International Journal of Finance, Insurance, and Risk Management
Volume XVI, Issue 3, 2026

pp. 79-114

Predictive Credit-Risk Models as Managerial Interventions in Chilean Life Insurance Companies*

Submitted 10/07/26, 1st revision 03/08/26, 2nd revision 19/08/26, accepted 30/09/26

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Abstract:

Purpose: *This study examines which type of predictive credit-risk model, used as a managerial intervention, is most effective in improving solvency stability and risk-adjusted profitability in Chilean life insurance companies. The study addresses delayed managerial recognition of issuer-level credit deterioration in long-term, relatively illiquid investment portfolios.*
Design/Methodology/Approach: *The study uses a Rapid Evidence Assessment (REA) to synthesize evidence on predictive credit-risk model types used in insurance and comparable institutional investment settings. Searches were conducted across academic and specialist databases and institutional sources. Studies were screened using explicit inclusion and exclusion criteria, critically appraised using the TAPUPAS framework, and synthesized through qualitative coding and thematic analysis within a CIMO (Context–Intervention–Mechanism–Outcome) framework. The final evidence base comprised 13 studies.*
Findings: *The evidence indicates that predictive, issuer-level models can improve forward-looking solvency management, risk anticipation, capital positioning, and portfolio performance when their outputs are interpretable, timely, and aligned with managerial decision processes. Structural, Merton-type approaches appear particularly actionable for Chilean life insurers because they combine issuer-level differentiation with relatively strong interpretability. However, the effects are conditional on data quality, market liquidity, regulatory requirements, governance, and managerial responsiveness.*
Practical Implications: *Life insurers should implement predictive credit-risk modelling through phased pilots focused on high-materiality issuers, develop standardized signal-to-action protocols, and align model outputs with solvency, compliance, actuarial, and governance processes. Predictive models should be complemented rather than replace professional judgment.*
Originality/Value: *The study integrates credit-risk modelling, insurance solvency, evidence-based management, and contingency theory to assess predictive models as managerial interventions rather than solely as technical forecasting tools. It provides context-sensitive implications for Chilean life insurers operating under long-duration liabilities, concentrated portfolios, and illiquid corporate bond markets.*

Keywords: *Predictive credit risk, life insurance, solvency, Merton model, predictive analytics, managerial intervention, risk-adjusted profitability, Chile.*

JEL Codes: *G22, G28, G32, C53, M15.*
Paper type: *Research article. *For dataset, tables and figures contact the author.*

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1. Introduction

Life insurance companies occupy a central position in modern financial systems, serving as long-term institutional investors while guaranteeing contractual benefits that extend for decades. Their ability to honor these promises depends on effective solvency management, prudent capital planning, and timely recognition of investment risk. Within this context, Chilean life insurance companies face a persistent and well-documented business management problem: delayed managerial recognition of issuer-level credit deterioration in investment portfolios (Merton type), particularly locally issued corporate bonds held to maturity.

This delay undermines solvency stability and erodes risk-adjusted profitability. Importantly, the problem does not arise from a lack of analytical tools. Instead, existing governance and management systems frequently fail to convert available credit-risk information into timely, actionable decisions (Escudero and Ruiz, 2020; Schmeiser and Wimmer, 2022; CMF, 2024). This problem emerges within a broader business environment characterized by heightened financial uncertainty.

Prolonged low interest rates, episodic market stress, and tightening solvency regulation have increased pressure on insurers to extract yield while preserving capital buffers (Nguyen, 2024). For life insurers, these pressures are amplified by structural features of their business model: long-duration liabilities, illiquid asset holdings, and accounting frameworks that prioritize amortized cost over fair-value transparency (IASB, 2023).

In Chile, the corporate bond market is relatively concentrated and thinly traded, further limiting the informational value of market prices as early warning signals (Escudero and Ruiz, 2020). As a result, managerial reliance on backward-looking indicators remains entrenched even as issuer risk becomes more dynamic.

There is substantial empirical and regulatory evidence that delayed recognition produces severe negative consequences. Studies of Chilean insurance portfolios show that credit deterioration is frequently identified only after rating downgrades or impairment events, triggering abrupt increases in capital requirements and volatility in solvency ratios (Escudero and Ruiz, 2021; CMF, 2025).

International insurance research similarly demonstrates that delayed responses amplify capital volatility and constrain long -term profitability (Schmeiser and Wimmer, 2022; Mahayni *et al.,* 2021). These outcomes appear as recurring patterns rather than isolated incidents, suggesting a structural management failure rather than episodic misjudgment. If this condition persists, the far-reaching consequences extend beyond short-term financial performance.

Persistent solvency volatility reduces insurers' capacity to offer competitively priced annuities, weakens policyholder confidence, and increases the likelihood of

procyclical capital adjustments during periods of stress. From a systemic perspective, delayed recognition concentrates risk within institutional portfolios and increases vulnerability during economic downturns.

Multiple stakeholders are affected: policyholders depend on long-term solvency, shareholders bear earnings volatility, regulators maintain confidence in the insurance system, and managers remain accountable for investment and risk decisions. While all stakeholders are implicated, this study focuses on investment and risk managers within Chilean life insurance companies, because they sit at the intersection of analytical information, governance structures, and decision authority.

2. Literature Review

Current efforts to address the problem rely primarily on compliance-oriented risk-management tools, including credit ratings, actuarial projections, Own Risk and Solvency Assessment (ORSA) processes, and aggregate stress testing. These mechanisms are essential for regulatory oversight but operate at aggregation levels that limit issuer-specific managerial intervention (Landriault and Lkabous, 2021; Chang and Schmeiser, 2022). Ratings update infrequently, actuarial models emphasize long-horizon balance rather than issuer differentiation, and ORSA scenarios often obscure emerging deterioration.

Empirical evidence indicates that, despite significant investment in risk infrastructure, these tools remain less than fully effective in supporting asset-level managerial action. Against this backdrop, predictive credit-risk modeling at the asset level represents a potentially fruitful avenue for alleviating delayed recognition. Advances in quantitative finance provide tools capable of producing earlier issuer-level signals (Merton, 1978; Vrins, 2020). Prior research suggests that predictive analytics can improve early detection and portfolio adjustment under certain organizational conditions (Bakshi *et al.,* 2022).

However, findings remain mixed, and effectiveness varies by model class and governance context. The purpose of this study is therefore not to assume superiority of any single approach, but to compare model types as managerial interventions. The central research question guiding this study is “Which type of predictive credit-risk model, as a managerial intervention, is most effective at improving solvency stability and risk- adjusted profitability in Chilean life insurance companies?” The remainder of the paper reviews the literature on predictive credit-risk modeling and insurance governance, defines key variables, outlines the theoretical framework, and describes a Rapid Evidence Assessment methodology designed to synthesize comparative evidence.

2.1 Genesis of the Business Management Problem and Context

The delayed recognition of issuer-level credit deterioration in life insurance portfolios is not a recent phenomenon but the product of historical investment and governance structures. Life insurers traditionally adopted buy-and-hold strategies designed to match long-duration liabilities with stable, predictable cash flows. Under relatively homogeneous credit environments, this structure supported solvency protection while minimizing transaction costs (Schmeiser and Wimmer, 2022). Risk monitoring relied heavily on external credit ratings, actuarial assumptions, and periodic financial reporting.

These tools were sufficient when issuer heterogeneity was limited and market volatility was low. Over time, however, credit markets evolved toward greater issuer-specific risk, increased leverage, and episodic stress events. In Chile, these dynamics are intensified by a concentrated corporate bond market and limited secondary-market liquidity, which restrict the informational content of prices (Escudero and Ruiz, 2020). Accounting conventions emphasizing amortized-cost treatment further delay impairment recognition (IASB, 2023).

Regulatory frameworks reinforce compliance-oriented governance rather than continuous issuer-level reassessment (CMF, 2024). Together, these historical developments create a structural context in which managerial responses to credit deterioration are systematically delayed, often allowing risks to accumulate until rating downgrades, capital shocks, or forced asset sales occur.

2.2 Relevant Bodies of Scholarship

Three primary bodies of scholarship inform analysis of this problem.

The first is the finance literature on credit-risk modeling, which provides quantitative methods for estimating default probabilities and loss distributions and directly informs how issuer-level deterioration can be detected earlier in investment portfolios. This literature includes structural models grounded in firm-value theory (Merton, 1978; Vrins, 2020), reduced-form econometric approaches, and more recent machine-learning techniques designed to capture nonlinear risk patterns (Bakshi *et al.,* 2022; Qi *et al.,* 2025). Together, these approaches provide the technical foundation for evaluating predictive models as managerial decision-support tools.

The second body of scholarship comes from insurance and actuarial research, which examines solvency governance, portfolio regulation, and risk aggregation frameworks such as ORSA. These studies emphasize regulatory alignment, balance-sheet resilience, and stress- testing methodologies (Landriault and Lkabous, 2021; Chang and Schmeiser, 2022). This literature is essential for evaluating whether a predictive model can operate within the institutional constraints faced by Chilean life insurers.

The third body of work emerges from management control and organizational theory, which analyzes how analytical tools interact with governance structures and managerial cognition. This literature highlights that the effectiveness of risk models depends not only on statistical accuracy but also on organizational embedding and decision authority (Otley, 2016; Andreeva and Chaika, 2006). Together, these literatures frame predictive modeling as a managerial intervention operating within institutional constraints rather than a purely technical innovation.

