UNIVERSITY OF LJUBLJANA
SCHOOL OF ECONOMICS AND BUSINESS

MASTER’S THESIS

A COMPARATIVE ANALYSIS OF IFRS 17 RISK ADJUSTMENT USING AN INTERNAL STOCHASTIC MODEL AND THE SOLVENCY II STANDARD FORMULA

Ljubljana, June 2026 MARIJA AJDINSKA

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ABSTRACT

This master thesis analyses the calculation of the Risk Adjustment (RA) under IFRS 17 for a life insurance portfolio and compares two alternative approaches: an internal stochastic model and the Solvency II Standard Formula (SF). The study first presents the conceptual and regulatory background of IFRS 17 and Solvency II, with particular focus on the role of the RA as compensation for bearing non-financial risk. Then, a synthetic endowment portfolio is constructed and valued consistently under both approaches. The empirical results show that both approaches produce relatively similar total RA amounts at a chosen confidence level, but differ materially in risk composition and diversification. The findings suggest that the SF can provide a practical approximation of the RA, but it is less sensitive to entity-specific risk characteristics. The internal model is therefore more consistent with the IFRS 17 objective of reflecting the insurer's own compensation for bearing uncertainty in non-financial risks.

KEY WORDS: Life insurance, Risk Adjustment (RA), IFRS 17, Solvency II Standard formula, Internal model

SUSTAINABLE DEVELOPMENT GOALS

POVZETEK

Magistrsko delo obravnava izračun prilagoditve za tveganje (RA) po MSRP 17 za portfelj življenjskih zavarovanj ter primerja dva alternativna pristopa: notranji stohastični model in standardno formulo Solventnosti II. V prvem delu so predstavljena konceptualna in regulativna izhodišča MSRP 17 in Solventnosti II, s poudarkom na vlogi prilagoditve za tveganje kot nadomestila za prevzem nefinančnih tveganj. Nato je oblikovan sintetični portfelj mešanega življenjskega zavarovanja, ki je ovrednoten na dosleden način po obeh pristopih. Empirični rezultati kažejo, da oba pristopa pri izbrani ravni zaupanja podata razmeroma podobno skupno vrednost prilagoditve za tveganje, vendar se bistveno razlikujeta v strukturi tveganj in učinkih diverzifikacije. Ugotovitve kažejo, da lahko standardna formula predstavlja praktičen približek za izračun prilagoditve za tveganje, vendar je manj občutljiva na specifične značilnosti portfelja. Interni model je zato bolj skladen s ciljem MSRP 17, da prilagoditev za tveganje odraža lastno nadomestilo zavarovalnice za prevzem negotovosti, povezane z nefinančnimi tveganji.

KLJUČNE BESEDE: Življenjska zavarovanja, Prilagoditev za tveganje (RA), MSRP 17, Standardna formula Solventnosti II, Interni model

CILJI TRAJNOSTNEGA RAZVOJA

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LIST OF ABBREVIATIONS

sl. – Slovene

BBA – (sl. Pristop z gradniki); Building Block Approach

BSCR – (sl. Osnovni zahtevani solventnostni kapital); Basic Solvency Capital Requirement

CoC – (sl. Metoda stroška kapitala); Cost of Capital

CSM – (sl. Pogodbena servisna marža); Contractual Service Margin

CTE – (sl. Pogojno pričakovano izguba); Conditional Tail Expectation

EFCF – (sl. Pričakovani prihodnji denarni tokovi); Expected Future Cash Flows

EIOPA – (sl. Evropski organ za zavarovanja in poklicne pokojnine); European Insurance and Occupational Pensions Authority

EU – (sl. Evropska unija); European Union

FCF – (sl. Izpolnitveni denarni tokovi); Fulfilment Cash Flows

GLM – (sl. Generalizirani linearni modeli); Generalized Linear Models

GMM – (sl. Splošni model merjenja); General Measurement Model

IASB – (sl. Odbor za mednarodne računovodske standarde); International Accounting Standards Board

IFRS – (sl. Mednarodni standardi računovodskega poročanja); International Financial Reporting Standards

LIC – (sl. Obveznosti za nastale škode); Liability for Incurred Claims

LRC – (sl. Obveznosti za preostalo kritje); Liability for Remaining Coverage

MCR – (sl. Minimalni zahtevani kapital); Minimum Capital Requirement

MLE – (sl. Metoda največje verjetnosti); Maximum Likelihood Estimation

ORSA – (sl. Lastna ocena tveganj in solventnosti); Own Risk and Solvency Assessment

PAA – (sl. Poenostavljeni pristop razporeditve premij); Premium Allocation Approach

PVFCF – (sl. Sedanja vrednost prihodnjih denarnih tokov); Present Value of Future Cash Flows

RA – (sl. Prilagoditev za tveganje); Risk Adjustment

RM – (sl. Dodatek za tveganje); Risk Margin

SCR – (sl. Zahtevani solventnostni kapital); Solvency Capital Requirement

SF – (sl. Standardna formula); Standard Formula

TVaR – (sl. Pogojna pričakovana repna tvegana vrednost); Tail Value at Risk

VaR – (sl. Tvegana vrednost); Value at Risk

VFA – (sl. Pristop variabilne provizije); Variable Fee Approach

1 INTRODUCTION

Insurance companies mainly operate within two major frameworks that directly shape and influence how uncertainty is measured and reported: IFRS 17 and Solvency II. IFRS 17 is a reporting standard designed to measure financial performance of insurance companies (IFRS Foundation, 2022), whereas Solvency II is the European legal framework that assesses the overall solvency of the insurance company and guarantees protection of the policyholders and beneficiaries (EIOPA, 2016).

The introduction of IFRS 17 has fundamentally reshaped the measurement and reporting of insurance liabilities, especially within the life insurance sector, where long-term cash flows and underwriting risks play a crucial role around the uncertainty about the timing and amount of fulfilment of cash flows. According to the IFRS 17 standard insurers must quantify not only the unbiased probability–weighted best estimate of fulfilment cash flows, but also the Risk Adjustment (hereinafter: RA). The RA is one of the components of liability measurement under IFRS 17 and it recognizes that fulfilment cashflows, even when calculated as probability–weighted estimates, do not fully reflect the uncertainty inherent in predicting future outcomes (IFRS Foundation, 2022). By measuring the variability around these expected cashflows, the RA transforms this uncertainty into a quantifiable liability component that represents the insurer's perspective on risk. The standard does not specify which method should be used to calculate and determine the RA. Some of the methods used in the insurance markets include Value at risk method (VaR), Conditional Tail Expectation (CTE), Cost of capital method (CoC), etc. This flexibility of choosing one's own method for calculating RA, introduces practical challenges to the life insurers, due to the lack of granular data needed to construct probability distributions of underwriting risks (Milliman, 2017).

In contrast, Solvency II provides a structured framework with predefined stresses and a correlation matrix for aggregating life underwriting risks under the Standard Formula (hereinafter: SF). These calibrations, defined through EIOPA and its predecessor CEIOPS (CEIOPS-DOC-70/10), are widely adopted and operationally simple, making them an attractive source for determining the RA under IFRS 17. Life insurers in the EU often rely on the Solvency II SF because it does not require extensive historical data, it is operationally efficient, it is approved by regulators, and it avoids the need for internal stochastic models. However, using Solvency II SF to calculate IFRS 17 RA might create a methodological inconsistency. SF reflects the characteristics of an average European insurer, which may differ from a specific life insurance portfolio (CEIOPS, 2010). As a result, the RA derived from the SF may differ from the RA produced by an internally developed stochastic model that aligns with IFRS 17 principles. Thus, life insurers may face a dilemma of how to develop an internal model that credibly captures the uncertainty in non-financial risks and how does the RA calculated using Solvency II SF reflect their own risk aversion if they rely on externally calibrated SF shocks.

The thesis aims to answer the following research questions:

1. How can a stochastic internal model for mortality, lapse, and expense risk be constructed to comply with IFRS 17 principles and characteristics?
2. How can Solvency II Standard Formula shocks and correlations (CEIOPS-DOC-70/10) be adapted and applied to calculate an IFRS 17 Risk Adjustment?
3. What are the quantitative differences between the Risk Adjustment calculated using the internal model versus the Risk Adjustment derived from the Standard Formula?
4. What methodological and modelling assumptions in each approach contribute most to the differences in the resulting Risk Adjustment?

This master thesis is structured in five main chapters. After the introduction, Chapter 2 reviews the regulatory framework under both IFRS 17 and Solvency II and introduces the calculation of the RA. Chapter 3 focuses on the data used and the methodology applied in both modelling approaches for calculating the RA. Chapter 4 analyses the RA results obtained from the models, based on the data and methodology applied from Chapter 3. Further, Chapter 4 analyses the implication for the insurers, and concludes the analysis with methodological strengths and limitations of the thesis. Lastly, Chapter 6 concludes the master thesis.

2 REGULATORY FRAMEWORKS AND LITERATURE OVERVIEW

This chapter explains the regulatory framework required for the analysis in later chapters. To provide a consistent foundation, the chapter first outlines the key principles of IFRS 17, with particular focus on the General Measurement Model (hereinafter: GMM) and its building blocks, as these determine the valuation of fulfilment cash flows and the RA for non-financial risk. The chapter then discusses alternative measurement approaches under IFRS 17 and introduces the role of the RA in greater detail. Lastly, Solvency II is presented as a regulatory framework and compared with IFRS 17 to highlight the conceptual and practical differences in the treatment of risk compensation and liability valuation. This framework is essential for interpreting the methodology and findings in subsequent chapters.

2.1 IFRS 17 – Insurance contracts

The following chapter provides an overview of IFRS 17 by first outlining its historical development, objectives and scope. Subsequently, the GMM is introduced and explained, which forms the core valuation framework under IFRS 17. Attention is given to the building blocks of the model, as these components are directly linked to the concept of the RA, which is further analysed in the subsequent chapters of this thesis.

2.1.1 History overview

The first international body responsible for setting accounting standards was the International Accounting Standard Committee (hereinafter: IASC). The IASC was established in 1973 by various accounting bodies from multiple countries in response to economic integration and growth of cross-border capital flows. Its main purpose was to develop and promote accounting standards to improve the overall quality of financial reporting (IAS Plus, 2012a). After nearly 25 years of work, in 2000, the IASC agreed to restructure itself into a full-time International Accounting Standard Board (hereinafter: IASB) in order to improve global convergence of accounting standards. The IASB represents an independent, private-sector body operating under the oversight of the legal entity International Financial Reporting Standard Foundation (hereinafter: IFRS Foundation), with full responsibility for developing and approving IFRSs. Through this structure, the IASB continues the legacy of the IASC, promoting high-quality, transparent, and internationally convergent financial reporting standards (IAS Plus, 2012b).

IFRS 17 is a reporting accounting standard issued by the IASB, designed to measure financial performance of insurance companies. Prior to IFRS 17, the accounting for insurance contracts under IFRS was governed by IFRS 4, established in March 2004. IFRS 4 was a response to the need for a temporary standard that can address the different accounting practices and complexities in the insurance industry, and its main aim was to offer guidance until a comprehensive standard could be developed (IFRS Foundation, 2022). IFRS 4 served its purpose allowing insurers to apply a variety of measurement methods and recognition criteria. However, that led to inconsistencies, and limited comparability between insurer’s financial statements (Schatte, 2023). Following more than a decade of development, in May 2017, the IASB completed its insurance contract project and issued IFRS 17 to replace IFRS 4 with a consistent global standard. The new standard was subsequently amended in June 2020 to facilitate implementation, and entities were required to apply IFRS 17 for annual reporting beginning on or after 1 January 2023 (IFRS Foundation, 2022). The development of IFRS 17 addressed the critical shortcomings of IFRS 4, such as the absence of a unified measurement model and the inconsistent recognition of profit and liability across insurers. By establishing a principle-based framework, IFRS 17 aimed to enhance comparability, reliability and transparency of financial reporting for insurance contracts (EY,2021).

2.1.2 Objective and scope of IFRS 17

The objective of IFRS 17 is to provide a comprehensive set of principles for the recognition, measurement, presentation and disclosure of insurance contracts that fall within the scope of the standard. The standard is designed to ensure that entities provide relevant information that accurately represents the effects of insurance contracts on their financial position, performance and cash flows. This enables users of financial statements to assess the timing, amount and uncertainty of future cash flows arising from insurance contracts (IFRS Foundation, 2022).

In terms of the scope of IFRS 17, according to IFRS Foundation, an insurance company is required to apply IFRS 17 to all insurance and reinsurance contracts it issues, to reinsurance contracts it holds, and investment contracts with discretionary participation features that it issues. The Standard applies not only to insurance contracts issued directly but also to those acquired through business combinations or portfolio transfers. It ensures consistent accounting regardless of how the insurance contracts are obtained. The scope of IFRS 17 is designed to ensure that all contracts that expose an insurance company to insurance risk are accounted for consistently, regardless of the type of entity that issues them. IFRS 17 is therefore a transaction-based standard rather than an entity-based one. This means that its application depends on the nature of the contract and the risks it transfers, not on whether the issuing entity is legally classified as an insurer. Although EU insurance regulation requires insurance contracts to be issued by authorized insurance companies, non-insurance entities can still fall within the scope of IFRS 17 if they issue contracts that meet the definition of an insurance contract (EY, 2021).

