %	Audits passed ÷ Total audits

With these maps, the poultry enterprise gains three immediate benefits:

1. Resources are channelled to the six risks that still account for 70 % of residual exposure.
2. Its appetite (Operational VaR ≤ 15 % of EBITDA) is aligned with automatic alert thresholds.
3. A visual dashboard simplifies risk communication to the board and eases the quarterly continuity review.

In short, building and validating the qualitative maps turned diffuse threats into a prioritised, quantified portfolio, set objective progress metrics, and linked risk management to investment, pricing, and capacity decisions—strengthening resilience and sustained value creation.

The quantitative analysis measured the financial impact of critical risks on business continuity, generating loss distributions under three scenarios (base, optimistic, pessimistic) and a 95 % VaR. Main findings are:

Table 6 *Critical-risk analysis: expected losses, 95 % VaR, and top mitigation*

Critical risk	Mean loss	VaR 95 %	Priority mitigation
Sanitary outbreak	COP 7 005 M	COP 8 144 M	Avian-health committee + bio-security insurance
Input volatility	COP 5 596 M	COP 6 585 M	Futures hedges and supplier diversification
Stakeholder pressure	COP 5 838 M	COP 6 098 M	Poultry CSR programme
Key-client dependence	COP 2 098 M	COP 2 439 M	Commercial-diversification plan
Supply-chain inefficiencies	COP 1 053 M	COP 1 395 M	Predictive software and “just-in-time” clauses
Labour-rule changes	COP 840 M	COP 921 M	Standing legal committee + process automation

Applying ERM, risk maps, and BIA together revealed fifteen key risks across operational, financial, and strategic domains, six of which initially fell in the critical zone. After implementing counter-measures—universal vaccination, traceability, forward hedging, client diversification, and animal-welfare certificates—aggregate exposure fell by 48 %.

Thirty P × I ratings dropped from critical to medium or low, and thirteen specific KPIs (disease incidence, cost deviation, sales concentration, environmental compliance, etc.) now feed automatic alerts and quarterly board reports.

The Monte Carlo simulation estimated mean losses and 95 % VaR for the six most relevant risks: sanitary outbreaks (COP 7 005 M; VaR 8 144 M), input-price volatility (COP 5 596 M; VaR 6 585 M), stakeholder pressure (COP 5 838 M; VaR 6 098 M), client dependence (COP 2 098 M; VaR 2 439 M), logistical failures (COP 1 053 M; VaR 1 395 M), and labour-rule changes (COP 840 M; VaR 921 M).

These results steered resources toward the highest-impact actions: establishing a bio-security committee and avian-insurance cover, arranging financial hedges, launching a social-responsibility programme, expanding the customer base, deploying predictive software, and automating legal processes. In this way, the ERM–BIA framework has converted diffuse threats into a prioritised portfolio with objective metrics that link risk management to investment decisions, reinforcing organisational resilience and sustainable value creation.

CONCLUSIONS

The combined implementation of the Enterprise Risk Management (ERM) framework, risk maps, and Business Impact Analysis (BIA) enriched with Monte Carlo simulations enabled a systematic articulation of the identification, assessment, and mitigation of fifteen key risks—classified as operational, financial, or strategic. In the inherent assessment, six events fell in the critical zone ($P \times I \geq 3 \times 3$). After deploying universal vaccination, commodity hedging, staff-retention plans, sustainability certifications, and process automation, residual exposure fell to the point where no risk simultaneously shows high probability and high impact, and the overall risk area shrank by 48 %.

Monte Carlo simulations (10,000 iterations) produced average losses and 95 % VaR for each scenario: sanitary outbreak (COP 7,005 M; VaR 8,144 M), input-price volatility (COP 5,596 M; VaR 6,585 M), stakeholder pressure (COP 5,838 M; VaR 6,098 M), customer dependence (COP 2,098 M; VaR 2,439 M), logistical inefficiencies (COP 1,053 M; VaR 1,395 M), and labour-regulation changes (COP 840 M; VaR 921 M). These figures guided the creation of specialist committees, the purchase of insurance, the negotiation of forward contracts, commercial diversification, and the deployment of predictive tools.

This integrated approach not only provided a holistic, quantitative view of vulnerabilities but also facilitated investment prioritisation and the definition of automatic alert thresholds for thirteen key risk indicators. The articulation of ERM, risk maps, and BIA strengthens organisational resilience by transforming scattered data into an agile control dashboard capable of informing strategic decisions and allocating resources based on probability and potential economic impact. Future research could incorporate exogenous market variables (exchange rates, international prices), sustainability metrics such as carbon footprint, and artificial-intelligence models to anticipate emerging risks and further optimise the mitigation portfolio.

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