2.3 Key Variables and Conceptual Definitions

This study is structured around a clearly defined set of variables derived from prior empirical and theoretical research. The independent variable is the type of predictive credit-risk model employed at the asset level. Model categories examined in the literature include structural (Merton-type) models, actuarial and ORSA-based approaches, rating-driven systems, and machine-learning predictive models.

The dependent variables are solvency stability and risk-adjusted profitability, because these outcomes directly capture the financial consequences of delayed credit recognition. Solvency refers to consistency in capital adequacy without abrupt regulatory shocks and is commonly operationalized using measures such as capital volatility and solvency ratios. Risk- adjusted profitability refers to earnings relative to capital risk exposure and is frequently measured through capital-adjusted return metrics (Escudero and Ruiz, 2021; Chang and Schmeiser, 2022).

A central mediating variable is managerial improvement, defined as enhanced interpretation of risk signals, faster escalation of concerns, and timelier portfolio and capital- planning decisions. Control variables identified in the literature include regulatory constraints, market illiquidity, portfolio concentration, issuer transparency, and accounting treatment. These contextual factors condition the relationship between predictive modeling and financial outcomes.

2.4 Relationships Among Variables in Prior Research

Prior research indicates that model classes relate differently to the study's core variables. Actuarial and ORSA-based frameworks improve regulatory transparency and long-horizon balance-sheet alignment, yet they provide limited support for issuer-level intervention in illiquid portfolios because their aggregation can mask emerging deterioration until capital ratios are affected (Aigner, 2025; Mahayni *et al.,* 2021).

Rating-based systems support governance consistency, but ratings frequently lag underlying fundamentals, delaying recognition and amplifying capital volatility when downgrades occur (Schmeiser and Wimmer, 2022; Escudero and Ruiz, 2020). Structural and data-driven models may differentiate issuer-level risk earlier, but their effectiveness still depends on governance embedding and managerial use. Across

model classes, analytical accuracy alone does not guarantee improved outcomes; managerial interpretation and organizational fit mediate the translation of model outputs into financial performance.

Structural and data-driven predictive models demonstrate potential for earlier issuer differentiation in illiquid environments (Vrins, 2020; Russo *et al.,* 2023). However, findings remain context-dependent, and model effectiveness varies according to governance embedding and managerial use. Across model classes, research repeatedly emphasizes that analytical accuracy alone does not guarantee improved outcomes; managerial interpretation mediates the translation of model outputs into financial performance.

2.5 Empirical Evidence on Predictive Credit-Risk Models as Interventions

The empirical literature on predictive credit-risk models in insurance and institutional investment settings provides important, yet inconclusive, guidance for managerial decision-making. Existing studies consistently show that predictive analytics can enhance early detection of credit deterioration, but they also reveal substantial variation in effectiveness across model types and organizational contexts. Importantly, these differences affect outcomes central to insurer performance, including solvency stability and risk-adjusted profitability. This section reviews empirical findings by model class, highlighting how each approach performs relative to the outcomes of interest and the extent to which managerial use mediates these effects.

Actuarial and ORSA-based models. Actuarial and ORSA-based approaches predominate in regulatory practice for life insurance. These models emphasize long-term balance-sheet resilience, scenario-based stress testing, and compliance with solvency capital requirements. Empirical studies show that ORSA frameworks improve transparency and regulatory alignment but offer limited support for issuer-level intervention or timely portfolio adjustment (Aigner, 2025; Mahayani *et al.,* 2021). Because these models operate at high levels of aggregation, emerging credit deterioration is often masked until it materially affects capital ratios. In relatively illiquid markets such as Chile's corporate bond market, this aggregation further limits their usefulness as early warning systems for portfolio managers.

Rating-based credit-risk systems. Credit ratings remain a central reference point for insurance investment decisions. Empirical evidence indicates that ratings provide standardized benchmarks and facilitate regulatory communication, yet they adjust slowly and frequently lag underlying fundamentals (Schmeiser and Wimmer, 2022).

Studies of insurance portfolios show that reliance on rating migration as a trigger for action contributes to delayed recognition of deterioration and amplifies capital volatility when downgrades occur (Escudero and Ruiz, 2020). While rating-based

systems support governance consistency, their limited sensitivity reduces their effectiveness as proactive managerial interventions.

Machine-learning and data-driven models. Recent research highlights the potential of machine-learning models to capture nonlinear relationships and tail-risk dynamics in credit portfolios. Empirical studies report improvements in predictive accuracy under certain conditions, particularly in liquid markets with rich datasets (Bakshi *et al.,* 2022; Qi *et al.,* 2025). However, evidence also documents significant challenges in insurance contexts, including sensitivity to data quality, limited out-of-sample robustness, and difficulties in interpretability and governance acceptance (Sun *et al.,* 2023; Zinvoru and Aziakpono, 2024). For Chilean life insurers, these challenges are compounded by smaller datasets, regulatory scrutiny of model transparency, and the need for risk models to be explainable within governance and supervisory frameworks.

Across model classes, a consistent empirical pattern emerges that predictive performance alone does not guarantee improved outcomes. Managerial interpretation, escalation mechanisms, and governance alignment mediate the relationship between predictive models and solvency or profitability. Models that are interpretable, transparent, and compatible with regulatory and accounting frameworks are more likely to be adopted and implemented, underscoring the importance of model choice as a managerial decision rather than a purely technical one. Structural (Merton-type) credit-risk models. Structural models grounded in firm-value theory occupy an intermediate position between actuarial aggregation and machine-learning complexity.

Empirical studies indicate that Merton-type models adapted to accounting fundamentals can improve issuer-level risk differentiation and may support earlier detection of deterioration in illiquid markets (Vrins, 2020; Russo *et al.,* 2023). Because these models rely on observable balance-sheet indicators, including leverage, profitability, liquidity, and cash flows, they allow incremental recalibration and can be aligned with held-to-maturity portfolio logic (Fischer *et al.,* 2023).

Some studies report associations between managerial use of structural models and reduced capital volatility or improved risk-adjusted profitability, while others note that outcomes depend on organizational context and governance embedding (Escudero and Ruiz, 2021; Chang and Schmeiser, 2022). The literature therefore characterizes structural models as one potentially effective class of intervention whose performance remains conditional rather than universally superior.

2.6 Theoretical Support: Contingency Theory

Contingency Theory provides the primary theoretical foundation for evaluating predictive credit-risk models as managerial interventions. The theory posits that organizational effectiveness depends on the alignment between control systems and

environmental uncertainty, rejecting the notion of universally optimal structures (Fiedler, 1964). Later extensions emphasize that management control systems must adapt dynamically as markets, regulations, and analytical capabilities evolve (Otley, 2016; Andreeva and Chaika, 2006). In this study, contingency theory helps explain why different predictive models may perform differently depending on organizational and environmental conditions.

In the context of life insurance, contingency theory suggests that predictive models alleviate delayed recognition only when they align with managerial cognition, governance routines, and regulatory constraints. Models that are overly complex or misaligned with decision authority create structural misfit, preventing risk signals from triggering action. Conversely, models that integrate seamlessly into control packages—linking analysis, interpretation, and execution—are more likely to support proactive management. This theoretical lens explains why model choice and managerial embedding are central to intervention effectiveness.

2.7 Literature Review Synthesis and Research Question

In summary, the literature reveals a persistent management problem rooted in historical investment practices, regulatory design, and governance structures. While predictive credit-risk models offer potential solutions, empirical findings are mixed, and adoption remains uneven. Existing research does not provide clear guidance regarding which model types of function most effectively as managerial interventions under the constraints faced by life insurers.

Accordingly, this study addresses the following research question, suitable for investigation through a Rapid Evidence Assessment: Which type of predictive credit-risk model, as a managerial intervention, is most effective at improving solvency stability and risk-adjusted profitability in Chilean life insurance companies?

3. Research Methodology

3.1 Rapid Evidence Assessment Design

This study will use a Rapid Evidence Assessment (REA) to synthesize empirical research on the comparative effectiveness of predictive credit-risk model types as managerial interventions in life insurance portfolios. An REA is a structured literature review method that uses systematic procedures, transparent question formulation, explicit inclusion criteria, reproducible search strategies, and critical appraisal to provide a balanced summary of what is known and not known about a managerial intervention.

Unlike a full systematic review, an REA makes explicit, justified concessions to breadth and comprehensiveness (e.g., limiting time windows, focusing on peer-

reviewed studies, narrowing databases) to deliver timely, decision- relevant evidence while retaining methodological rigor (Barends *et al.,* 2017; CEBMa, 2020).

REA is appropriate for the present research question because the evidence base spans multiple disciplines (finance, insurance/actuarial science, and management control), employs heterogeneous methods (structural modeling, econometrics, simulation, and machine learning), and yields mixed findings regarding solvency stability and profitability. In evidence-based management, REA is explicitly recommended for contexts in which decisionmakers face fragmented and sometimes contradictory empirical findings and where comparative synthesis is needed to guide practice (Barends *et al.,* 2017; CEBMa, 2020). The objective is therefore not to test a single hypothesis, but to systematically compare model classes and identify the conditions under which each appears most effective as a managerial decision-support intervention, consistent with the logic of intervention-focused evidence synthesis.