The standard also specifies exclusions for items that fall outside its scope in order to avoid overlap with other IFRS Standards. For example, product warranties issued by manufacturers or dealers are accounted for under IFRS 15, which governs revenue arising from contracts with customers. Employer assets and liabilities arising from employee benefit plans are accounted for under IAS 19 or IFRS 2. IAS 19 prescribes the accounting for standard employee benefits such as salaries and pensions, while IFRS 2 governs transactions where a company compensates employees with its own equity. Most financial guarantee contracts fall within the scope of IFRS 9 financial instruments, which means that those contracts are also excluded unless the issuer elects to apply IFRS 17. Contractual rights or obligations contingent on non-financial items, such as certain licence fees or royalty arrangements, are also excluded. In addition to these exclusions, IFRS 17 requires entities to identify and separate non-insurance components within an insurance contract. Such contracts may include an insurance component together with investment or service components. For example, a life insurance contract may include a savings component that can be withdrawn independently, as well as additional services such as medical check-ups. In such cases, the insurance coverage remains within IFRS 17, while the investment component is accounted for under IFRS 9 and the service component under IFRS 15. This separation ensures that each component is measured consistently with its underlying economic characteristics (IFRS Foundation, 2022).

Once a contract is determined to be within the scope of IFRS 17, it must be accounted for under that Standard for its entire life. Overall, the scope of IFRS 17 is designed to capture all contracts that expose an entity to significant insurance risk while clearly separating them from financial instruments, service contracts, and other arrangements covered by different IFRS Standards. By clearly defining what is included and excluded, IFRS 17 aims to ensure consistent, transparent, and comparable accounting for insurance-related activities across entities and jurisdictions (EY, 2021).

2.1.3 General measurement models (GMMs)

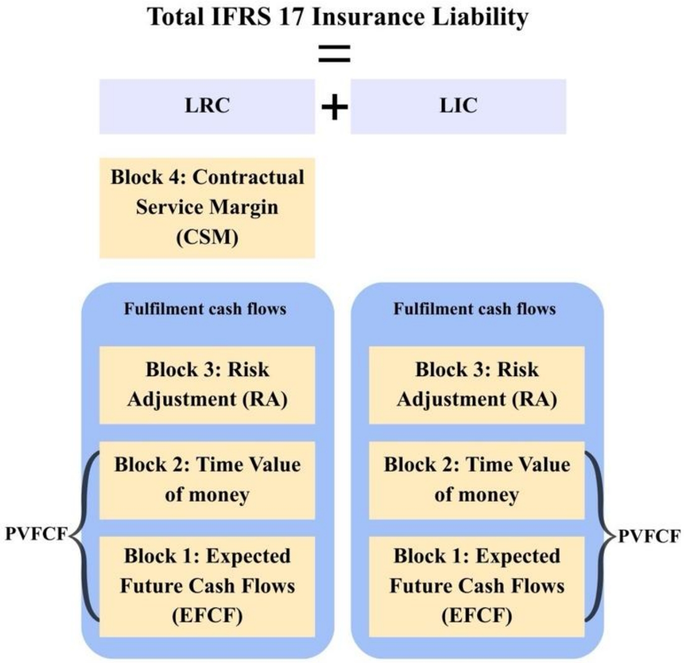
IFRS 17 establishes a framework for measuring the insurance contracts liabilities. General Measurement Model (hereinafter: GMM) is considered the default measurement model for insurance contracts issued and reinsurance contracts held. It applies to all insurance contracts unless they meet the criteria for either the Premium Allocation Approach (hereinafter: PAA) or the Variable Fee Approach (hereinafter: VFA), which will be discussed further in this chapter.

The GMM provides a principles-based framework for measuring insurance liabilities that ensures current estimates of future cash flows are used, uncertainty is explicitly recognised, and profit is deferred until services are delivered. It is referred to as the Building Block Approach (hereinafter: BBA) because it is constructed using four blocks that build the measurement model. Those blocks are the Expected future cash flows (hereinafter: EFCF), the RA, the time value of money and the Contractual Service Margin (hereinafter: CSM). Together, these components capture the expected cost of fulfilling obligations, the uncertainty inherent in the obligations, and the unearned profit to be recognised systematically over the coverage period (EY, 2021).

Before applying the GMM, insurance contracts must first be grouped into portfolios that consist of contracts sharing similar risks and are managed together. In practice, contracts within the same product line (e.g. endowment product) are typically included in the same portfolio (e.g. endowment portfolio), and they are managed together, whereas contracts from different product lines generally form separate portfolios due to their differing risk profiles. Each portfolio is further divided into groups based on profitability at initial recognition. Groups include ‘onerous contracts’, which are expected to generate a loss. Then, ‘not onerous’ contracts, which are expected to be profitable. And ‘other contracts’ that do not clearly fall into either category. These groups are established at the inception of the portfolio and cannot be changed later, even if the expected profitability changes. For instance, if a group of onerous contracts, at some point becomes profitable (not onerous), they will remain in the group of the onerous contracts as established at the initial recognition. Furthermore, contracts issued more than one year apart are placed in separate groups, forming annual cohorts. This level of aggregation ensures that losses from onerous contracts are recognised promptly, prevents profits from non-onerous contracts from being used to offset losses, and determines the pattern of profit recognition, which directly affects the calculation and release of the CSM (IFRS Foundation, 2022).

GMM distinguishes between Liability for remaining coverage (hereinafter: LRC) and Liability for incurred claims (hereinafter: LIC). The total carrying amount of insurance liabilities is made up of the sum of those two components. LRC represents obligation for future insurance services, whereas LIC is the obligation for insured events that have already incurred (Munich Re, 2021).

Figure 1: IFRS 17 GMM – Building blocks of insurance contract liabilities



Source: Adapted from Deloitte & Touche (2021).

As shown in Figure 1, the fulfilment of cash flows is composed of the EFCF, time value of money and the RA. The EFCF are unbiased, probability weighted estimates, that the insurer will need to honour the obligations arising from the contracts within the contract boundary. Specifically, a cash flow is within the contract boundary if it occurs while the insurer is still committed to the contract, meaning the insurer cannot cancel or avoid providing the coverage without the policyholder's consent, and the insurer cannot change the price or terms of the contract to fully reflect the risks for that future period (IFRS Foundation, 2022). These cash flows include expected claims and benefits, acquisition and administration costs, and premiums receivable. These cash flows are then discounted to reflect the time value of money and financial risks, ensuring the liability reflects current economic conditions. Thus, the EFCF, discounted with the appropriate discount curve, form the present value of future cash flows (hereinafter: PVFCF) (Deloitte & Touche, 2021). Because insurance contracts are uncertain, the RA is added to the PVFCF to reflect the compensation the insurer requires for bearing non-financial risk. The RA is entity-specific, reflecting the insurer's risk appetite and applied consistently across contracts in the portfolio (Munich Re, 2021). The whole concept of the RA is explained in Chapter 2.2. The CSM represents unearned profit and is determined at initial recognition to ensure that no day-one profit is recognised. In the equation (2) it is shown, if the fulfilment cash flows and RA indicate a net loss, the contract is considered onerous, the CSM is set to zero, and the expected loss is recognised immediately in profit or loss statement. Otherwise, the CSM absorbs any expected profit and is subsequently released to profit as insurance services are provided, as shown in equation (1) (EY, 2021).

$$PVFCF + \ Risk\ Adjustment < 0 \rightarrow CSM \tag{1}$$

$$PVFCF + Risk\ Adjustment > 0 \rightarrow Loss\ component, \text{CSM} \ = \ 0 \tag{2}$$

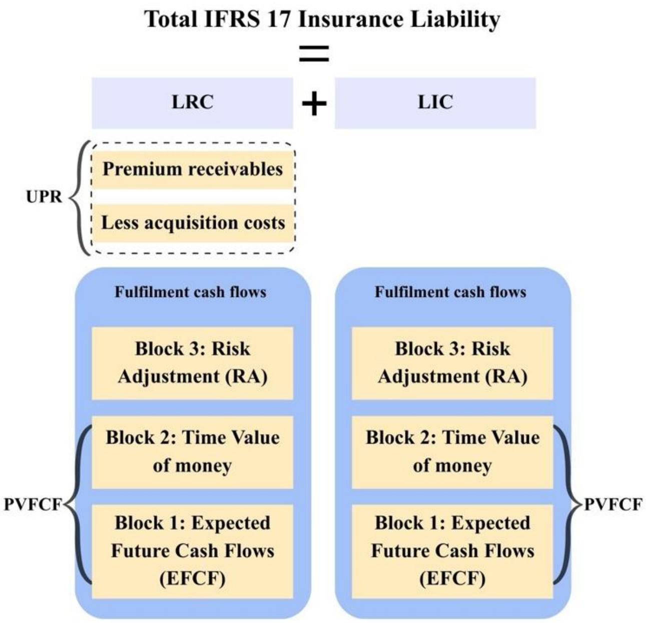
At initial recognition, the GMM measures a group of insurance contracts as the sum of the fulfilment cash flows consisting of PVFCF plus RA and the CSM, if applicable. This ensures that the liability fully captures the expected costs, the compensation for uncertainty, and defers profit recognition over time. At each subsequent reporting date, the insurer remeasures the group using updated assumptions consistent with current market information. Changes in fulfilment cash flows and the RA related to past or current service are recognised immediately in profit or loss, while changes related to future service adjust the CSM. Discount rates used to measure the PVFCF are updated to reflect current market conditions. Changes in discount rates can be recognised either in profit or loss or in other comprehensive income, depending on the accounting policy chosen at the portfolio level. Once this accounting policy is elected, it must be applied consistently across all contracts in the portfolio (EY, 2021).

When all obligations under a group of contracts have been fulfilled or extinguished, the PVFCF and RA are reduced to zero, and the CSM has been fully released to profit. At this point, the group of contracts is derecognised from the balance sheet (IFRS Foundation, 2022). In summary, the GMM, provides a comprehensive framework for measuring insurance contract liabilities under IFRS 17. By following this approach, insurers ensure that liabilities are measured consistently, transparently, and in line with current market conditions, providing both regulatory compliance and economic fidelity in financial reporting (Grant Thornton, 2023a).

2.1.3.1 Premium Allocation approach (PAA)

IFRS 17 allows for a simplified approach for measuring insurance contracts for LRC. PAA is allowed for the short-term contracts where the coverage period of the group of contracts is one year or less, or it is also allowed if the insurer can prove that the PAA will not significantly deviate from the GMM (Munich Re, 2021). If applicable, the entity has the choice to adopt the PAA, but is not required to do so. However, most entities choose the PAA, due to its simplification that the LRC is equal to the unearned premium, meaning there is no need to account for the CSM. Moreover, discounting is not needed when the coverage is less than a year. The RA for LRC is not required, unless the group of contracts is onerous, in such case, the RA is mandatory and the GMM must be applied (Worden Zaluski Consulting Actuaries, 2023). As shown in Figure 2, under PAA the LRC is initially measured as the premium received less any acquisition costs and subsequently adjusted each reporting period for premiums received, acquisition cash flows, insurance revenue recognized, and any changes in the financing component. However, the calculation of LIC should be calculated in the same way as in GMM, which means that RA should also be calculated for the LIC. This approach aligns conceptually with traditional unearned premium methods but within the IFRS 17 framework. Revenue is recognized over the coverage period as insurance service is provided, and acquisition costs are amortized consistently over time. This provides a practical and efficient solution for insurers that issue short-term contracts, such as many non-life insurance products (Grant Thornton, 2023b).

Figure 2: Premium allocation approach (PAA) - insurance contract liabilities



Source: Adapted from Deloitte & Touche (2021).

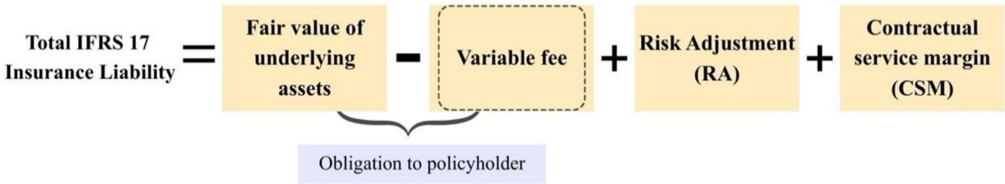
2.1.3.2 Variable fee approach (VFA)

The VFA is a modified version of the GMM that is applied to groups of insurance contracts with direct participation features (Munich Re, 2021). Contracts with direct participation features are investment related service contracts under which an entity promises policyholders a return that depends on the fair value of identified underlying items, such as investment assets. These contracts are commonly found in life insurance and annuity products. Under the VFA, the insurer invests policyholders' funds in underlying assets whose value is expected to change over time. In return for managing these investments, the insurer earns a 'variable fee', representing its share of the returns on the underlying items. This fee fluctuates in line with the value of the underlying assets. Conceptually as the Figure 3 suggests, the insurance contract liability under the VFA reflects the net of:

- the obligation to pay the policyholder, which is an amount equal to the fair value of the underlying items,
- and the variable fee earned by the insurer for managing those items.