3.2 REA Methodological Design and its Execution

Background clarification:
As reviewed in the introduction, the institutional and financial background is necessary for interpreting empirical findings. The review situates predictive credit-risk modeling within the governance environment of Chilean life insurers, characterized by long-duration liabilities, held- to-maturity bond portfolios, market illiquidity, and solvency regulation (CMF, 2024; Escudero and Ruiz, 2020; Schmeiser and Wimmer, 2022).

This structural context explains why issuer-level deterioration can remain latent until capital impacts become unavoidable, particularly under amortized-cost accounting frameworks that delay impairment recognition (IASB, 2023; Mahayni *et al.,* 2021). Background clarification therefore frames the management problem as a breakdown in the signal-to-action chain rather than an absence of analytical tools (Otley, 2016; Andreeva and Chaika, 2006).

Question formulation:
In the previous sections, the research question "Which type of predictive credit-risk model, as a managerial intervention, is most effective at improving solvency stability and risk- adjusted profitability in Chilean life insurance companies?" was presented and discussed. This question is operationalized using a CIMO framework, which specifies context, intervention, mechanism, and outcomes, as presented in Table 1.

The context consists of Chilean life insurance firms managing concentrated corporate bond portfolios. The intervention is the class of predictive credit-risk models employed at the asset level. The mechanism is managerial interpretation and escalation of risk signals. The outcomes are solvency stability and risk- adjusted

profitability. Framing the question in comparative terms ensures that the assessment evaluates relative effectiveness rather than binary success or failure.

The REA is designed as an impact (cause-and-effect) question rather than a non-impact (attitudinal or process -oriented) question. This decision is justified because the core inquiry examines a causal relationship between:

1. Cause (Intervention): the implementation of an asset-by-asset predictive credit -risk model based on issuer fundamentals (a managerial and analytical intervention),

2. Effect (Outcome): organizational performance variables such as solvency, profitability, stability, and capital-shock mitigation in Chilean life-insurance portfolios.

This causal framing aligns with CEBMa's definition of impact questions, which seek to determine what works, for whom, and under which circumstances (Duker and Eekhout, 2021; Van Aken and Berends, 2022). The objective is to evaluate the empirical effect of predictive modeling interventions on measurable financial and governance outcomes, rather than merely describing perceptions or attitudes toward risk management.

Furthermore, the intervention has a direct managerial and quantitative dimension modifies the firm's internal decision-making systems and measurable financial indicators. This differentiates it from process -oriented or non -impact research, which would instead focus on understanding how managers perceive or interpret risk practices.

Inclusion and exclusion criteria:
Eligibility criteria prioritize empirical studies that evaluate predictive credit-risk models using measurable solvency, capital volatility, or profitability outcomes in insurance or comparable institutional portfolios. Studies must specify model class and provide quantitative or simulation-based evidence.

Research published between approximately 2019 and 2025 is prioritized to reflect current regulatory and data environments, while seminal theoretical works are retained for conceptual grounding. Conceptual essays without empirical evaluation and studies unrelated to institutional credit portfolios are excluded to maintain comparability and reduce selection bias.

In Table 2, the Framework for the articles' inclusion and exclusion criteria is presented based on the following principles:

1. Recency and relevance: Empirical studies from 2019 –2025 that capture current data-science techniques and regulatory contexts.

2. Theoretical continuity: Inclusion of seminal works maintains conceptual coherence and supports the construction of a theory tree tracing how Contingency Theory and structural credit-risk models evolved and intersect.

3. Managerial applicability: The focus remains on organizational and portfolio -level performance, consistent with your REA's causal (impact) design.

These principles were applied to the CIMO, focusing on the main themes around the REA Question:

1. *Context (C):* life insurance, solvency regulation, investment portfolios;

2. *Intervention (I):* predictive analytics, structural models, Merton models;

3. *Mechanism (M):* organizational fit, adaptive control, and managerial interpretation;

4. *Outcome (O):* profitability, solvency ratio, risk management performance.

Specifically, the criteria used to define inclusions, considering both perspectives, are described in Table 2. In summary, it's aimed to include studies from the last 7 years, seminal papers, articles written in English or Spanish (since the regional nature of the question), peer -reviewed articles, the financial markets framework, firm -level or portfolio -level studies, quantitative outcomes, risk and return models as the intervention, validated sources of data or methodology.

Search strategy:
Search procedures use Boolean strings derived directly from the study's variables and conceptual framework. Core terms combine predictive credit-risk modeling, insurance solvency, capital volatility, and portfolio management. Searches are executed across Scopus, Web of Science, ProQuest, SSRN, and specialized finance databases. Priority screening is given to insurance and risk-finance journals. Search logs record exact strings, filters, and database outputs to ensure reproducibility and auditability.

The objective of the search strategy is to systematically identify, screen, and retrieve the most relevant and methodologically robust studies that address the causal impact of predictive credit-risk modeling on solvency and profitability outcomes in life insurance companies (LICs). The search aims to balance empirical evidence from 2019 –2025 with seminal theoretical works foundational to Contingency Theory and structural credit-risk modeling.

Table 3 presents the databases and the justification for considering those sources. Six sources were inspected (Scopus, Web of Science, ProQuest, EBSCO, SSRN, JSTOR, and Institutional and Regulatory sources). The UMGC library search,

Elsevier engines, Elic it, and Perplexity AI tools were used to gather information from these sources.

The core Boolean Structure to find the article was the following: ("life insurance" OR "insurance companies" OR "pension funds" OR "institutional investors") AND ("predictive model*" OR "credit risk model*" OR "structural model*" OR "Merton model" OR "machine learning" OR "logistic regression" OR "survival analysis") AND ("solvency" OR "capital adequacy" OR "risk equity" OR "profitability" OR "default probability") AND ("contingency theory" OR "organizational fit" OR "management control systems")

Later, it was complemented and refined by a Regional Context Extension: AND ("Chile" OR "Latin America" OR "emerging markets").

Study selection:
Study selection proceeds in two stages. Titles and abstracts are screened against eligibility criteria, followed by full-text review for methodological relevance. A PRISMA-style flow record documents inclusion and exclusion decisions. This step ensures that synthesis is grounded in comparable evidence rather than convenience sampling. The filter applications are presented in Table 4, which is consistent with Table 2 outlining the inclusion criteria. The search identified 573 records across six databases.

After removing 21 duplicates, 552 records remained for screening. Title and abstract review reduced this set to 223 potentially relevant articles. Full-text screening identified 323 studies that were not directly related to the REA question or relied on outdated databases (prior to 2015). Twenty -two articles were excluded because full text was unavailable, and eleven because they were not published in English or Spanish. In the retrieval stage, 27 articles required direct author or librarian requests to obtain full text.

A total of 163 articles were assessed for eligibility, of which 45 did not match the intervention context, 33 relied on individual-level samples, 22 were qualitative or descriptive, 31 lacked managerial implications, and 15 had unclear or unverifiable methodology. Four articles were excluded after appraisal for failing to meet the quality criteria.

The resulting corpus of 13 studies, described in Table 5, reflects a high degree of alignment with the REA's causal framework, as indicated by the abstract, title, and conclusion. This alignment combines cross-sectional, longitudinal, and stochastic modeling designs with moderate- to-large, reported effects on solvency, profitability, and capital resilience. In the data extraction stage, these works provide a balanced empirical foundation for evaluating whether predictive credit-risk modeling effectively enhances solvency management in life-insurance portfolios under illiquidity constraints.

3.3 Data extraction and Description of the Dataset

Data extraction employs a standardized template capturing model class, portfolio context, outcome measures, and managerial mechanisms. Direct financial effects and mediated managerial effects are coded separately. This structure allows synthesis to distinguish technical performance from organizational translation.

The studies presented in Tables 5 and 6 were systematically analyzed against key methodological dimensions, author and publication year, population or sector, research design, sample size, main findings, outcome measures, potential mediators or moderators, effect size with a 95% confidence interval, and level of trustworthiness (Barends *et al.,* 2017). The corpus primarily encompasses the insurance and financial risk sectors, with a focus on predictive modeling, solvency forecasting, and portfolio risk optimization across both developed and emerging markets. Most studies employ quantitative and analytical research designs, including cross-sectional, longitudinal, and stochastic simulations, with sample sizes ranging from firm-level panels to macro-insurance datasets.

3.4 Critical Appraisal

Study quality is evaluated using the TAPUPAS framework, which assesses transparency, accuracy, purposively, utility, propriety, accessibility, and specificity. Appraisal scores inform confidence weighting during synthesis. This step ensures that conclusion s reflect evidential strength rather than publication volume and this framework effectively highlights the strengths and weaknesses of the various aspects of the research, allowing us to evaluate the quality and rigor of the article considering its transparency, accuracy, purposively, utility, accessibility, and specificity of the methodology, literature review, and results, giving each category a score and a justification regarding each element analyzed. This method is very flexible, since it focuses on the generic standards of, not replacing judgment but letting the researcher organize where the worth and the weaknesses of the appraised article (Ryan and Rutty, 2019).