At initial recognition, the VFA follows the same fulfilment cash flow and CSM principles as the GMM. However, the difference between GMM and VFA becomes evident in the subsequent measurement, where rather than recognising changes in investment related assumptions immediately in profit or loss, the VFA adjusts the CSM, resulting in profit being recognised progressively as insurance services are provided. Without this approach, the investment related movements would give inaccurate results. Overall, the VFA aligns the measurement of insurance liabilities with the performance of underlying assets, reducing accounting mismatches and supporting a more stable and accurate recognition of profits and losses over time (Grant Thornton, 2023c).

Figure 3: Variable fee approach (VFA) - insurance contract liabilities



Source: Adapted from KPMG IFRG Limited (2017).

2.2 Risk Adjustment under IFRS 17

Under IFRS 17, RA is one of the blocks in the measurement of insurance liabilities. It represents an explicit adjustment to the present value of future cash flows to reflect the compensation an entity would require for bearing uncertainty arising from non-financial risks. Non-financial risks are risks that are inherent in the insurance contract but are not market financial risks. Risks like mortality, morbidity, lapse, expense risks, etc., are all non-financial risks (IFRS Foundation, 2022).

IFRS Foundation (2022) explains the RA as the compensation required for an entity to be indifferent between fulfilling two liabilities. For instance, one liability may have uncertain outcomes, with a 50% probability of requiring EUR 90 and 50% probability of requiring EUR 110, while another liability has a fixed amount of EUR 100. The RA therefore captures the extra amount the insurer would require to be indifferent to accepting the uncertainty.

2.2.1 Characteristics and conceptual background

According to the International Actuarial Association (2018), the main purpose of the RA is to reflect uncertainty in the cash flow estimates, the range of possible outcomes, and the risk of estimation error. Therefore, insurance liability is increased beyond its expected present value to reflect the risk and uncertainty. Insurance contracts generate both cash inflows and cash outflows. When measuring the RA, IFRS 17 considers the uncertainty associated with these inflows and outflows together rather than calculating separate adjustments for each. In practice, the uncertainty related to future cash outflows is usually greater than the uncertainty associated with cash inflows, as the timing and amount of claims are more difficult to predict. As a result, the combined RA generally increases the value of insurance liabilities. Under IFRS 17, the RA for insurance contracts cannot be negative and therefore either increases the liability or is equal to zero. Moreover, RA is calculated only based on insurance contract cash flows and excludes uncertainty arising from investment returns or asset price movements, as these risks are already reflected through the discount rate and the time value of money (IAA, 2018).

Although RA is measured at a specific point in time, the risks it reflects relate to cash flows that will occur in the future. Because of this, the time value of money must also be considered when calculating RA. If the RA is already calculated using the present value of future cash flows, then the time value of money is already included, and no additional adjustment is needed. However, if the RA is calculated without considering discounting, it must be adjusted to reflect the time value of money. Under IFRS 17, insurers are not required to calculate a separate RA that ignores the time value of money. As the insurer provides insurance coverage, the uncertainty regarding future claims decreases, the RA is gradually released over the coverage period. This release reduces the carrying amount of the insurance contract liability and is recognised in profit or loss as part of the insurance service result. At the same time, the discount applied to the RA unwinds. The unwinding of the discount factor over time is recognised separately as insurance finance income or expense in accordance with IFRS 17 requirements (IAA, 2018).

According to the IFRS 17 Foundation (2022), the RA should reflect the following characteristics:

a.) Risks that occur infrequently but involve potentially large losses should result in higher RA than risks that occur frequently but lead to smaller losses. For instance, a large catastrophic event like a hurricane would occur rarely, but costs associated with such event are high and would result in higher RA, rather than accident claims which are a occurring a lot but have low severity.

b.) For similar risks, contracts that have longer duration, will have higher RA, since you hold on to that risk longer, rather than short-term contracts.

c.) The RA should increase when the probability distribution of possible outcomes has heavier tail distribution, as this indicates greater likelihood of extreme losses.

d.) The less is known about the risk, the higher the RA would be.

e.) As the insurers becomes more certain and familiar about the risk, the RA will decrease and vice versa.

2.2.1.1 Non-financial risks

The IAA (2018) describes the difference in insurance liabilities between life insurance contracts and non-life insurance contracts. These differences can be observed in the non-financial risks that are likely to affect the cash flows, which the RA aims to capture. Some of the non-financial risks that affect non-life insurance include frequency risks, severity risks, legal environment risk, etc. However, in life insurance, we observe different types of risks, such as mortality risks, longevity risks, lapse risk, etc. Since, this master thesis focuses on the RA for life insurance contracts, we explain below the concept and the nature of some of the life insurance risks.

a.) Mortality risk and longevity risks – the future pattern of deaths or survivals among policyholders is a key risk. Misestimating mortality trends, failing to account for demographic changes, medical advances, or extreme events like pandemics can lead to under or overestimation of liabilities.

b.) Lapse risk – policyholder behaviour may be different than expected, such as surrendering a policy early or exercising embedded options. These behaviours can be influenced by market conditions or policy design and introduce additional uncertainty in cash flows.

c.) In addition, life insurance contracts often have longer durations, requiring projections of cash flows over long periods. This introduces uncertainty in future expenses, fluctuations in the number of active policies, and other long-term trends, all of which must be considered when estimating the RA.

2.2.1.2 RA and its composition

Before presenting specific techniques for calculating the RA, it is necessary to clarify its conceptual composition and economic meaning. Although the RA is described as a compensation for bearing risk, the RA does not represent an amount that will be explicitly received or paid. Instead, it is an accounting adjustment that modifies the measurement of insurance liabilities. The RA is expressed as a single monetary estimate and forms part of the carrying value of insurance liabilities in the balance sheet. It is neither an income item nor a cash flow and it should not be confused with pricing margins, solvency capital, or profit targets, even though these concepts may be related economically.

The IAA (2018) identifies several interrelated elements that underline the estimation of the RA and help explain why different calculation approaches may be appropriate in different circumstances.

a.) The first element is risk assessment, which involves identifying and evaluating the sources of uncertainty affecting future insurance cash flows. These may include risks related to mortality, policyholder behaviour, expenses, etc. In life insurance, for example, uncertainty may arise from incorrect assumptions about mortality trends, anti-selection, or changes in policyholder behaviour. In many cases, limited historical data or lack of experience may make it difficult to quantify these uncertainties precisely, requiring the use of expert judgement, scenario analysis, or sensitivity testing.

b.) Closely related to risk assessment are risk drivers, which describe how these uncertainties influence the amount and timing of future cash flows. Some drivers can be modelled directly using statistical methods, while others may only be taken into account indirectly through judgement. For example, when the available data are limited or unreliable, the resulting estimates are more uncertain, which may justify a higher RA.

c.) To quantify the uncertainty, insurers rely on risk models. These models provide mathematical representations of risk and generate measures such as probability distributions, confidence levels, or tail expectations. The complexity of these models may vary from simple scenario analyses to fully stochastic simulation models. However, models themselves introduce additional uncertainty, as they may not perfectly represent real-world behaviour. When model uncertainty is significant, this should be reflected in the calibration of the RA.

d.) Another important component is risk preferences, which describe how an entity evaluates and responds to uncertainty. These preferences include concepts such as risk aversion, risk appetite, and risk tolerance. IFRS 17 recognises that these preferences differ across insurers and are often not directly observable. As a result, the RA is inherently entity-specific and reflects the insurer's judgement regarding the compensation required for bearing risk.

These elements together determine the level of risk compensation required by the insurer. In addition to the expected value of future cash flows, insurers require compensation for the possibility that actual outcomes may be worse than expected.

Finally, IFRS 17 requires that RA calculation techniques satisfy certain qualitative characteristics. Methods should be applied consistently over time, rely on assumptions consistent with best-estimate cash flows, reflect sound insurance principles, and appropriately capture differences between products and risk profiles. In addition, they should support transparent disclosure and allow meaningful comparisons between entities by ensuring that differences in RA reflect differences in risk exposure rather than methodological inconsistencies.

2.2.2 Risk Adjustment calculating techniques

IFRS 17 does not prescribe a single method for calculating the RA. Instead, it establishes the qualitative characteristics explained in Chapter 2.2.1 that any chosen technique must satisfy. As a result, insurers apply a range of methodologies in practice, depending on data availability, modelling capabilities, and alignment with internal risk management frameworks (IFRS Foundation, 2022).

The most frequently applied techniques in practice are confidence level or Value at risk approach, the conditional tail expectations (CTE) and the cost of capital (CoC) approach.

2.2.2.1 Value at risk approach (VaR)

The Value at risk (hereinafter: VaR) approach is a quantile-based technique that is used to quantify the RA by explicitly linking liability valuation to the probability distribution of future insurance cash flows. As we already know, insurance contract cash flows are essentially uncertain and are therefore modelled as a random loss variable X, arising from insurance liabilities. Using stochastic actuarial techniques, a probability distribution as in equation (3) is constructed, capturing the range of possible outcomes and their associated likelihoods. For a selected confidence level $\alpha \in (0,1)$, the VaR is defined as the α-quantile of this distribution, as shown in equation (4) (IAA, 2010). Equation (5) provides the probabilistic interpretation of VaR, indicating that losses will not exceed the VaR level with probability α. In other words, there is a probability of $1 - \alpha$ that actual losses will exceed the VaR threshold (McNeil et al., 2015).

$$F_X(x) = \mathrm{P}(X \leq x) \tag{3}$$

$$\mathrm{VaR}_\alpha(X) = F_X^{-1}(\alpha) = inf\ \{x \mid F_x(x) > \ \alpha\} \tag{4}$$

$$P(\,X \leq VaR_\alpha(X)\,) = \alpha \tag{5}$$

In the risk measurement world, there are few ways of how VaR can be calculated in practice. One of them is the variance-covariance method, which uses variances of individual risks and the covariances between them. This is parametric method, where it is assumed that the risks follow the normal or the lognormal distribution and that the volatility of cash flows and the correlation between risks remain stable over the projection period. While this method offers a simple analytical solution, it cannot fully capture the tail risk if a distribution is skewed. Also, linearity between multiple risk drivers cannot be assumed. A more robust method used in practice is the Monte Carlo simulation. This method involves generating large number of potential future outcomes based on the assumed stochastic model. The distribution of future losses is obtained by repeatedly simulating the underlying risk factors. This allows for more complex and non-linear relationship between risks. However, it is time consuming and requires careful specification of the underlying models. Lastly, a historical simulation method is a non-parametric approach that estimates VaR directly from historical data without assuming any underlying models. Instead of modelling the distribution of losses, the method uses past observations to approximate the empirical distribution. However, this method is limited by the historical data and may not adequately represent the risk for future outcomes (IAA, 2010).

In the literature, VaR is often criticized because of its properties. The first criticism of VaR was introduced by Artzner et al. (1999) with the concept of coherent risk measure. A risk measure $\rho(x)$ is considered coherent if it satisfies the following mathematical properties:

1.) Translation invariance - equation (6) defines that adding a certain, deterministic loss c to the random loss X increases the value of the risk measure by the same amount.

$$\rho(X + c) = \rho(X) + c \tag{6}$$

2.) Subadditivity – equation (7) states that the combining two risks should not produce greater level of risk than the total risk obtained when each risk is evaluated separately.

$$\rho(X + Y) \leq \rho(X) + \rho(Y) \tag{7}$$

3.) Positive homogeneity – equation (8) states that if the size of the portfolio is multiplied by a positive factor, the corresponding risk measure increases proportionally by the same factor.

$$\rho(\lambda X) = \lambda \rho(X), \qquad \lambda > 0 \tag{8}$$

4.) Monotonicity – equation (9) defines that if one risk is always greater than or equal to another risk, then its measured risk should also be greater than or equal to the other risk.

$$X \leq Y \rightarrow \rho(X) \leq \rho(Y) \tag{9}$$

Artzner et al. (1999) showed that VaR does not always satisfy the property of subadditivity. VaR only measures the loss at a specific quantile of the loss distribution and ignores losses beyond that point. VaR fails to capture the events that happen with low frequency but high severity. Consequently, the VaR of a combined portfolio may exceed the sum of the individual VaRs, meaning that diversification effects are not properly captured.

Within the IFRS 17 framework, the RA under VaR approach is calculated as the difference between this adverse percentile outcome and the probability-weighted expected value of the cash flows.

$$\mathrm{RA} = \mathrm{VaR}_{\alpha}(X) - \mathbb{E}[X] \tag{10}$$

Equation (10) reflects the additional compensation an insurer requires for bearing uncertainty beyond the best estimate of future cash flows. Conceptually, the confidence level α represents the insurer's tolerance for risk and is often interpreted as a probability of sufficiency, meaning that the recognised insurance liability, including the RA, is sufficient to cover future cash outflows in α% of scenarios (Moody's Investors Service, 2020). Under IFRS 17, the insurer is free to choose the confidence level. However, since the confidence level must be disclosed, insurance companies tend to keep the confidence level similar to their competitors (Rickaby, 2018). Higher confidence levels correspond to greater prudence and larger RA, consistent with increased risk aversion.