As mentioned, TAPUPAS is a suitable screening framework and is valuable for systematic reviews, because the tool does not replace the judgment of the researcher but helps in a post - positivist and simple framework way to assess the quality of the article, this approach outlines strategies for planning, conducting, and disseminating research and emphasizes the importance of philosophical principles but also evaluate the quality and trustworthiness of the article in a clear way using a rating scale and criteria, providing a numerical indicator that allows a better comparison method of quality between research evidence (Todd and Smith, 2022; Armstrong and Lauder; 2015).

Finally, CASP and WOE were seen as less effective appraisal tools for the selected articles since CASP relies on the subjective interpretation of the appraiser, which can

lead to different conclusions and primarily focuses on the methodological aspects of a study and many of the papers to be appraised appreciate mixed methods. In the case of WOE, even though it allows to effective evaluation of the quality and relevance of the research article separating generic quality criteria from those specifically related to the research question and the suitability of the methods employed, has some limitations such as being complex and require a deep understanding of research methodologies and synthesis processes and involves subjective judgments, which can vary between appraisers (Gough, 2012).

In Figure 2, the TAPUPAS scoring is presented. The scale provided to evaluate the 7 categories (transparency, accuracy, purposively, utility, propriety, accessibility and specificity) goes from 1 to 10 being able to sum up to 70 points in the overall score of the article. As presented in the appendix, each category was rated from very strong to very weak based on the clarity and strength of the evidence supporting its methodology, literature review, and results. To assign a score to each category of the TAPUPAS appraisal of each article the focus was on the quality of the methodology, literature review, and results establishing the following definition for each point using the definition Rutty and Ryan (2019).

Regarding the total score, the overall evaluation ranged in five levels from a highly credible article to a not credible article at all. The proposed cutoffs were 10 points per rating of the overall score, since the maximum is 70 points.

3.5 Evidence Synthesis and Confidence Assessment

To complement critical appraisal, assess the confidence in synthesized claims using CERQual-informed logic adapted to this managerial evidence context. Specifically, confidence judgments will consider methodological limitations (TAPUPAS results), coherence across studies, adequacy of the evidence base for each synthesized claim, and relevance to the Chilean life insurance context. This approach supports transparent communication of where the evidence is strong, mixed, or insufficient, thereby aligning the REA outputs with managerial decision needs.

Regarding the synthesis, the most suitable articles identified by the appraisal were qualitatively analyzed using CAQDAS (Atlas.ti). In the first approach, the 13 appraised papers were uploaded and separately started to generate first cycle codes using a method examining the data to identify a word or phrase that could have a deeper meaning to subsequently produce a code using a descriptive coding method, that is assigning labels to data to summarize, using the word or phrase, the primary topic of a portion of qualitative data (Saldaña, 2021). Regarding second - cycle coding methods, each article was revisited creating groups of codes, avoiding assigning them the role of a category or higher code (Friese, 2019), that shared commonalities and themes to be inspected.

The coded material primarily came from the findings, discussion, theoretical framing, and conclusion sections of each study, rather than the full article text. This approach aligns with the Rapid Evidence Assessment methodology, which prioritizes extracting analytically relevant knowledge rather than preserving the whole narrative structure.

The evidence extraction matrix created earlier in the project served as the structural foundation for initial coding, allowing consistency across studies of diverse research designs. The coding process also included theoretical elements when these were explicitly connected to solvency behavior, modelling logic, or risk-decision frameworks, reflecting the view that coding can incorporate both conceptual and empirical meaning when appropriate.

Because the research question had been previously structured using CIMO logic, the coding framework aligned with this causal configuration rather than PICOC, reinforcing the focus on identifying Context-Intervention-Mechanism-Outcome configurations in the evidence base (Duker and Eekhout, 2021).

The coding procedure unfolded in iterative stages consistent with Saldaña's (2021) guidance on the qualitative research model. The first coding cycle served as an exploratory stage, to remain open to the variety of ways solvency, modelling, and insurance-sector behavior were represented in the studies. Coding at this stage included the use of descriptive and structural techniques, guided partly by the categories already developed in the evidence extraction table and expanded as needed to capture emergent expressions of mechanisms, constraints, and effects. Throughout this first cycle, analytic miming was used to document interpretive decisions, tentative conceptual connections, and areas of ambiguity; these memos functioned as a reflexive record and helped preserve the reasoning behind coding decisions.

Once the initial layer of coding was complete, a second cycle of analysis was conducted to consolidate and interpret meaning across the corpus. This stage relied on pattern and axial coding to connect fragmented units of coded meaning into more coherent conceptual groupings. Rather than treating each study as a discrete unit of analysis, the data at this stage were examined across cases, following the principle that synthesis requires connection rather than enumeration.

Patterns began to emerge that reflected similarities in how predictive modelling interacted with solvency constraints, how regulatory environments influenced the effectiveness of risk- prediction approaches, and how modelling sophistication intersected with insurer decision- making. This second cycle represented a shift from tagging content to interpreting causal architecture; no new codes were created beyond this point. However, a final confirmatory pass ensured alignment with the analytic aims of the REA and the logic of the research question (Halpin, 2024).

The development of themes occurred gradually and iteratively as the coding process progressed. The movement from raw coded excerpts to thematic structure involved organizing early codes into conceptual clusters; these clusters were then compared across studies to determine whether they reflected isolated observations or recurring patterns. Only the patterns supported by multiple studies and consistent with CIMO logic were elevated into full themes. Cross-case rather than within-case analysis guided this step, reinforcing the goal of producing synthetic insights rather than article-level summaries (Mortelmans, 2025). Through this process, themes began to emerge on how predictive credit-risk modelling enabled earlier detection of deteriorating asset quality, how modelling approaches influenced capital allocation decisions, and how contextual constraints, such as regulation, liquidity pressures, and data maturity, moderated these effects.

In a process approach, raw data from the initial codes were systematically grouped into conceptually related clusters, refined through pattern and axial coding, and then consolidated into final themes using a framework synthesis approach. That means raw codes were processed to produce clustered codes, which, in turn, led to the emergence of themes. In Table 4, the relationship between the CIMO framework and the purpose of coding is presented, highlighting that the focus of the research question is the predictive model, which is the intervention, and the enhancer is the mechanism, that is, managerial improvement, over portfolio performance and stability outcomes (Locke *et al.,* 2022).

In sum, evidence is synthesized thematically across model classes, with attention to conditional findings and governance context. Confidence in conclusions is evaluated using CERQual principles, which consider methodological limitations, coherence, adequacy, and relevance of contributing studies. The synthesis distinguishes strong, mixed, and conditional evidence and explicitly documents limitations. Managerial implications are derived only where evidential confidence supports practical inference.

4. Analysis and Findings

4.1 Analysis of the Dataset

As presented in Table 6, regarding the dataset characteristics, a key dimension of this continuum becomes evident when comparing datasets across studies. Several works draw on large-scale administrative or regulatory datasets covering long time horizons, most notably Escudero and Ruiz (2020, 2021), Bayar *et al.* (2022), Rahma *et al.* (2025), and the structured empirical synthesis included in Bakshi *et al.* (2022).

These studies examine insurer behaviors such as investment allocation, annuity pricing, and systemic solvency influences in real market settings. Their use of multi-year panel structures, population-level insurance contract data, and regulatory

disclosures make them particularly relevant to solvency research grounded in observed insurer decision pathways.

A second group relies not on archival or real-world datasets but on theoretical, simulated, or structurally modelled risk environments. Examples include Mahayni *et al.* (2021), Landriault *et al.* (2021), and Chang and Schmeiser (2022). Although their calibration is hypothetical, these studies provide conceptual and mechanistic clarity: they examine how guarantees behave under volatility, how surrender and liquidity risks interact, and how ruin probabilities evolve under Lévy distribution assumptions. Their data structures are synthetic, yet their explanatory value lies in making solvency behavior intelligible in dynamic rather than static conditions. In this sense, they serve as interpretive scaffolding for empirical findings.

A third group reflects emerging or forward-looking approaches to solvency and underwriting practices. Studies such as Qi *et al.* (2025), Kalfin *et al.* (2022), Eling (2024), and Yanes *et al.* (2024) explore themes including machine-learning-based insurance modelling, resilience and disaster systems, ESG considerations, and genomic-based pricing. These do not directly measure solvency or credit risk outcomes, but they illustrate what the future operating environment for insurers may require. Their data is less structured, but their value lies in signaling direction rather than validating current practice.

Across these studies, main findings converge on the predictive capacity of data -driven, issuer-level models to anticipate solvency deterioration and enhance capital adequacy. Reported effect sizes are generally moderate to large (Cohen's $d \approx 0.5$–0.8), indicating practical significance in solvency improvement, though some studies reveal sensitivity to parameter uncertainty and market illiquidity. Standard mechanisms include governance quality, technological capability, and regulatory alignment, while moderating factors often involve data transparency, portfolio concentration, and liquidity constraints. Limitations across the evidence base relate to data lags, small or region-specific samples, and restricted generalizability outside the regulatory frameworks studied.

Taken together, these patterns begin to suggest that issuer -level structural models may prove the most actionable option in the Chilean context because they combine predictive usefulness with greater interpretability in illiquid markets.

4.2 Appraised Evidence

The evidence base established in this Rapid Evidence Assessment reflects a methodologically diverse yet coherent body of literature relevant to solvency management, predictive modelling, and investment decision-making in life insurance portfolios.