The VaR approach is widely applied due to its intuitive interpretation, direct linkage to probability theory, and ease of implementation within stochastic modelling frameworks. However, it captures risk only at a single point of the distribution and therefore ignores the severity of losses beyond the selected percentile. In addition, VaR is not a coherent risk measure, as it fails the subadditivity property, limiting its ability to fully reflect diversification benefits and making it less suitable for granular risk allocation (Jiang & Society of Actuaries, 2020). Despite these limitations, VaR provides a clear and transparent foundation for quantifying uncertainty under IFRS 17 and serves as a natural starting point for more tail-sensitive risk measure such as Tail Value at Risk.

2.2.2.2 Tail Value at risk (TVaR)

Tail Value at Risk (hereinafter: TVaR), also referred to as Conditional Tail Expectation (hereinafter: CTE), is an extension of the VaR approach that addresses its limitations by explicitly incorporating the severity of adverse outcomes beyond a selected confidence level. Similar to the VaR framework, future insurance contract cash flows are modeled as a random loss variable X (Milliman, 2017). The CTE is then defined as the conditional expected value of losses exceeding the VaR threshold, as shown in Equation (11).

$$\mathrm{CTE}_{\alpha}(X) = \mathbb{E}[\, X \mid X > \mathrm{VaR}_{\alpha}(X)\,] \tag{11}$$

This measure represents the average of the worst $1-\alpha$ proportion of outcomes and therefore captures not only the likelihood of adverse events, but also their magnitude. In contrast to VaR, which focuses on a single percentile, the CTE incorporates all outcomes in the tail of the distribution above the selected confidence level (BWCI Group, 2021). Under IFRS 17, when the CTE approach is applied, the RA is calculated as the difference between the conditional tail expectation and the probability-weighted expected value of the cash flows.

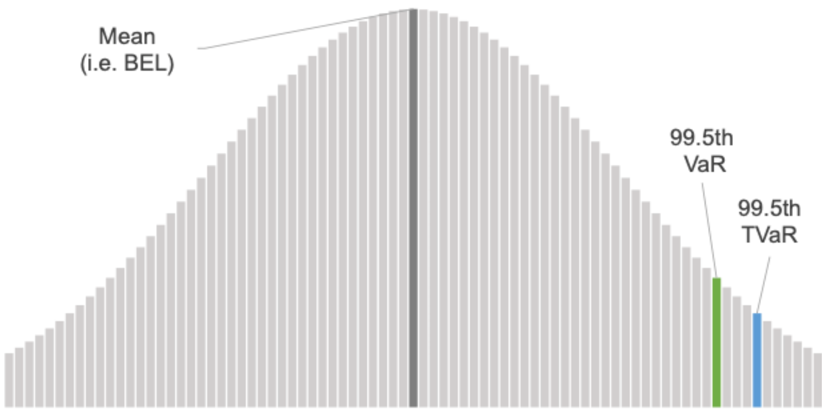
$$\mathrm{RA} = \mathrm{CTE}_{\alpha}(X) - \mathbb{E}[X] \tag{12}$$

The equation (12) reflects the additional compensation required by an insurer for bearing uncertainty in extreme but plausible adverse scenarios (IAA, 2010). The selected confidence level α continues to represent the insurer's risk appetite, while the CTE reflects the full range of unfavourable outcomes beyond the VaR threshold, rather than only the boundary value itself (Milliman, 2017).

The CTE approach provides a more comprehensive representation of tail risk and is particularly well suited to insurance portfolios exposed to skewed or heavy-tailed loss distributions. Importantly, CTE is a coherent risk measure, satisfying all the properties including subadditivity, which allows diversification benefits to be appropriately reflected and facilitates allocation of the RA to lower levels of aggregation. However, the method requires a well-specified tail distribution and is more sensitive to modelling assumptions, often demanding robust stochastic models and larger simulation volumes (IAA, 2018).

Shown in Figure 4 we can see that, at a chosen confidence level of 99.5%, VaR represents the loss level at the 99.5th percentile, whereas CTE measures the expected value of all outcomes beyond that percentile. As a result, CTE captures not only the likelihood but also the severity of extreme tail losses, while VaR reflects only the threshold at which those extreme outcomes begin (Milliman, 2017).

Figure 4: Illustration of VaR and TVaR (CTE) at the 99.5% confidence level



Source: Milliman (2017).

2.2.2.3 Cost of capital approach (CoC)

The Cost of capital (hereinafter: CoC) approach measures the RA for non-financial risk by quantifying the cost incurred by an insurer for holding capital to support insurance obligations over their lifetime. Rather than determining the RA directly from a probability distribution, the CoC approach focuses on the amount of capital required to absorb adverse outcomes and the cost of holding this capital over time (BWCI Group, 2021).

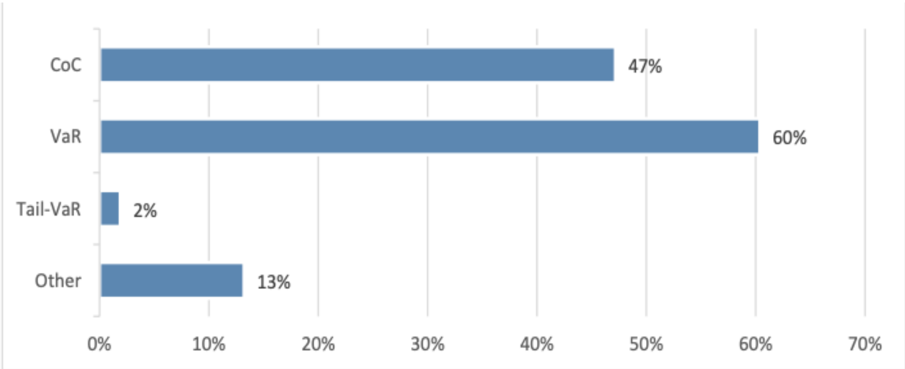
Under this approach, the insurer first determines the required risk capital RC_t at each future time period t, representing the capital needed to support non-financial risks at the chosen confidence level. In practice, this capital requirement is often aligned with regulatory capital in Solvency II, where the capital level corresponds to a 99.5% confidence VaR, representing a one-in-200-year adverse event (Milliman, 2017). Because insurance contracts generally extend beyond a one-year horizon, the capital requirement is projected over the full run-off period of the contracts, reflecting the persistence of non-financial risks over time (Jiang, 2020). Equation (13) shows that the RA is then calculated as the present value of the future cost of holding this capital. The cost is determined by applying a cost of capital rate CoC to the projected capital amounts and discounting them using risk-free interest rates.

$$\text{RA} = \text{CoC} \times \sum_{t \geq 0} \frac{RC_t}{(1+r_{t+1})^{t+1}} \tag{13}$$

where RC_t denotes the required risk capital at time t, CoC is the annual cost of capital rate, and r_{t+1}represents the risk-free discount rate applicable to period $t + 1$ (Milliman, 2017).

Conceptually, the CoC approach reflects the compensation an insurer requires for committing capital to support non-financial risks over the lifetime of insurance contracts. The confidence level used to determine the capital requirement captures the insurer's risk appetite, while the cost of capital rate reflects the return demanded by investors for bearing this risk (BWCI Group, 2021). Although the method is widely used as economically intuitive and consistent with regulatory capital frameworks, it is sensitive to assumptions regarding confidence levels, and the selected cost of capital rate. As a result, the CoC approach may produce RA that differ significantly from those derived using purely distribution-based techniques, particularly when long-duration contracts or highly skewed risk profiles are involved (Jiang, 2020).

Figure 5: IFRS 17- Insurance contract report, RA calculation method used



Source: EIOPA (2024).

In 2024 an IFRS 17 insurance contract report was published by EIOPA, where insurers responded to the implementation of the new standard. Among other aspects, the calculation of RA was also analysed. As shown in Figure 5, the results from the report showed that 60% of insurers use VaR approach for calculating the RA, 47% of them use CoC approach and only 2% use CTE approach. It should be noted that these percentages do not add up to 100%, since many insurers use more than one method. 80% of the insurers use only one method, which shows us that the choice of method is mainly an entity level decision rather than a product decision.

2.2.3 Sources of uncertainty

Overall, the calculation of RA involves more actuarial techniques, probability models and complex statistical techniques. The practical role of the RA is to help the users of financial statements to better understand the impact of the uncertainty in the valuation of the insurance liabilities. According to the International Actuarial Association (2018), the calculation of RA involves three key sources of uncertainty:

a.) Model risk – or specification risk arises when the selected model does not accurately represent the probabilities of future cash flows. For instance, choosing an inappropriate model for observed data can misrepresent expected outcomes, particularly if unusual events or shifts occur that the model cannot capture.

b.) Parameter risk – or estimation risk relates to errors in estimating the model parameters. For example, the mean or variance used to forecast future events may be inaccurately determined.

c.) Process risk – or variability risk reflects the randomness in future cash flows. Even if the model and its parameters are correct, natural variations will still occur.

2.3 Solvency II regulatory framework

Solvency II is the European legal framework that assesses the overall solvency of the insurance company and guarantees protection of the policyholders and beneficiaries. Its primary objective is to ensure that insurers hold sufficient capital to withstand adverse events and protect policyholders. Unlike IFRS 17, which focuses on financial reporting and the measurement of insurance liabilities, Solvency II is concerned with solvency, capital adequacy, and risk management. Despite these different objectives, both frameworks address uncertainty in insurance cash flows and therefore provide complementary perspectives on insurance risk (EIOPA, 2016).

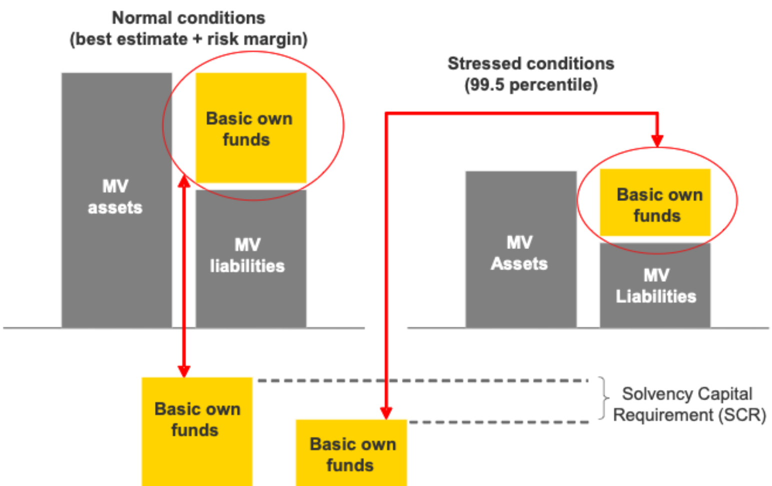
Solvency II is applied consistently across EU member states under the oversight of national supervisors and coordination by European Insurance and Occupational Pensions Authority (EIOPA). The Solvency II framework is based on three pillars. Pillar I establishes quantitative requirements for the valuation of assets and liabilities, and the calculation of capital requirements such as Solvency Capital Requirement (hereinafter: SCR) and Minimum Capital Requirement (hereinafter: MCR). Pillar II addresses governance, risk management and supervisory overview through the Own Risk and solvency Assessment (hereinafter: ORSA). Pillar III focuses on public disclosure and reporting requirements (IAA, 2010).

2.3.1 Solvency II Standard Formula

The Directive 2009/138/EC of the European Parliament and of the Council on the taking up and pursuit of the business of insurance and reinsurance (Solvency II) establishes the regulatory framework for insurers, where at its core lies the SCR that insurers must calculate. The SCR represents the amount of own funds an insurer must hold to limit the probability of insolvency to 0.5% over one-year horizon. Formally, the SCR is calibrated to correspond to the VaR at the 99.5% confidence level of the basic own funds (Directive 2009/138/EC).

The Solvency II Standard Formula (hereinafter: SF) is a standardized calculation method that aims to capture the main quantifiable risks that most insurers are exposed to. The SF gives a simplified estimate of the economic capital required under Solvency II. It turns the goal of surviving severe events with a 99.5% confidence level over one year into a set of fixed stress scenarios and calculation rules applied to a market value balance sheet (EIOPA, 2014). Within this framework, MV stands for market value, which represents a market-consistent valuation approach. According to Article 75(1) of Directive 2009/138/EC, the MV of assets must be valued at the amount for which they could be exchanged between knowledgeable willing parties in an arm's length transaction, while the MV of liabilities are valued at the amount for which they could be transferred or settled. Therefore, as we can see in Figure 6, SCR measures the immediate drop or the change in own funds under a shock scenario, rather than the impact over the full lifetime of future cash flows (EIOPA, 2014).

Figure 6: SCR as the change in basic own funds under stressed condition



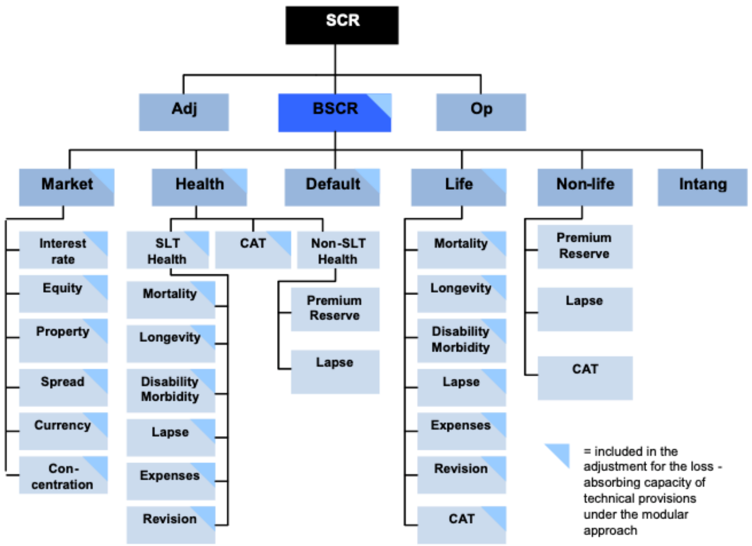
Source: Thoren (2015).

To calculate the SCR, the SF follows a so-called modular, bottom-up structure. The structure can be seen at Figure 7, where risks are first identified at the level of major risk modules, which include market risk, counterparty default risk, life underwriting risk, health underwriting risk, non-life underwriting risk, and intangibles. Each module is further decomposed into sub-modules capturing more granular sources of risk. For each sub-module, a capital requirement is calculated either by applying prescribed stresses to the Solvency II balance sheet or through formula-based calculations (EIOPA, 2014). These capital charges represent the loss in basic own funds resulting from the specified adverse scenario. Importantly, when calculating stressed balance sheets, the Solvency II risk margin (hereinafter: RM) is excluded in order to avoid circularity, since the RM itself depends on future SCRs (CEIOPS, 2010).

It should be noted that the SF does not aim to reflect the exact risk profile of each individual undertaking. Instead, it is calibrated to represent the risk profile of a hypothetical average

European insurer. As a result, in some cases, it may not accurately reflect the entity's actual risks or the amount of own funds it needs (EIOPA, 2014).

Figure 7: Bottom-up structure of the Solvency II Standard Formula



Source: EIOPA (2014).

2.3.2 Standard Formula calibration logic

The calibration logic under the SF aims to translate the regulatory solvency objective into a set of deterministic stresses and aggregation rules. Rather than modelling full probability distributions of losses, the SF applies predefined adverse shocks to key risk drivers and measures the resulting immediate loss in basic own funds. These losses are then aggregated using correlation matrices to approximate the tail of the joint loss distribution (EIOPA, 2014).

2.3.2.1 Calibration of individual risk stresses

At the level of individual sub-modules, the SF applies predefined shocks to underlying risk drivers. These stresses are designed to represent extreme but plausible adverse developments over a one-year period. The magnitude of the shocks is determined through a combination of historical data analysis, expert judgment, and regulatory calibration (EIOPA, 2014). A key feature of the SF calibration is that stresses are defined at the level of risk drivers, not directly at the level of financial outcomes. The calibration process therefore implicitly assumes that changes in these drivers adequately capture the main sources of variation in basic own funds. While this assumption is reasonable for many standard products, it may be less accurate for complex portfolios with nonlinear risk profiles. The prescribed shocks for all sub-modules are defined in European Commission Delegated Regulation (EU) 2015/35 and are provided in Appendix 3.

2.3.2.2 Diversification between risks

Once the individual sub-modules SCRs are determined, they must be aggregated to obtain the total capital requirement. Since different risks do not occur simultaneously with perfect correlation, the SF incorporates diversification effects through prescribed correlation matrices. These matrices specify the dependence structure between individual risks and are used within the aggregation formula shown in equation (14), that produces the BSCR (CEIOPS, 2010).

$$\mathrm{BSCR} = \sqrt{\sum_i \sum_j SCR_i \cdot \mathrm{SCR}_j \cdot \rho_{i,j}} \tag{14}$$

Where SCR_i and SCR_j denote the capital requirements of individual risk modules, and $\rho_{i,j}$ are the regulatory correlation coefficients specified in the Solvency II framework. These correlation parameters are not empirical correlations estimated from historical data. Rather, they are calibration parameters chosen to ensure that the aggregated capital requirement approximates the 99.5% one-year VaR of total risk under the simplifying assumptions of the SF (CEIOPS, 2010). After determining the BSCR, the total SCR is obtained as shown in equation (15).

$$\mathrm{SCR} = \mathrm{BSCR} + \mathrm{SCR}_{\mathrm{operational}} - \mathrm{Adj}_{\mathrm{LAC}} \tag{15}$$

where $\mathrm{SCR}_{\mathrm{operational}}$ represents the capital requirement for operational risk, and $\mathrm{Adj}_{\mathrm{LAC}}$ denotes adjustments for the loss-absorbing capacity of technical provisions and deferred taxes. Equation (14) reflects the fact that some losses can be partially absorbed by reduced profit participation or deferred tax effects, thereby reducing the net capital required.

The aggregation formula used in the SF implicitly assumes that the distribution of losses can be approximated by a joint elliptical distribution. In probability theory, elliptical distributions such as the multivariate normal or Student-t distributions, represent a class of symmetric joint distributions where the dependency structure is linear. According to CEIOPS (2010), aggregating capital requirements with a correlation matrix mathematically assumes that the risks follow this type of distribution, which allows the formula to produce a theoretically correct aggregate of quantiles using simple linear correlation coefficients. However, in practice, insurance risks often exhibit skewness, heavy tails, and nonlinear dependencies. Regulators therefore acknowledge that the SF aggregation approach represents a pragmatic approximation rather than a theoretically exact representation of the joint loss distribution (CEIOPS, 2010).

2.3.3 Life underwriting risk

Life underwriting risk is one of the modules of the Solvency II SF as we have already seen in Figure 7. It captures the uncertainty inherent in the amount and timing of future benefit payments arising from life insurance contracts. Within the SF, life underwriting risk is explicitly treated as a non-financial risk, distinct from market or counterparty risks and it is decomposed into several sub-modules, each representing a distinct source of risk. These sub-modules are mortality risk, longevity risk, disability–morbidity risk, lapse risk, expense risk, revision risk, and life catastrophe risk (CEIOPS, 2010).

- Mortality risk - the risk that death rates are higher than assumed, leading to increased benefit payments on life insurance contracts that pay out on death. It arises from uncertainty in mortality levels, trends, and volatility, including the risk that mortality assumptions used in valuation are mis-estimated.

- Longevity risk – the risk that policyholders live longer than expected, increasing the cost of annuities and other survival benefits. It is driven by uncertainty in future mortality improvements, particularly the risk that life expectancy increases faster than expected.

- Disability – morbidity risk – the risk that more policyholders than expected become disabled or sick, or that recoveries occur more slowly than expected, increasing benefit payments and technical provisions.

- Lapse risk – the risk from unexpected changes in policyholder behaviour, such as higher surrenders, lower lapse rates, or mass lapse events. Its financial impact depends strongly on product design, as lapses can either increase or decrease liabilities depending on guarantees, charges, and profit emergence patterns.

- Expense risk – the risk that expenses incurred in servicing insurance contracts are higher than expected, due to increases in costs such as staff, commissions, IT, or property expenses. It arises mainly from uncertainty in future expense levels and expense inflation.

- Revision risk – the risk that annuity payments increase unexpectedly following a reassessment of claim status or legal entitlement, rather than due to demographic developments. It mainly affects annuities arising from non-life claims, where benefit amounts may be revised upward during the payout phase.

- Life catastrophe risk (CAT) – the risk from exposure to rare, extreme events such as pandemics, that cause a sudden and highly correlated increase in mortality or morbidity across the insured population. It is treated separately because such events are not adequately captured by standard mortality or morbidity stresses.

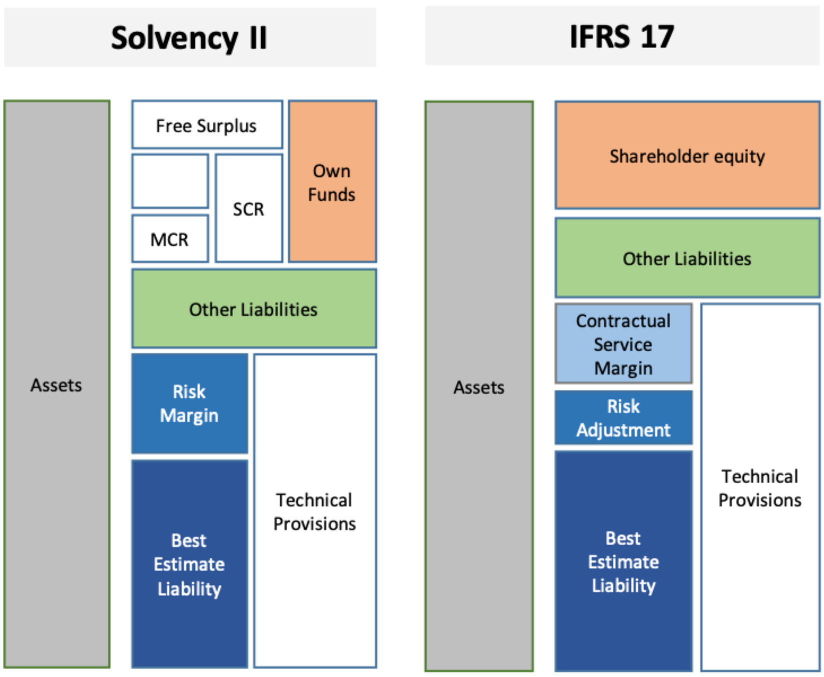
The SF treats each sub-module risk as a single factor shock, then aggregates them using the prescribed correlation matrix. This provides a standardized, transparent approach that can be implemented by insurers even without full stochastic modelling capacity (EIOPA, 2014).

2.3.4 Solvency II vs IFRS 17

As we have already mentioned in previous chapters, the main difference between IFRS 17 and Solvency II is that they have different purposes. Solvency II is a regulation framework for policyholder's protection and risk management that applies to insurance companies, whereas IFRS 17 is a reporting standard that applies to insurance contracts.

Figure 8 compares the balance sheet structures under Solvency II and IFRS 17 and shows how each framework reflects uncertainty in insurance liabilities. In both cases, the insurance liabilities are built on the best estimate of future cash flows, and both have risk compensation item, RA and RM. Even though RA and RM might appear conceptually similar, they are part of different balance sheet structures and measurement frameworks, which lead to differences in their calibration, scope and impact on reported results.

Figure 8: Comparison of balance sheet structure under Solvency II and IFRS 17



Source: 3Blocks (2019).

The Solvency II RM is calculated using a fully prescribed cost of capital (CoC) approach based on the SCR and a fixed cost of capital rate. Historically, this rate was fixed at 6% from the framework's inception to provide a standardized and highly comparable measure across insurers. However, following the Solvency II legislative review, Directive (EU) 2025/2 amended the framework, officially reducing the mandatory CoC rate from 6% to 4.75% to reduce capital volatility and financial burdens for long-term obligations. In contrast, IFRS 17 allows entities to determine the RA using valuation methods and confidence levels that best reflect their own risk profile and risk aversion, leading to greater flexibility but also increased heterogeneity in outcomes (Volada & Addactis, 2019). According to the EIOPA report (2024), in practice, IFRS 17 RA confidence levels are typically lower, most commonly ranging between 75% and 85%, with an average close to 80% for both life and non-life business. The same report from EIOPA, quantifies the impact of these differences. For life insurance business, the RA is on average significantly lower than the RM by approximately 33% for contracts measured under the GMM and by around 44% for contracts under the VFA. Conversely, for non-life business, RAs are on average around 11% higher than RMs, reflecting differences in business mix, risk profiles, and methodological choices. Further differences arise from the scope of risks covered. The RM reflects the cost of holding capital for a broad range of risks included in the SCR, such as market risk, counterparty default risk, and operational risk. In contrast, the RA is explicitly limited to non-financial risks arising from insurance contracts and excludes financial risks, as well as certain operational and counterparty risks. Additionally, diversification effects across legal entities are not permitted under Solvency II, whereas IFRS 17 allows diversification benefits to be reflected within the reporting entity. Differences in projection horizon, discount rate determination, and the linkage to regulatory capital requirements versus capital held further contribute to material divergences between the RM and the RA, even when similar valuation techniques are applied (EIOPA, 2024).

3 DATA AND METHODOLOGY

The following chapter presents the data, portfolio design and modelling methodology used to estimate the RA under IFRS 17. Since the data for life insurance portfolios are sensitive and highly protected, the portfolio used in this thesis is entirely synthetic. The analysis is based on a hypothetical life insurance portfolio constructed for the purpose of measuring the IFRS 17 RA under two alternative approaches, an internal stochastic model and a Solvency II SF approach. The chapter first describes the synthetic portfolio and the valuation inputs and then explains the modelling framework used under each approach.