Following CEBMa appraisal procedures (CEBMa, 2020), the final dataset comprised 13 peer-reviewed studies, each evaluated for methodological rigor, relevance, transparency, and contribution to practice. The screening and appraisal process demonstrated strong alignment between the evidence base and the research question, which examines whether implementing asset-level predictive credit-risk modelling enhances solvency compliance and profitability outcomes for Chilean life insurers.

The appraisal process, presented in Tables 6 and 7, including TAPUPAS scoring and CEBMa trustworthiness confidence judgments, revealed meaningful differentiation in evidence strength. Empirical studies scored highest due to transparency, replicability, and practical relevance. Simulation studies showed moderate confidence due to theoretical coherence but lacked real-world verification, while conceptual or exploratory studies contributed valuable context but carried lower certainty. Despite differences, the collective evidence demonstrated strong thematic convergence, particularly regarding:

- The role of predictive modelling in enhancing forward-looking solvency management.
- The influence of managerial responsiveness and interpretability on model effectiveness.
- The conditional relationship between regulation, modelling architecture, and portfolio performance.

These thematic patterns indicate that implementation, not merely existence, of predictive modelling tools influences outcomes, reinforcing the relevance of managerial capability as a mediating factor.

In Table 7, the TAPUPAS evaluation of the 13 -study corpus is presented, revealing a credible and methodologically rigorous evidence base, with average scores ranging from 7.7 to 9.0 (mean = 8.5). Approximately 75% of the studies were at least highly credible across the core criteria of Transparency, Accuracy, Purpose, and Utility, confirming firm empirical grounding and theoretical coherence, which was considered fulfilling the credibility tier (7.5 or more), resulting in credible articles (13 articles).

The highest-rated studies— Escudero and Ruiz (20 10), Rhama (2025) and Bakshi (2022) fulfilled the thresholds, using longitudinal econometric designs, stochastic simulations, and solvency-stress modeling that enable robust causal inference and reproducibility. Their findings consistently support the predictive capacity of issuer-level credit-risk models to improve solvency management and capital efficiency. Overall, the corpus demonstrates strong theoretical alignment with Contingency and Dynamic Capabilities theories and a high Level of purposively, reflecting a clear connection between predictive interventions, such as ORSA simulations or solvency optimization, and organizational adaptation under regulatory uncertainty.

Transparency and Accuracy scored highest, indicating reliable reporting and data integrity, while Accessibility was slightly lower due to proprietary insurer datasets and limited replicability in illiquid markets. Overall, the evidence base exhibits robust methodological quality, theoretical consistency, and empirical transparency, affirming that predictive, data -driven credit -risk modeling can significantly enhance solvency resilience and profitability in life insurance portfolios operating under regulatory and market uncertainty.

Across the evidence base, as reported in Tables 5 and 6, three broad types of studies were identified. First, a subset of works relied on real-world regulatory or portfolio datasets, including multi-year insurance balance sheets, annuity contract behavior, and solvency disclosures. These studies (e.g., Escudero and Ruiz, 2020; Rahma *et al.,* 2025; Bayar *et al.,* 2022) demonstrated the strongest direct applicability to practice due to their grounding in observed insurer behavior and real market constraints. Their findings were particularly relevant because they addressed solvency-linked outcomes such as default behavior, reserve adequacy, and capital management.

A second cluster consisted of simulation-based or theoretical modelling studies, including those applying Merton-type structural approaches, dynamic surrender-value models, and Lévy-based solvency projections. While these studies offered less empirical validation, they provided valuable explanatory insight into mechanisms driving solvency deterioration and model responsiveness under stress conditions (e.g., Mahayni *et al.,* 2021; Chang and Schmeiser, 2022; Landriault *et al.,* 2021). Their contribution to the evidence base was interpretive rather than observational, clarifying how predictive models operate when tested against extreme volatility or illiquidity.

The final grouping comprised forward-looking conceptual and emerging-evidence studies that explored machine learning inputs, ESG-aligned solvency frameworks, demographic trend modelling, and regulatory adaptation. These studies (e.g., Qi *et al.,* 2025; Kalfin *et al.,* 2022; Yanes *et al.,* 2024) demonstrated relevance not in validating current solvency behavior, but in indicating how future solvency systems and modelling practices may evolve. Taken together, they formed an anticipatory evidence layer, guiding how predictive frameworks may be needed to account for new data structures, underwriting approaches, and supervisory expectations.

In summary, the appraised evidence base provides a sufficiently credible, contextually relevant, and theoretically convergent foundation for decision-making by Chilean life insurers. While methodological variation limits meta-analytical synthesis, the coherence of findings across designs supports meaningful insight into how predictive modelling interacts with solvency management and investment governance. Accordingly, the evidence provides a reliable and actionable platform for conceptual framework development and managerial recommendations.

4.3 Description of the Codes for Synthesis

This section presents the synthesized findings from the qualitative analysis of the thirteen included studies. The results are organized into overarching themes and associated themes developed through iterative coding, co-occurrence mapping, and framework synthesis in Atlas.ti. As the synthesis progressed from first-cycle descriptive encoding to second-cycle pattern coding, and then to interpretive aggregation, themes emerged that explained not only what findings were present across the body of evidence, but also how and why these findings interact within the solvency and predictive modeling context. Confidence assessments accompanying each theme draw on CERQual and reflect methodological rigor, coherence across studies, adequacy of supporting evidence, and relevance to the research question.

In Figure 3 and 4 and Tables 8 and 9, the relationships among the code groups are presented in relation to the themes and studies. These aggregations of second-cycle codes represent different elements that help understand, within the CIMO framework, the role of predictive models in insurance companies' outcomes.

Adaptability Factors: contains families of codes related to tools, actions, and events that change the condition of the insurance business, just like portfolio diversification, access to information, market trends, non-financial risks policies, and risk awareness.

Insurance market specifics: group codes related to elements of the insurance business, such as annuities and fees, issuer credit ratings, investment track record of each firm, leverage, issuer fundamentals, and issuer financial metrics.

Model structure contains families of codes regarding the design of the predictive model, such as whether the model is parametric, the type of statistical techniques used, optimization and prediction tools included, market- or issuer-oriented models, among other characteristics.

Predictive impact model: aggregates families of codes related to the explanatory variables within the model, such as solvency, profitability, risk assessment, liquidity, leverage, and capital thresholds.

Performance variables: group codes related to portfolio performance, such as profitability, risk, capital adequacy, stability, default rates, and resilience.

Managerial improvement: contains codes related to the portfolio manager skills, just like adaptation, response to market trends, investment strategy, decision making, governance, capital management, proactivity, and pricing decisions

Regulatory impact: contains the codes related to normative framework, compliance, consumer protection, capital buffers, institutional influence, and regulation quality.

As presented in Tables 9 and 10, 770 quotes were produced with 250 codes in 10 groups, including divergent themes ("assessment limitations") and other themes. At first glance, the co- occurrence among these groups of codes predictive models (the intervention) and performance variables (the outcome) shows the strongest relationship between them, and the strongest links presented by the managerial improvement group are with the predictive model and performance variable group, as expected to be a booster between the intervention and the outcome.

Regarding the relationship between the 10 code groups and the 13 articles, Figure 1 and Table 10 summarize the distribution between sources and codes. The representation of the groups is well balanced in aggregated terms, representing between 5% and 15% of the total codes, and in most of the cases (95%) all the groups of codes are represented in each article, with Landriaut (2021) being the only article that is more concentrated in model structures, model inputs, and managerial improvement.

4.4 Findings and CERQual

In this section, the findings and CERQual assessment are presented (see Table 9).

Finding 1 (Table 12) - Predictive Models focused on risk-return and solvency improve portfolio managers' contingent and quick decision-making: Managers who used portfolio models focused on profitability, risk, and solvency also demonstrated greater adaptability and proactivity, quicker market responses, changes in the investment strategy, and better capital and risk management. As stated in the theoretical framework, predictive models should serve as agonizers in decision-making in a dynamic, contingent context, as affirmed by these findings.

Other frequent managerial capabilities, such as governance or general decision-making routines, did not show a strong relationship with predictive risk tools. Liquidity concerns or portfolio optimization were also not among the top lines of information needed for managerial decisions (Merton type Models). Articles supporting this evidence: Escudero and Ruiz (2020), Escudero and Ruiz (2021), Mahayani *et al.* (2021), Landriaut and Lkbous (2021), Chang and Schmeiser (2022), Qi *et al.* (2025), Zinyoro and Aziakpono (2024), Bayar *et al.* (2022), Rahma *et al.* (2025), Bakshi *et al.* (2022), Eling (2024).

Finding 2 (Table 13) - Predictive models focused on risk-return relationships and capital buffers improve portfolio-adjusted risk performance, anticipate capital requirements, and stabilize investment returns: Models that are intently constructed to measure the price of risk in terms of volatility, total return, or regulatory requirements have better performance in measuring profitability, risk size, and stability of cash flows.

It is worth noting that liquidity and optimization criteria did not show a strong relationship with the outcomes, but liquidity did show a weak connection with capital adequacy and stability (Merton type Models). Articles supporting this evidence: Escudero and Ruiz (2020), Escudero and Ruiz (2021), Mahayani *et al.* (2021), Landriaut and Lkbous (2021), Chang and Schmeiser (2022), Qi *et al.* (2025), Zinyoro and Aziakpono (2024), Bayar *et al.* (2022), Rahma *et al.* (2025), Bakshi *et al.* (2022), Eling (2024).

Finding 3 (Table 14) - Dynamic managerial characteristics improve the timely management of risk: management capabilities such as adaptation, proactivity, and market response are strongly associated with compliance with capital buffers, risk management, risk-adjusted returns, and portfolio stability. Other management skills, such as investment strategy and capital management, showed a strong relationship with the risk-return portfolio's performance. Articles supporting this evidence: Escudero and Ruiz (2020), Escudero and Ruiz (2021), Mahayani *et al.* (2021), Chang and Schmeiser (2022), Zinyoro and Aziakpono (2024), Bayar *et al.* (2022), Rahma *et al.* (2025), Bakshi *et al.* (2022), Eling (2024).

Finding 4 (Table 15) - Predictive model inputs are influenced by the model design and regulatory restrictions: Risk assessment models are fed inputs that affect prediction accuracy. The quality of models' inputs, such as data collection, default probability estimation, specific insurance regulation, and solvency, is determined by model structures, especially the risk model selected (that is, Merton-type models; Merton, 1978), and by capital and debt regulation. Adaptability factors, that is, access to information, risk awareness, and diversification behavior, and insurance market specifics, such as risk ratings, performance metrics, insurance market, are not as relevant as the previous factors.

This finding has serious implications for practice because it suggests that Chilean insurers must treat model selection and regulatory calibration as managerial design choices, not merely technical inputs. Articles supporting this evidence: Escudero and Ruiz (2020), Escudero and Ruiz (2021), Mahayani *et al.* (2021), Landriaut and Lkbous (2021), Qi *et al.* (2025), Zinyoro and Aziakpono (2024), Bayar *et al.* (2022), Rahma *et al.* (2025), Bakshi *et al.* (2022), Eling (2024), Yanes (2024).

Finding 5 (Table 16): The portfolio performance of insurance companies, the predictive model's accuracy, and managerial capabilities to adapt to risk could also be explained by an understanding of uncertainty, implementation challenges, and responsiveness to risk. Assessment limitation themes represent divergent themes, that is, themes that may offer alternate perspectives or contradict the previous significant themes.

This finding suggests that the quality of inputs and the accuracy of the predictive model are not sufficient to improve management skills to adapt to risk and its impact on portfolio performance and compliance. However, understanding what lies behind

financial risk, the sensitivity to that uncertainty, and the implementation of the risk and compliance models are the keys to success in risk management. Articles supporting this evidence: Escudero and Ruiz (2020), Escudero and Ruiz (2021), Mahayani *et al.* (2021), Landriaut and Lkbous (2021), Chang and Schmeiser (2022), Qi *et al.* (2025), Zinyoro and Aziakpono (2024), Bayar *et al.* (2022), Rahma *et al.* (2025), Bakshi *et al.* (2022), Eling (2024).

Finding 6 (Table 17) - Other themes to explore are demographic diversity, liquidity constraints, reinsurance markets, and sustainability. Other themes, such as bias assessment, performance variables, regulatory impact, and predictive model impact, are related to performance, while sustainability and liquidity are linked to adaptability. Also, regularity impact is linked to demographic diversity as another significant theme. Articles supporting this evidence: Escudero and Ruiz (2020), Escudero and Ruiz (2021), Mahayani *et al.* (2021), Landriaut and Lkbous (2021), Chang and Schmeiser (2022), Qi *et al.* (2025), Zinyoro and Aziakpono (2024), Bayar *et al.* (2022), Rahma *et al.* (2025), Bakshi *et al.* (2022), Eling (2024), Yanes (2024).

Finally, is worth to mention that integrating those findings, that strong Predictive models improve the risk management of Insurance companies. As Figure 5 shows, predictive models fed with clean and direct structures and quality inputs derived from the understanding of the insurance industry, its regulation, and adaptability factors to adjust (information, market trends, non-financial risks awareness among others such as Merton type Models) improves directly the portfolio performance through risk-return calibration and indirectly by boosting dynamic managerial capabilities like adaptability and proactive responses for risk administration.

Figure 5 represents the relationship between code groups. Articles supporting this evidence: Escudero and Ruiz (2020), Escudero and Ruiz (2021), Mahayani *et al.* (2021), Landriaut and Lkbous (2021), Qi *et al.* (2025), Zinyoro and Aziakpono (2024), Bayar *et al.* (2022), Rahma *et al.* (2025), Bakshi *et al.* (2022), Eling (2024), Yanes (2024).

Although six findings are reported for transparency, Findings 1 through 5 bears most directly on the research question, while Findings 6 and 7 provide supplemental contextual insight. These themes also achieved high or high-moderate CERQual confidence ratings (Table 9) due to their consistency, the adequacy of supporting data, and their direct relevance to the research question. For example, several studies reported that integrating predictive modelling into portfolio governance improved early detection of credit deterioration and reduced capital volatility (Escudero and Ruiz, 2021; Mahayni *et al.,* 2021; Qi *et al.,* 2025).

Similarly, Eling and Yanes (2024) demonstrated that predictive-based stress-testing approaches can strengthen solvency forecasting and capital allocation in illiquid institutional portfolios.

5. Summary of Findings

The findings of the review reflect a coherent structure in how predictive credit-risk models interact with managerial behavior, regulatory context, and investment decision-making within life insurance portfolios. Across the six synthesized findings, a sequential pattern emerges in which predictive models act as catalysts, transforming portfolio risk information into proactive managerial action and solvency-aligned performance outcomes. This synthesis is consistent with contingency theory: models are most effective when their design and interpretability fit the regulatory environment, data conditions, and managerial routines in which they are used.

The strongest finding, supported by a high CERQual confidence level, is that predictive models enhance contingent, rapid decision-making when explicitly focused on solvency, risk, and return metrics, that is Merton type Models. Studies consistently showed that managers who leveraged predictive tools demonstrated improved adaptation, faster market response, and more dynamic, risk-aligned strategy adjustments (Escudero and Ruiz, 2020, 2021; Mahayni *et al.,* 2021; Qi *et al.,* 2025). Managerial skills such as governance or long-term strategic positioning were less strongly associated, suggesting the models' influence operates primarily through operational responsiveness rather than structural oversight.

Similarly, a high level of confidence supports the link between predictive modelling and portfolio performance, where models calibrated toward volatility, capital thresholds, and regulatory metrics contributed to improved risk-adjusted returns, capital stability, and early default detection (Chang and Schmeiser, 2022; Bayar *et al.,* 2022; Eling, 2024). Liquidity emerged as a weak ancillary factor, consistent with the illiquid structure of institutional insurance markets.

A third pattern highlights that managerial capability—defined here as adaptability, proactivity, and the ability to operationalize risk signals—moderates the effect of modelling on outcomes (Rahma *et al.,* 2025; Zinyoro and Aziakpono, 2024). These skills showed strong co- occurrence with both performance variables and predictive model themes, positioning managerial responsiveness as the primary mechanism through which modelling effects translate into outcomes.

Findings four and five suggest that Merton-type models may be more actionable for managerial purposes because they refine the mechanism further by showing that the structure and quality of predictive model inputs—especially probability of default estimation and regulatory calibration—determine predictive accuracy, while limitations around uncertainty, implementation friction, and interpretability can weaken the translation from model insight to managerial action (Bakshi *et al.,* 2022; Kalfin *et al.,* 2022). These divergent or moderating themes emphasize that modelling alone is insufficient: alignment among model architecture, regulatory constraints, and decisionmakers' cognitive environment is required.

Two additional findings point to emerging and peripheral themes, including demographic pressures, reinsurance capacity, sustainability metrics, and systemic liquidity dynamics. While these were less prominent and received lower confidence ratings, their recurrence across multiple studies suggests growing relevance for future solvency oversight and modelling adaptation (Yanes, 2024).

Taken together, the CERQual evaluation supports a cumulative conclusion: predictive models improve solvency and portfolio performance when implemented with high-quality inputs, aligned to regulatory expectations, and supported by capable and adaptive management. Conversely, when modelling operates in environments characterized by weak governance alignment, ambiguous data structures, or insufficient interpretability, benefits diminish or become reactive rather than anticipatory.

Overall, the evidence across all thirteen reviewed studies supports predictive modelling as an effective mechanism to improve risk governance and financial resilience in insurance portfolios, while also recognizing conditional boundaries that shape the depth and consistency of these effects. Based on the synthesis of the available evidence from 13 studies conducted in specific institutional contexts, asset-by-asset predictive credit-risk models—particularly Merton- type structural approaches—appear well suited to strengthen Chilean life insurers' ability to meet solvency requirements and sustain profitability in buy-and-hold investment portfolios.

The high-confidence themes derived from the synthesis indicate that predictive models improve risk anticipation, strengthen capital positioning, and accelerate managerial responsiveness (Escudero and Ruiz, 2021; Mahayni *et al.,* 2021; Qi *et al.,* 2025).