3.1 Portfolio description and data

The portfolio is constructed for an endowment product. Endowment or mixed life insurance provides a benefit either upon death during the contract term or upon survival to maturity, whichever occurs first. This product was selected because it differs in its cash-flow structure and in its sensitivity to the non-financial risk drivers in comparison to other life products. Endowment products include both mortality and survival maturity payments (Dickson et al., 2013).

The portfolio is identical for both models, with consistent assumptions and valuation inputs, in order to ensure comparability of the results. This ensures consistency with GMM explained in Chapter 2.1.2. For each policy, the main contract characteristics include issue age, current age, elapsed duration, remaining term, sum assured, and annual premium. These variables determine the timing and amount of future cash flows and therefore define each policy's exposure to the relevant risk drivers.

For the endowment portfolio, issue ages are randomly generated between 18 and 65 years, while policy terms are randomly assigned between 5 and 30 years, subject to the restriction that no policy matures after age 80. This condition avoids unrealistic maturities at very advanced ages and keeps the projection horizon within a plausible range. The sum insured is generated as an age-dependent function. Young policyholders are assigned higher coverage amounts than older policyholders. This introduces a realistic relationship between age, benefit amount and mortality exposure and creates a richer liability structure than would be obtained under a uniform sum insured assumption. Moreover, a lapse behaviour is incorporated through a lapse curve that determines the expected probability of policy surrender in each future policy year. Lapse rates are assumed to decrease with policy duration. That implies relatively high lapse rates in early policy years and lower lapse rates in later durations.

Mortality assumptions are based on the Slovenian 2023 life tables published by Eurostat, which are applied uniformly across the portfolio. The life tables are shown in Appendix 1. Discounting is performed using the EIOPA risk-free term structure as of 30 September 2025, ensuring market-consistent valuation of future cash flows in line with IFRS 17 requirements.

The portfolio is constructed as a single, static cohort of contracts at the valuation date $t = 0$. All of the contract's characteristics are generated once and do not vary. Thus, the portfolio serves as the identical baseline for both internal model and Solvency II SF.

Premiums are calculated using classical actuarial equivalence principles. The actuarial present value of premium and benefits is defined using commutation functions provided by Anderson (1999). These actuarial present value functions form the basis for gross premium calculations. The gross premium is determined by applying the actuarial equivalence principle under which the expected present value of premiums equals the expected present value of benefits and expenses. Expense assumptions are explicitly incorporated into the gross premium calculation. These include an initial expense α expressed per unit of sum assured, a proportional expense loading β applied to each premium and a fixed annual running expense γ per unit of sum assured (Dickson et al., 2013). The formulas used for premium calculation for endowment portfolio are provided in Appendix 2. The premium is adjusted by a pricing margin, so that premiums remain economically plausible while still being generated from a common actuarial pricing framework. The premium is used as a common input for both internal model and SF model. The projection of future cash flows is performed on an annual basis. Premiums are assumed to be received at the beginning of each policy year, whereas death benefits, surrender payments, maturity benefits and renewal expenses are assumed to occur at the end of the year. This timing structure is kept identical in both the internal model and the SF approach.

3.2 Internal stochastic model

The estimation of the RA in life insurance requires an explicit modelling of uncertainty. When sufficient internal data and modelling infrastructure are available, the modelling of uncertainty can be achieved through a stochastic framework. In actuarial practice, stochastic internal models are used to evaluate the distribution of insurance liabilities and to quantify the impact of non-financial risks (Canadian Institute of Actuaries, 2025).

In this thesis the internal model follows a Monte Carlo simulation framework. Monte Carlo simulation is a standard technique in actuarial modelling, and it allows complex insurance portfolios to be evaluated under many possible future scenarios. In the internal model, Monte Carlo translates the uncertainty in key risk drivers into a distribution of possible future outcomes for the portfolio. The RA is then derived from this loss distribution using a VaR measure at selected confidence level (IAA, 2010).

The internal model focuses on three non-financial risk drivers such as mortality risk, lapse risk and expense risk. These risks influence the timing and magnitude of future cash flows and therefore determine the uncertainty surrounding the fulfilment cash flows of the insurance liabilities.

3.2.1 Deterministic baseline valuation

Before introducing stochastic variability, the model first computes a deterministic baseline valuation of the portfolio. Using the mortality table, lapse assumptions, discount rates and premium structure described in Chapter 3.1, the expected present value of future cash flows is calculated for each policy. The future cash flows consist of premium inflows, death benefit payments, surrender payments arising from lapses, maturity benefits and expense outflows. Following the standard actuarial framework for life insurance valuation, the present value of the future loss random variable is defined as the difference between the present value of future outgo and the present value of future premium income (Dickson et al., 2013). For an individual policy i, the deterministic $PVFCF$ and the loss variable is given by equations (16) and (17).

$$PVFCF_i = PV_i(benefits) + PV_i(expenses) - PV_i(premiums) \tag{16}$$

$$L_i = PVFCF_i \tag{17}$$

where present values are calculated using the discount factor described in Chapter 3.1. For consistency with risk measurement, a loss variable L_i is defined as the $PVFCF_i$.

At the portfolio level, the deterministic expected loss is obtained by aggregating the individual policy losses across all policies in the endowment portfolio:

$$\mathbb{E}[L] = \sum_{i=1}^{N} L_i = PVFCF_0 \tag{18}$$

These deterministic values serve as the baseline valuation from which stochastic deviations are measured in the simulation framework.

3.2.2 Calibration of stochastic risk drivers

For successful construction of a stochastic internal model, the individual risk drivers must be statistically modelled. Mortality, lapse and expense risks are modelled using Generalised Linear Models (hereinafter: GLMs), which are estimated from simulated experience data generated from the portfolio.

GLMs are well suited to these insurance risks because they allow the distribution of the response variable to be chosen in line with the nature of the underlying risk, while ensuring that model outputs remain within acceptable ranges. In addition, GLMs offer a transparent structure in which covariate effects can be interpreted economically and they provide a natural framework for statistical inference, which enables parameter uncertainty to be incorporated into the stochastic simulation. GLMs are widely used in actuarial science because they provide a flexible statistical framework for modelling insurance data that follow distributions from the exponential family (De Jong & Heller, 2008).

3.2.2.1 Mortality risk

Mortality risk represents one of the primary sources of uncertainty affecting life insurance liabilities, as it determines the timing and occurrence of death benefit payments. In a life insurance portfolio, mortality directly influences fulfilment cash flows through the payment of death benefits and the termination of future premium income and expenses (Dickson et al., 2013). Within the internal model, mortality is represented as a binary outcome indicating whether death occurs for a given policyholder during a particular projection year. Binary response variables are commonly modelled using binomial GLMs with a logit link function, which ensures that predicted probabilities remain within the interval (0,1) (Goldburd et al., 2025). The objective of modelling mortality risk is to estimate annual death probabilities as a function of policy characteristics, such as attained age and policy duration.

Since real insurer data is not available, synthetic mortality experience data are generated to replicate the structure of a realistic life insurance portfolio. The synthetic dataset is constructed by simulating death events using baseline mortality probabilities obtained from the mortality table described in Chapter 3.1. For each policyholder i and projection year t, death events are generated through Bernoulli trials with probability equal to the corresponding mortality rate q_x. This produces a policy-year dataset with the same structure as mortality experience data and allows estimation of the GLM parameters. Based on this dataset, a binomial GLM with a logit link function is estimated:

$$\text{logit}(q_{i,t}) = \log\left(\frac{q_{i,t}}{1-q_{i,t}}\right) = \beta_0 + \beta_1 \cdot \text{Age}_{i,t} + \beta_2 \cdot \text{Duration}_{i,t} \tag{19}$$

where $q_{i,t}$ denotes the model-estimated probability of death for a specific policyholder i in a given projection year t. Consequently, $\text{Age}_{i,t}$ and $\text{Duration}_{i,t}$ represent the attained age and policy duration of individual i at time t , respectively.

The logit link ensures that estimated death probabilities lie strictly between zero and one and allows the exponential increase of mortality with age to be captured in a transparent way. The fitted GLM is used to represent stochastic deviations in mortality around the deterministic life-table basis. In addition, the estimated covariance matrix of the regression coefficients quantifies uncertainty in the mortality assumptions and enables parameter risk to be incorporated into the stochastic framework.

During the Monte Carlo simulation, the GLM is used as a probability engine. For each scenario, policy, and projection year, the fitted GLM is used to generate scenario-specific mortality adjustments around the deterministic annual death probabilities (Goldburd et al., 2025). These probabilities are then applied within the cash flow projection to determine expected death outflows and to update in-force probabilities over time. Repeating this process across 1000 scenarios generates a distribution of present values of fulfilment cash flows, capturing both the process risk and parameter risk.

3.2.2.2 Lapse risk

Lapse risk represents the uncertainty associated with policyholder behaviour regarding the timing and occurrence of the policy termination before maturity. In a life insurance portfolio, lapses affect fulfilment cash flows through the loss of future premium income, the termination of future expenses and benefit obligations, and the payment of surrender values at the time of termination (Dickson et al., 2013).

Policy lapse behaviour has been widely studied in the insurance literature, where statistical models are used to analyse surrender behaviour and estimate lapse probabilities as functions of policyholder and contract characteristics (Eling & Kochanski, 2012). Within the internal model, lapse events are represented as binary outcomes indicating whether a policy terminates during a given projection year. Binary response variables of this type are commonly modelled using binomial GLMs with a logit link function, which ensures that predicted probabilities remain within the interval (0,1) (Goldburd et al., 2025). This statistical framework is therefore applied to estimate lapse probabilities conditional on policyholder characteristics and contract duration.

Similarly, as the mortality risk, synthetic lapse experience data are generated to calibrate the statistical model. The synthetic dataset is constructed by simulating lapse events using baseline lapse probabilities defined in Chapter 3.1. For each policyholder i and projection year t, lapse events are generated through Bernoulli trials with probability equal to the assumed lapse rate. This procedure produces a dataset that mimics the structure of real lapse experience data and allows the estimation of the GLM parameters. The logit function in equation (20) allows the model to capture variations in surrender behaviour across policyholders and over time.

$$\text{logit}(\ell_{i,t}) = \log\left(\frac{\ell_{i,t}}{1-\ell_{i,t}}\right) = \beta_0 + \beta_1 \cdot \text{Issue Age}_i + \beta_2 \cdot \text{Duration}_{i,t} \tag{20}$$

where $\ell_{i,t}$ denotes the model-estimated probability of lapse for a specific policyholder i in a given projection year t. The covariate Issue Age_i represents the fixed age of policyholder i at contract inception, and $\text{Duration}_{i,t}$ represents the policy duration of individual i at time t.

The calibrated lapse model is then embedded into the stochastic cash flow projection and used as a probability generator during the Monte Carlo simulation. For each scenario and each policy year, annual lapse probabilities are computed from the fitted GLM (Goldburd et al., 2025). These probabilities are then applied within the projection framework to determine expected surrender related cash outflows and to update in-force probabilities over time. Repeating this process across the 1000 simulation scenarios generates a distribution of present values of fulfilment cash flows, capturing the uncertainty associated with policyholder lapse behaviour.

3.2.2.3 Expense risk

Expense risk represents the uncertainty in future expenses related to insurance contracts. In a life insurance portfolio, expenses affect fulfilment cash flows through recurring administrative costs, maintenance costs, premium related and sum assured related expenses. Expense risk does not affect the timing of policy termination or benefit payments. Instead, it acts purely through the increasing or decreasing the present value of future cash outflows (Dickson et al., 2013). Therefore, expense risk is a severity type risk rather than a frequency type risk. The key uncertainty lies in how large the expenses are in each future year, not whether an event occurs.

Insurance expense data are typically positive, continuous and right-skewed, reflecting the fact that costs cannot be negative and that occasional high expenses may occur. Variables with these characteristics are commonly modelled using Gamma distributions within the GLM framework (De Jong & Heller, 2008). Gamma GLMs with a logarithmic link function is particularly suitable because they ensure that predicted values remain strictly positive and allow multiplicative effects of explanatory variables to be captured (McCullagh & Nelder, 1989).

Within the internal model, the expense risk is modelled using Gamma GLM with log link function. The dependent variable represents a stochastic expense factor that scales the baseline expense assumptions. In each simulation scenario, the baseline expense level is multiplied by this factor, allowing the model to capture potential deviations of realised expenses from their expected values:

$$\log(\mu_t) = \beta_0 + \beta_1 \cdot Year_t \tag{21}$$

where μ_t denotes the expected expense factor in year t.

The fitted GLM provides a portfolio specific expected expense path over time. The calibrated expense model is then embedded into the internal stochastic cash flow projection. During the Monte Carlo simulation, the GLM is used as a severity generator rather than a probability generator. For each scenario and each projection year, the expected expense factor μ_t is computed using the fitted GLM. In the GLM framework, the response variable is assumed to follow a Gamma distribution with mean equal to the value predicted by the model. Therefore, conditional on the expected value μ_t, stochastic expense factors are simulated from a Gamma distribution with mean μ_t (McCullagh & Nelder, 1989). These realised factors are then applied multiplicatively to the baseline expense cash flows in the corresponding projection year. Repeating this process across simulation scenarios generates a distribution of present values of fulfilment cash flows, capturing the uncertainty associated with future expense levels.