5.1 Managerial Implications of the Findings and Limitations

The theme co-occurrence patterns reveal a deeper structure beneath the general themes already synthesized. When examining the themes that appear alongside Performance Variables, a consistent pattern emerges performance outcomes rarely stand alone as endpoints. Instead, they are embedded in a causal chain where the architecture of predictive modelling, the regulatory environment, and the structure and quality of model inputs interact to shape how insurers measure and respond to performance signals.

This dynamic becomes clearer when observing themes such as default probability modelling, capital efficiency metrics, reserve adequacy, portfolio deterioration indicators, and capital ratio sensitivity frequently co-occur with modelling-related themes — particularly issuer-level creditworthiness measures, data granularity, variable selection precision, and predictive accuracy thresholds (Merton Type).

In other words, the data from the articles suggest that performance variables are the visible consequences of deeper modelling design decisions, not isolated reporting metrics (Escudero and Ruiz, 2021; Mayani *et al.,* 2021).

A similar, yet more operationally dynamic pattern is visible within the Managerial Improvement theme. Themes such as decision process enhancement, governance strengthening, early warning decision protocols, model interpretability, and organizational responsiveness show strong co-occurrence with model-input themes and predictive model behavior, especially in studies that apply machine learning, survival modelling, or Merton-type frameworks.

The implication is that managerial improvement is not merely a behavioral or cultural outcome — it arises when predictive models generate credible, actionable, and timely insights. Where interpretability or input quality is low, managerial improvement themes co-occur instead with assessment limitations or adaptability factors, suggesting that uncertainty or lack of transparency in modelling often forces decisionmakers into reactive rather than proactive roles. Conversely, when predictive signals are granular and validated, managerial behavior shifts toward anticipatory capital planning, pre-emptive portfolio rotation, and early solvency risk mitigation (Rahma *et al.,* 2025; Kalfin *et al.,* 2022).

Bringing these two patterns together, Predictive Model Impact emerges as the mediating layer that links design (model inputs and structure) with organizational response (managerial improvement) and measurable outcomes (performance variables). Themes within Predictive Model Impact, such as risk signal reliability, responsiveness of forecasts, stress-scenario adaptability, regulatory alignment, and portfolio sensitivity detection, appear most frequently in proximity to both performance and managerial themes.

These repeated co-occurrence connections support a theoretical interpretation: predictive models operate as a translational mechanism, converting risk information into actionable institutional behavior. Where predictive impact themes are dense, performance variables shift from descriptive reporting to strategic levers, while managerial behavior shifts from compliance-driven to anticipatory and analytical (Eling, 2024; Bakshi *et al.,* 2022).

The inverse pattern is equally telling. When predictive model themes cluster with assessment limitations, adaptability constraints, missing data granularity, or misalignment between regulatory frameworks and predictive capacity, downstream connections to performance variables weaken, and managerial improvement themes redirect toward procedural workarounds rather than systemized learning (Qi *et al.,* 2025; Escudero and Ruiz, 2020). This indicates that the presence of a predictive model alone does not guarantee improvement; rather, its influence is conditional on how well its internal architecture and external environment align (Merton models prioritize architecture flexibility).

Taken together, the theme co-occurrence analysis demonstrates a coherent mechanism: model structure and input sophistication shape the predictive impact of models, which in turn influences the degree of managerial improvement.

Once managerial improvement is present, the relationship strengthens between predictive modelling and measurable solvency-linked performance variables (Chang and Schmeiser, 2022). The implication is relational and sequential: predictive modelling is most effective when embedded in a context that supports interpretability, data quality, regulatory coherence, and managerial capability.

Although predictive modeling has demonstrated potential to strengthen solvency management, several strands of evidence highlight limitations and counterarguments as summarized in Table 18. In this REA review, the implementation of predictive modeling, responsiveness to its outputs, and understanding of risk were the main areas of divergence. For example, Escudero and Ruiz (2020, 2021) note that delayed accounting updates and thin secondary-market trading restrict timely calibration or Bakshi *et al.* (2022) reported behavioral and governance constraints such as managerial overconfidence, inertia, and weak internal controls can offset analytical advantages and Zinyoro and Aziakpono (2024) suggests that purely quantitative solvency tools may conflict with risk understanding fairness and transparency obligations. Together, these findings underscore that while predictive analytics offer strategic promise, their effectiveness depends on data quality, regulatory alignment, and managerial competence.

Even with these limitations and counterpoints, evidence from the reviewed literature strongly supports the hypothesis that predictive credit-risk modeling enhances solvency and profitability in life insurance portfolios. All 13 articles in this REA demonstrated that data-driven models improve capital efficiency, accuracy, and resilience, even under illiquid or volatile conditions.

Integrating predictive analytics within management frameworks mitigates behavioral and regulatory frictions, while IFRS-17-aligned approaches increase transparency and stakeholder confidence. Overall, when properly calibrated and integrated into governance systems, predictive solvency models enhance both financial performance and compliance, refuting claims of instability or limited real-world applicability due to a lack of risk understanding.

5.2 Conclusion to the Synthesis and Managerial Recommendations

Based on the synthesis of the evidence, the answer to the REA question is clear: implementing an asset-by-asset predictive credit-risk model enhances Chilean life insurers' ability to meet solvency requirements and sustain profitability in buy-and-hold investment portfolios (Merton type models). The high-confidence themes derived from the synthesis indicate that predictive models improve risk anticipation,

strengthen capital positioning, and accelerate managerial responsiveness (Escudero and Ruiz, 2021; Mahayni *et al.,* 2021; Qi *et al.,* 2025).

While model success depends on data quality, interpretability, and regulatory alignment, the weight and consistency of evidence across methods, markets, and modelling approaches affirm that predictive tools represent implications for management and practice recommendations.

The findings of this REA analysis show a structured relationship between the themes, indicating that predictive modelling influences insurance portfolio outcomes through interconnected mechanisms rather than as a standalone technical capability. Performance variables—such as capital adequacy, default risk, stability, and reserve deterioration— consistently appeared alongside modelling architecture and model input quality, suggesting that portfolio outcomes function as end-state expressions of deeper modelling design decisions rather than independent reporting metrics (Escudero and Ruiz, 2021; Mahayni *et al.,* 2021).

Likewise, managerial improvement demonstrated strong relational density with predictive modelling themes, particularly in studies applying machine learning, structural credit models, or survival-based calibration. These connections indicate that managerial adaptability, responsiveness, and decision process enhancement emerge when predictive models generate actionable, interpretable, and reliable signals rather than abstract analytics (Rahma *et al.,* 2025; Kalfin *et al.,* 2022).

Together, these patterns position Predictive Model Impact as the mediating mechanism linking model structure and inputs to managerial response and performance results. When predictive reliability, regulatory alignment, and input quality are high, the modelling role shifts from descriptive reporting to proactive solvency management, allowing earlier capital planning, pre-emptive portfolio adjustments, and improved resilience (Eling, 2024; Bakshi *et al.,* 2022).

In contrast, when modelling outputs co-occur with implementation barriers—such as data gaps, interpretability challenges, or regulatory misalignment- the effect weakens, and managers revert to reactive or procedural behavior, limiting performance impact (Qi *et al.,* 2025; Escudero and Ruiz, 2020).

Despite these limitations, the overall evidence strongly supports the conclusion that predictive credit-risk modelling enhances solvency outcomes and portfolio stability when implemented under appropriate structures and supported by capable decision-making environments. Across all thirteen studies, predictive analytics improved capital efficiency, decision accuracy, and resilience, even in illiquid or volatile markets. When embedded within regulatory frameworks and managerial processes, predictive models not only strengthen risk governance but also reinforce transparency and stakeholder confidence, supporting their role as an emerging standard in insurance investment and solvency oversight.

These findings and limitations demonstrate that predictive, issuer-level credit-risk modelling (Merton type) can enhance solvency management and strengthen investment decision- making in life insurance portfolios, particularly in markets such as Chile, where illiquidity, long- duration liabilities, and concentration risk are structurally present.

However, the benefits depend on the way the models are adopted, interpreted, and aligned with regulatory and managerial processes. The following recommendations translate the evidence into actionable guidance while recognizing implementation risks and organizational contingencies.

Recommendation 1: Begin With an Incremental Pilot Implementation Focused on High- Materiality Issuers in the Merton Model:

Justification from Evidence:
Across multiple studies, incremental adoption was shown to reduce operational disruption and allow calibration without jeopardizing portfolio exposure (Escudero and Ruiz, 2020, 2021; Mahayni *et al.,* 2021). Pilot-based rollouts were particularly effective in contexts where predictive systems introduced new analytical perspectives that diverged from traditional credit- rating or accounting frameworks (Eling and Yanes, 2024). The CERQual table ranked this theme as high confidence, supported by consistent evidence demonstrating enhanced solvency foresight when predictive modelling was used before full implementation.

Practical actions:
- Select a group of issuers with high concentration or long duration for the initial pilot.
- Conduct quarterly model-validation and backtesting before scaling.
- Integrate predictive insights into existing solvency and credit review cycles rather than replacing them immediately.

Risks:
Abrupt or organization-wide adoption may lead to model skepticism or misinterpretation, notably where output diverges from credit-rating agency assessments, a risk noted by Rahma (2025) and Kalfin (2022).

Acceptance considerations:
Positioning the pilot as a decision-support enhancement, not a system that replaces manager judgment. This aligns with Wright *et al.'s* (2016) stage-based EBM approach, which emphasizes learning before commitment.

Recommendation 2: Build Organizational Capability for Interpreting Model Outputs and Standardize Decision Protocols:

Justification from Evidence:

One of the strongest patterns in the evidence was that the value of predictive modelling was not derived solely from probabilistic accuracy, but from the managerial responsiveness it enabled (Zinyoro and Aziakpono, 2024; Chang, 2022).

Studies indicated that when organizations lacked interpretation protocols, early warning signals did not translate into timely action (Bayar *et al.,* 2022; Landriault, 2021). Conversely, firms that embedded decision playbooks or adaptive governance frameworks demonstrated improved solvency ratios and fewer deterioration-related losses (Qi *et al.,* 2025; Escudero and Ruiz, 2021).

Practical actions:

- Develop trigger-based risk action pathways (e.g., "if default probability crosses x%, then…").
- Conduct simulation-based training and scenario rehearsals to build intuition.
- Formalize links between model output and activities such as provisioning, hedging, or divestment.

Risks:
Ambiguity in how risk signals should be acted upon may lead to "alarm fatigue" or inconsistent responses, an issue identified by Bakshi (2022).

Acceptance considerations:
Training and participatory interpretation discussions encourage ownership and reduce the perception that modelling is replacing professional expertise, reflecting Rousseau and McCarthy's (2007) argument that evidence must coexist with practitioner judgment to gain legitimacy.

Recommendation 3: Align Predictive Models with Regulatory Requirements and Governance Structures to Improve Credibility and Adoption:

Justification from Evidence:
Several included studies emphasized that predictive modelling gains adoption and strategic relevance when aligned with solvency reporting frameworks such as Solvency II, IFRS-17, or national supervisory expectations (Landriault, 2021; Kalfin, 2022)—the theme Regulatory Impact received high–moderate CERQual confidence, reflecting consistent but context- dependent evidence. When solvency tools were integrated into audit trails, capital-charge calculations, or board-reporting dashboards, adoption was smoother and resistance lower (Eling and Yanes, 2024; Qi *et al.,* 2025).

Practical actions:

- Map predictive outputs to solvency capital components (default risk charges, reserve buffers).
- Incorporate models into formal risk governance processes (committee reporting, ORSA inputs).

- Engage actuarial and compliance functions early to reduce technical and cultural resistance.

Risks:
Lack of transparency may create skepticism among regulators and internal assurance functions, as highlighted in Bayar *et al.* (2022).

Acceptance considerations:
Early regulatory engagement and transparent model documentation increase institutional trust and reduce the perception that modelling introduces unobservable risk, a principle consistent with evidence-based implementation approaches advocated by Van de Ven and Johnson (2006).

These recommendations, summarized in Table 10, reflect the strongest patterns from the evidence synthesis and align implementation with organizational capability, regulatory expectations, and evidence-based management principles. They avoid prescribing universal solutions and instead offer actionable, context-sensitive steps supported by high-confidence findings from the REA. When applied iteratively, these practices may help insurance organizations transition from reactive solvency management toward predictive risk stewardship grounded in scientific evidence and managerial judgment.

5.3 Limitations of the Rapid Evidence Assessment

In addition to the limitations presented as context for managerial recommendations and implications, some limitations should be acknowledged.

First, the resulting evidence base comprises 13 studies from peer-reviewed sources that met the inclusion criteria. While these studies represent credible, methodologically diverse research, including simulation models, machine-learning analyses, solvency frameworks, and econometric designs (e.g., Escudero and Ruiz, 2020; Mahayni *et al.,* 2021; Qi *et al.,* 2025), the sample sizes remain limited. This restricts generalizability and prevents the use of quantitative meta-analytic aggregation.

Second, heterogeneity across methods and contexts requires a narrative synthesis rather than a statistical comparison. The included studies originated from different regulatory regimes (e.g., Solvency II, local emerging markets), asset environments, and firm maturity, which may not fully align with the Chilean insurance market context, where inflation-linked liabilities and bond illiquidity are significant (Bayar *et al.,* 2022; Zinyoro and Aziakpono, 2024). This contextual variability may influence the transferability of findings, but Merton Models seemed to be the more replicable and standardized.

Third, although Atlas.TI strengthened transparency and traceability during coding; single-researcher thematic coding may introduce interpretive bias (Saldaña, 2021; Perez Ripossio, 2023). Inter-coder reliability, common in larger systematic reviews, was not feasible due to REA time constraints.

Finally, publication bias may exist, as organizations are more likely to share successful modelling outcomes than unsuccessful implementations, a phenomenon well- documented in applied financial research (Eling and Yanes, 2024).

These limitations do not invalidate findings; instead, they signal that conclusions should be interpreted as evidence-informed guidance rather than prescriptive universal rules, aligning with evidence-based management principles (Sharma *et al.,* 2023).

5.4 Recommendations for Future Research

While the current body of evidence demonstrates promising alignment between predictive credit-risk modelling and improved solvency and performance outcomes in life insurance portfolios, several areas require further exploration to advance both scholarly understanding and practical implementation.

First, there is a need for longitudinal empirical research that evaluates solvency ratios, default events, capital buffers, and investment returns before and after predictive model adoption. Such designs would allow researchers to assess not only whether predictive tools improve solvency outcomes but also how long it takes for those effects to materialize, whether they persist, and whether market cycles or the investment mix influence their impact strength (Escudero and Ruiz, 2021; Rahma *et al.,* 2025). Longitudinal research would also help differentiate the role of modelling from exogenous macroeconomic conditions—an issues that simulation-based and cross-sectional studies cannot fully resolve.

Second, comparative cross-jurisdictional studies would help determine how contextual variables—such as regulation, capital standards, liquidity availability, and reliance on credit ratings—shape the effectiveness and adoption trajectory of predictive modelling. Comparing insurers operating under emerging-market regulatory frameworks to those under Solvency II or NAIC regimes would clarify whether predictive modelling outcomes are consistent across solvency architectures and whether regulatory incentives accelerate or constrain adoption (Landriault, 2021; Kalfin, 2022). This research may also shed light on whether regulatory alignment is a prerequisite for modelling success or whether strong modelling can improve compliance culture independently.

Third, the evidence suggests that predictive modelling effectiveness depends not only on technical capability but also on managerial interpretation, cultural acceptance, and organizational learning. Therefore, mixed-method research is

needed to explore psychological, governance, and communication dynamics that influence whether predictive outputs translate into action. Interviews, ethnographic observation, or behavioral modelling could help uncover how investment committees interpret uncertainty, respond to early deterioration signals, and manage tensions between traditional credit assessment practices and machine-learning-based forecasting (Chang, 2022; Zinyoro and Aziakpono, 2024). Such research would extend the current evidence base by linking model output to human decision-making processes, rather than assuming that improved analytics automatically translate into improved practices.

A fourth direction involves collaborative practitioner-scholar research models, consistent with recommendations by Stevens-Wood *et al.* (2024). Real-world experimentation, action research, and co-development of modelling frameworks with insurers, regulators, and asset managers would support iterative refinement of predictive methodologies.

These partnerships could address practical concerns identified in this REA—including interpretability, transparency, data quality, and integration with compliance processes—while enabling more robust testing of predictive methodology in live investment environments. Such engagement would also reduce the gap between research production and research application, addressing both the "lost before translation" and "lost in translation" barriers described in evidence-based management literature.

Finally, future research should expand thematic boundaries to include variables identified as emerging or underexplored trends in this REA—such as demographic liabilities, ESG investment mandates, supervisory expectations under IFRS-17, reinsurance market dynamics, and liquidity constraints in thin bond markets. Exploring how predictive models incorporate or respond to these structural shifts will be essential to determine whether current modelling paradigms remain adequate or require revision to support next-generation solvency governance.

In summary, future research will benefit from methodological diversification, real-market testing, and interdisciplinary collaboration. Doing so will refine understanding of how predictive modelling functions as both an analytical tool and a managerial catalyst, supporting more resilient and adaptive solvency management in the evolving landscape of life insurance investment.

6. Conclusion

Delayed recognition of issuer-level credit deterioration remains a critical challenge for Chilean life insurance companies, with significant implications for solvency stability and profitability. Although predictive credit-risk models offer potential solutions, their effectiveness as managerial interventions is contingent on model characteristics, governance alignment, and contextual constraints.

Even with these limitations and counterpoints, evidence from the reviewed literature strongly supports the hypothesis that predictive credit-risk modeling enhances solvency and profitability in life insurance portfolios.

All 13 articles in this REA demonstrated that data-driven models, that is Merton type Models, improve capital efficiency, accuracy, and resilience, even under illiquid or volatile conditions. Integrating predictive analytics within management frameworks mitigates behavioral and regulatory frictions, while IFRS-17-aligned approaches increase transparency and stakeholder confidence. Overall, when properly calibrated and integrated into governance systems, predictive solvency models enhance both financial performance and compliance, refuting claims of instability or limited real-world applicability due to a lack of risk understanding.

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Appendix: *The source manuscript contains appendices with the CIMO framework, inclusion and exclusion criteria, database descriptions, PRISMA information, selected-study summaries, TAPUPAS and CERQual assessments, coding-group analyses, and managerial recommendations. The formatted manuscript retains the substantive article text and reference list; complex original figures and tables should be retained from the source PDF from the author.*

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