3.2.3 Scenario generation and simulation of cash flows

Stochastic scenarios are generated using Monte Carlo simulation with 1000 scenarios. In addition to the randomness of future experience, the simulation framework incorporates parameter uncertainty arising from the estimation of the GLM models. The parameters of mortality, lapse and expense risks described in Chapter 3.2.2 are estimated using maximum likelihood estimation (hereinafter: MLE). Under standard statistical assumptions, the distribution of the estimated parameter vector $\hat{\beta}$ can be approximated by a multivariate normal distribution with mean equal to the estimated coefficients and covariance matrix equal to the estimated variance–covariance matrix of the model (De Jong & Heller, 2008):

$$\beta \sim N(\hat{\beta}, \hat{\Sigma}) \tag{22}$$

In each simulation scenario, parameter vectors are therefore randomly drawn from this multivariate normal distribution. These parameter draws generate alternative mortality, lapse and expense paths that deviate from the deterministic baseline assumptions. For each scenario, the cash flows of every policy in the portfolio are recalculated using the simulated risk factors. The simulation therefore produces different scenario-specific of mortality probabilities, lapse probabilities and expense levels. Each scenario represents a possible future development of the portfolio experience.

For each scenario, the model projects the cash flows of each policy over its remaining lifetime. Cash flows for each policy include premiums received while the policy remains active, death benefits payable upon death, surrender payments payable upon lapse, maturity benefits for endowment contracts and expense outflows. These cash flows are discounted using the risk-free discount factors described in Chapter 3.1. The result of each scenario is a simulated present value of future cash flows for the entire portfolio.

The simulation produces a distribution of possible present values of future cash flows across all scenarios. Let $PVFCF^{(s)}$ denote the present value obtained in scenario s. The corresponding loss measure is defined as:

$$L^{(s)} = PVFCF^{(s)} \quad (23)$$

The set of simulated losses $\{L^{(1)}, L^{(2)}, \ldots, L^{(S)}\}$ forms the empirical loss distribution of the portfolio.

3.2.4 RA calculation

RA is calculated using the VaR approach applied to the simulated loss distribution. For a confidence level p, the equation (24) defines RA as the difference between the p-quantile of the loss distribution and its expected value (IFRS Foundation, 2022):

$$RA^{IM}(p) = VaR_p(L) - \mathbb{E}[L] \quad (24)$$

where $VaR_p(L)$ denotes the p-quantile of the loss distribution and $\mathbb{E}[L]$ denotes the expected loss.

This definition measures the additional liability required to move from the expected outcome to a specified adverse percentile. The RA calculated using VaR answers the question of how much additional liability is required such that losses exceed this level only with a small probability (Canadian Institute of Actuaries, 2025). The use of VaR in this model is motivated by its intuitive interpretation and its widespread use in insurance risk management. In order to analyse the sensitivity of the RA to the degree of risk aversion, several confidence levels are considered in the analysis, ranging from moderate to extreme percentiles.

3.2.5 Diversification and allocation of RA

Diversification plays an important role in the measurement of the RA under IFRS 17 and arises in insurance portfolios because the non-financial risks are not perfectly correlated. Adverse outcomes in different risks, such as mortality, lapses or expenses, do not occur simultaneously. For instance, in one scenario, mortality might be high, and in other lapses might be high, but they may not happen at the same time. Such interactions illustrate the principle of diversification, where the combined uncertainty of multiple cash flows is less than the sum of individual risks and that creates a diversification benefit.

$$RA_{total}(p) < RA_{mort}(p) + RA_{lapse}(p) + RA_{exp}(p) \quad (25)$$

The diversification benefit reduces the overall level of risk faced by the insurer and consequently lowers the level of RA required to compensate for bearing the uncertainty (IAA, 2018).

Aggregation refers to the process of combining individual risks into a total RA. Diversification is therefore the economic outcome of aggregation when risks are not perfectly correlated. When risks are aggregated, their joint behaviour must be considered, including possible dependencies or correlations between them (Volada & Addactis, 2019). At the entity level, insurers typically combine risks arising from different portfolios, products, or types of insurance contracts in order to determine the total RA required for the entire portfolio of liabilities. If the RA is calculated at this entity level, the measurement can capture diversification benefits across all insurance risks held by the insurer. As a result, the total RA may be lower than the sum of the RAs calculated for individual portfolios or risk components. In contrast, if the RA is determined at a more granular level, such as at the portfolio or group of contracts level, only diversification within that specific group is captured. Consequently, the resulting RA would generally be higher because diversification benefits across portfolios would not be fully reflected (Canadian Institute of Actuaries, 2025).

The existence of diversification benefits creates the need for risk allocation. Allocation refers to the distribution of the total aggregated RA to individual portfolios, groups of contracts or individual risks. The purpose of the allocation is to determine how much each risk, portfolio, or group of contracts contributes to the total. This allows insurers to properly measure liabilities and recognise the corresponding insurance service result for each group of contracts (Canadian Institute of Actuaries, 2025). In practice, there are several methods used to allocate the total RA. One of them is proportional allocation, where the total RA is distributed according to the relative size of the stand-alone risks. In this method, each risk receives a share of the total RA proportional to its individual risk measure calculated in isolation:

$$RA_i^{alloc} = RA_{total} \frac{RA_i^{stand-alone}}{\sum_j RA_j^{stand-alone}} \quad (26)$$

where $RA_i^{stand-alone}$ denotes the stand-alone RA of risk driver i, and the denominator represents the sum of the stand-alone RAs across all risk drivers j included in the portfolio. The advantage of proportional allocation is its simplicity and transparency, although it does not explicitly capture the interaction effects between risks after diversification (McNeil et al., 2015). In the internal model, proportional allocation approach is used to allocate total RA across individual risk drivers based on their standalone contributions.

Another commonly used allocation method is the Euler allocation, which distributes the total risk according to the marginal contribution of each risk to the aggregated portfolio risk. Under this allocation approach, the contribution of a risk is determined by how much the total RA would change if the exposure to that particular risk increased slightly. Euler allocation is widely applied in capital allocation frameworks because it reflects the marginal impact of each risk driver while ensuring that the allocated contributions sum exactly to the total risk measure (Tasche, 2008).

3.3 Solvency II Standard Formula model

As discussed in the theoretical Chapter 2.3, the Solvency II SF model measures non-financial risks through deterministic stress scenarios rather than through Monte Carlo simulation. The methodology follows the structure of the Solvency II Standard Formula, which is used in this section as the basis for estimating RA. The SF model in this thesis considers the same three non-financial risk drivers as the internal model. The underlying portfolio, cash flow model and discounting assumptions remain unchanged. The RA is obtained on the same confidence levels as in the internal model, and only one confidence level is chosen for analysis. Consequently, the difference between the two approaches lies solely in the method used to measure uncertainty.

Table 1: *Solvency II SF stresses calibrated to a 99.5% VaR level*

SF Submodule	Detail	Value at Risk (99.5%)
Mortality		+15.0%
Lapse	Up	+50.0%
	Down	-50.0%
	Mass	+40.0%
Expense	Nominal	+10.0%
	Inflation	+1.0%

Source: Adapted from European Commission (2015).

Since this thesis is focusing on a life insurance portfolio, the module of interest is the life underwriting risk. Therefore, the calculation of RA in the SF approach relies on the prescribed SF shocks provided by the European Commission Delegated Regulation (EU) 2015/35 for the life underwriting risk and its sub-modules. Table 1 shows the prescribed shocks of the life underwriting sub-module risks used for the calculation of RA in this master thesis. All the Solvency II SF prescribed shocks are defined in Appendix 3.

In contrast to the internal stochastic model, the SF approach does not simulate random outcomes but evaluates the effect of deterministic adverse changes in the relevant assumptions.

3.3.1 Deterministic baseline valuation

The starting point of the SF calculation is the same deterministic best estimate liability described in Section 3.2., denoted $PVFCF_0$. Under the Solvency II framework, risk modules are evaluated through the impact of prescribed stress scenarios on the insurer's balance sheet, measured as the change in basic own funds resulting from the application of a stress (Directive 2009/138/EC, 2009). Since basic own funds are defined as the difference between assets and liabilities, when a stress primarily affects the liability side of the balance sheet the impact of the scenario can be expressed as the change in the best estimate liability.

Each risk driver is then shocked separately, and the liability is recalculated under the stressed assumption. For risk i, $BEL_i(p)$ denotes the best estimate liability recalculated under the specific regulatory stress scenario calibrated to confidence level p. The stand-alone impact of that risk is defined as the adverse increase in liability, shown in equation (27) (Directive 2009/138/EC, 2009).

$$SCR_i(p) = \Delta_i(p) = \max(0, BEL_i(p) - BEL_0) \tag{27}$$

Although the notation SCR is retained because it follows the SF terminology, in this thesis it should not be interpreted as Solvency II own funds capital. Rather, it represents the stand-alone stressed increase in the best estimate liability. Since the best estimate liability corresponds to the present value of future cash flows, this can be interpreted as an increase in fulfilment cash flows attributable to a given non-financial risk driver. Accordingly, throughout the thesis, for the SF approach BEL is expressed in terms of $PVFCF$.

3.3.2 Rescaling the Standard Formula shocks

Under Solvency II, the prescribed stresses in the SF are calibrated to represent extreme adverse outcomes corresponding to approximately 99.5% VaR over a one-year horizon, as defined in Article 101 of Directive 2009/138/EC. In contrast, IFRS 17 does not prescribe a specific confidence level for the RA. Instead, insurers may select a confidence level reflecting their own risk appetite, and empirical evidence as the EIOPA report (2024) suggests that reported confidence levels are typically lower than the 99.5% confidence levels.

To evaluate the RA at alternative confidence levels, the SF stresses must therefore be rescaled from their original 99.5% calibration to the desired confidence level. Since the SF provides deterministic stresses rather than a full probability distribution, an additional modelling assumption is required to translate between confidence levels. In this thesis, for the SF modelling approach, the loss distribution is approximated by a normal distribution, which allows the VaR to be expressed as a function of the standard normal quantile.

Under this assumption, the VaR at confidence level p for a normally distributed loss variable L is given by equation (28) (McNeil et al., 2015):

$$VaR_p(L) = \mu + \sigma\Phi^{-1}(p) \tag{28}$$

where μ is the expected loss, σ is the standard deviation of losses, and $\Phi^{-1}(p)$ is the inverse cumulative distribution function of the standard normal distribution.

The deviation of the VaR from the expected loss is therefore (McNeil et al., 2015):

$$VaR_p(L) - \mu = \sigma\Phi^{-1}(p) \tag{29}$$

Similarly, the deviation corresponding to the original SF calibration at 99.5% is given by (30) and (31).

$$VaR_{0.995}(L) = \mu + \sigma\Phi^{-1}(0.995) \tag{30}$$

$$VaR_{0.995}(L) - \mu = \sigma\Phi^{-1}(0.995) \tag{31}$$

The conversion between Solvency II stresses calibrated at the 99.5% confidence level and IFRS 17 RA at alternative confidence levels can be expressed through scaling relationships between quantiles of the loss distribution (El Alami, 2023):

$$\frac{VaR_p(L) - \mu}{VaR_{0.995}(L) - \mu} = \frac{\Phi^{-1}(p)}{\Phi^{-1}(0.995)} \tag{32}$$

Under this approximation, a stress calibrated at 99.5% can be rescaled to another confidence level p, shown in equation (33).

$$Shock(p) = Shock(0.995) \cdot \frac{\Phi^{-1}(p)}{\Phi^{-1}(0.995)} \tag{33}$$

This rescaling is a modelling assumption that allows the SF stresses to be mapped to lower confidence levels in a transparent way. It does not imply that the full loss distribution of the underlying insurance risks is observed or modelled. Rather, it provides a practical bridge between the Solvency II calibration framework and the confidence level disclosure used for IFRS 17 RA. The rescaled stresses for different confidence levels are presented in Table 2, based on the scaling approach proposed by El Alami (2023) and the Solvency II calibration defined in the European Commission Delegated Regulation (EU) 2015/35.

Table 2: Rescaled SF stresses across confidence levels

Item	Confidence level 99.5%	90%	85%	80%	75%
$\Phi^{-1}(p)$	2.576	1.282	1.036	0.842	0.674
Scaling factor $\left(\frac{\Phi^{-1}(p)}{\Phi^{-1}(0.995)}\right)$	1.0000	0.4975	0.4021	0.3268	0.2617
Mortality	15.00%	7.46%	6.03%	4.90%	3.93%
Lapse Up	50.00%	24.87%	20.11%	16.34%	13.09%
Lapse Down	-50.00%	-24.87%	-20.11%	-16.34%	-13.09%
Lapse Mass	40.00%	19.90%	16.08%	13.07%	10.47%
Expense Nominal	10.00%	4.98%	4.02%	3.27%	2.62%
Expense Inflation	1.00%	0.50%	0.40%	0.33%	0.26%

Source: Own work based on European Commission (2015) and El Alami (2023).

Once the shocks are rescaled to the desired confidence level, the stressed liabilities are recalculated for each risk driver in order to determine the stand-alone impact of the corresponding risk. For mortality risk, the stress is applied as a proportional increase in mortality rates. The resulting capital impact is therefore shown in (34) (EIOPA, 2014).

$$\Delta_{Mort}(p) = RA_{mort}(p) = \max\{0, PVFCF_{mort}(p) - PVFCF_0\} \tag{34}$$

Similarly, expense risk is modelled through an increase in future expense levels and the corresponding impact on the liability is as shown in (35) (EIOPA, 2014).

$$\Delta_{Exp}(p) = RA_{exp}(p) = \max\{0, PVFCF_{exp}(p) - PVFCF_0\} \tag{35}$$

Lapse risk is treated differently. The SF specifies three alternative stresses reflecting different lapse behaviours: lapse-up, lapse-down and mass lapse. Each stress is evaluated separately, and the stand-alone lapse capital requirement is defined as the most adverse outcome among these scenarios (EIOPA, 2014):

$$\Delta_{Lapse}(p) = RA_{lapse}(p) = \max\{RA_{lapse,up}(p), RA_{lapse,down}(p), RA_{lapse,mass}(p)\} \tag{36}$$

This reflects the asymmetric nature of lapse risk in life insurance, where both higher and lower lapse rates can increase the insurer's liability depending on product characteristics. Accordingly, the SF approach does not model a continuous lapse distribution. Instead, it selects the most onerous lapse stress from a limited set of prescribed scenarios (EIOPA, 2014).

3.3.3 Diversification and allocation

Once the individual sub-modules SCRs are determined, they must be aggregated to obtain the total capital requirement. Since different risks do not occur simultaneously with perfect correlation, the SF incorporates diversification effects through prescribed correlation matrices. These matrices specify the dependence structure between individual risks and are used within the aggregation formula shown in Chapter 2.3.2, equation (14), that produces the BSCR (CEIOPS, 2010).

The Solvency II SF prescribed correlation matrix for the life underwriting risk sub-modules is presented in Figure 9. The matrix contains correlation coefficients between the individual life underwriting risk sub-modules, including mortality, longevity, disability, lapse, expenses, revision risk, and catastrophe risk. Each element $\rho_{i,j}$ represents the assumed dependence between two risks and determines the extent to which diversification effects are recognised when aggregating their SCRs (CEIOPS, 2010).

Figure 9: Correlation matrix for life underwriting risk under Solvency II SF

	mortality	longevity	disability	lapse	expenses	revision	CAT
mortality	1						
longevity	-0.25	1					
disability	0.5	0	1				
lapse	0	0.25	0	1			
expenses	0.25	0.25	0.5	0.5	1		
revision	0	0.25	0	0	0.25	1	
CAT	0	0	0	0	0	0	1

Source: CEIOPS (2010).

The correlation parameters $\rho_{i,j}$ are therefore not intended to represent empirical correlations observed under normal conditions. Instead, they are calibration parameters selected to ensure that the aggregated SCR provides a reasonable approximation of the 99.5% VaR of total risk. In this sense, correlations in the SF reflect dependence under stressed conditions, recognizing that diversification benefits tend to decrease during periods of financial or demographic stress (CEIOPS, 2010).

The aggregation structure for SF approach used in this thesis follows the same mathematical framework as the Solvency II SF calculation of the BSCR. By analogy, once the stand-alone impacts $\Delta_{\mathrm{i}}(p)$ are calculated, they are aggregated using the same correlation structure shown in equation (37) and (38).

$$\Delta(p) = \begin{pmatrix} \Delta_{\mathrm{Mort}}(p) \\ \Delta_{\mathrm{Lapse}}(p) \\ \Delta_{\mathrm{Exp}}(p) \end{pmatrix} \tag{37}$$

$$RA_{SF}(p) = \sqrt{\Delta(p)^\top C \Delta(p)} \tag{38}$$

where C is the prescribed correlation matrix between life underwriting risk sub-modules and $\Delta(p)$ is the vector of stand-alone stressed liability impacts. This matrix representation is mathematically equivalent to the standard Solvency II aggregation formula used for the BSCR (CEIOPS, 2010).

In the SF framework, diversification is not generated through simulated joint outcomes. Instead, it is imposed externally through the fixed correlation matrix. This is a fundamental methodological difference from the internal model. In the internal model, diversification emerges from the joint stochastic distribution of risk drivers. In the SF approach, diversification is formula-based and depends entirely on the prescribed correlations.

Within each product, the SF aggregation allows the total RA to be decomposed across the individual risk drivers. Since the aggregation formula explicitly defines how risks are combined, the Euler allocation can be applied. For risk driver i, the Euler allocation is shown by equation (39). This allocation sums exactly to the RA_{SF} and is the theoretically consistent allocation under the square-root aggregation formula (38).

$$Alloc_i = \frac{\Delta_i (C\Delta)_i}{RA_{SF}} \tag{39}$$

4 RESULTS AND ANALYSIS

The following chapter focuses on the presentation and interpretation of the RA results obtained from the calculated internal stochastic model and Solvency II SF model. All the calculations are done for IFRS 17 reporting purposes.

Both approaches are applied to the same deterministic fulfilment cash flow model, ensuring comparability between the models. Both models were calculated on several confidence levels such as 75%, 80%, 85%, 90% and 99.5%. For the analysis a confidence level of 80% was chosen. This confidence level is chosen because it is consistent with observed market practice under IFRS 17 and lies close to the average confidence levels reported by EIOPA (2024) for European insurers. However, the calculation for the rest of the confidence levels can be found in Appendix 4.

The objective of this chapter is to interpret how uncertainty is incorporated in each method, how risk drivers influence tail outcomes, how diversification is captured, and how the methodological differences translate into different RA and therefore different financial statement impact.

4.1 Internal model results

Table 3 presents the construction of FCFs under the internal model at the 80% confidence level. The deterministic *PVFCF* equals -930,999 EUR and serves as the best estimate benchmark from which the RA is measured. Present value of premiums amounts to 6,347,474 EUR, while present value of benefits and expenses equals 4,564,543 EUR and 851,931 EUR respectively. The negative PVFCF indicates that expected premium inflows exceed expected outflows, so the portfolio is profitable on a best estimate basis. However, IFRS 17 requires that the liability also reflects compensation for bearing non-financial risk. The internal model therefore adds a RA of 118,026 EUR, corresponding to 12.67% of the total PVFCF. After including the RA, the FCFs increase from -930,999 EUR to -812,973 EUR (i.e. become less negative). Economically, this means that a portion of the expected profitability is absorbed by compensation for uncertainty in non-financial cash flows.

Table 3: Construction of FCFs under the internal model

Item		Value (in EUR)
1.	PV premiums	6,347,474
2.	PV mortality benefits	380,018
3.	PV lapse/ surrender benefits	428,532
4.	PV maturity benefits	3,755,993
5.	PV total benefits = (2) + (3) + (4)	4,564,543
6.	PV expenses	851,931
7.	PVFCF = [(5) + (6)] - (1)	-930,999
8.	${RA^{IM}}_{0.80}$	118,026
9.	Fulfilment cash flows (FCFs) = (7) + (8)	-812,973
10.	RA%PVFCF = (8)/ | (7) | *100	12,67%

Source: Own work.

The internal model is consistent with IFRS 17 because the RA is derived from a stochastic loss distribution that reflects entity-specific uncertainty in mortality, lapse and expense risk. As mentioned in Chapter 3.2.4, the RA is measured as the difference between the selected percentile of the simulated loss distribution and the deterministic *PVFCF*. The RA is not an additional expected cash outflow, rather, it is the amount of compensation the insurer requires to move from the best estimate to a more adverse but still plausible percentile outcome. This is aligned with IFRS 17, which defines the RA as compensation for bearing uncertainty arising from non-financial risk and states that wider, longer tailed and less certain distributions should lead to higher amounts of adjustments.

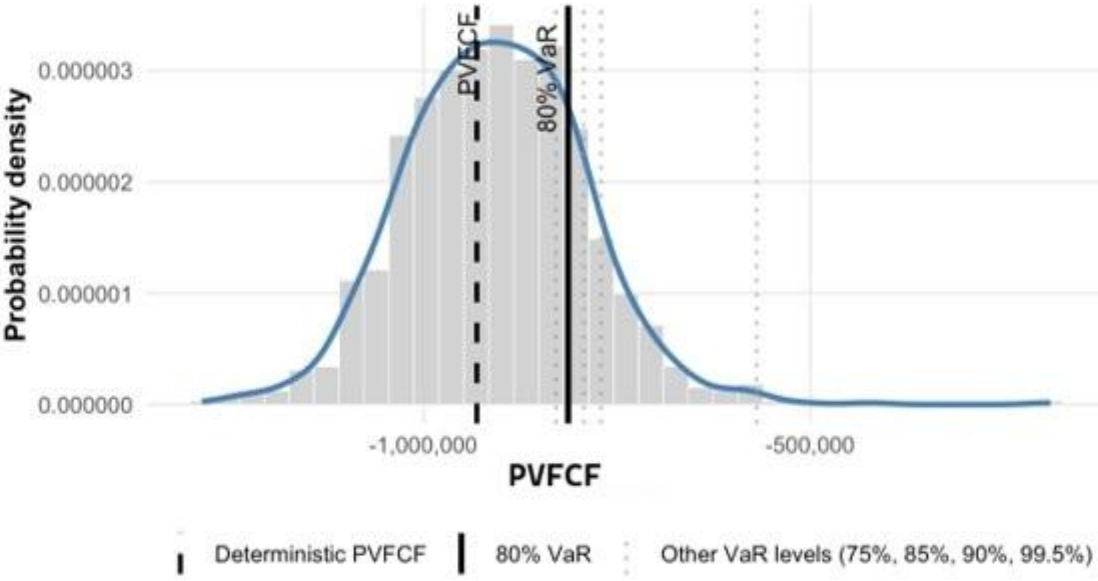
Table 4: Internal model summary at 80% confidence level

Item		Value (in EUR)
1.	Total $RA^{IM}{}_{0.80}$	118,026
2.	Stand-alone mortality $RA^{IM}{}_{0.80}$	68,235
3.	Stand-alone lapse $RA^{IM}{}_{0.80}$	58,547
4.	Stand-alone expense $RA^{IM}{}_{0.80}$	36,243
5.	Sum of stand-alone $RA^{IM}{}_{0.80}$ = (2) + (3) + (4)	163,026
6.	Diversification benefit = (5) – (1)	45,000
7.	Allocated mortality $RA^{IM}{}_{0.80}$	49,401
8.	Allocated lapse $RA^{IM}{}_{0.80}$	42,387
9.	Allocated expense $RA^{IM}{}_{0.80}$	26,239
10.	Mortality share of total $RA^{IM}{}_{0.80}$ = (7)/ (1)	41.9%
11.	Lapse share of total $RA^{IM}{}_{0.80}$ = (8)/ (1)	35.9%
12.	Expense share of total $RA^{IM}{}_{0.80}$ = (9)/ (1)	22.2%

Source: Own work.

Table 4 presents the decomposition of the internal model RA at the 80% confidence level. The decomposition of the internal model RA provides further insight into the portfolio's risk profile. The stand-alone RA amount to 68,235 EUR for mortality risk, 58,547 EUR for lapse risk and 36,243 EUR for expense risk, giving a total undiversified amount of 163,026 EUR. The undiversified sum exceeds the total portfolio RA of 118,026 EUR by 45,000 EUR. The difference represents a diversification benefit of 27.6% of the undiversified sum. In the internal model this diversification is generated endogenously through the joint stochastic behaviour of the risk drivers rather than being imposed externally. In other words, the model allows adverse mortality, lapse and expense outcomes to interact in a portfolio-specific way, and the total RA is lower than the sum of stand-alone risks because the worst outcomes for each driver do not always occur together with full intensity. After proportional allocation, mortality contributes 41.9% of the total RA, lapse contributes 35.9%, and expense contributes 22.2%. This indicates that the internal model sees the non-financial risk profile of the endowment portfolio as relatively balanced, although mortality is the largest contributor to the allocated RA. This result is actuarially plausible. For an endowment contract, uncertainty in mortality influences both death related benefit payments and the pattern of survival to maturity, which means that mortality affects the timing and amount of several major cash flow components. Lapse risk is also material because surrender behaviour alters both future premium inflows and surrender benefit outflows. Expense risk is smaller than the other two drivers but remains meaningful, especially given the long-duration nature of the contracts.

Figure 10: Loss distribution for the simulated endowment portfolio



Source: Own work.

Figure 10 illustrates the simulated distribution of losses for the endowment portfolio. The dashed line represents the deterministic *PVFCF* with a value of -930,999 EUR, while the full line indicates the 80% VaR that is used to determine the RA. The 80% VaR defines the loss threshold that is not exceeded with a probability of 80%, implying that there is a 20% probability of experiencing more adverse outcomes. The distribution exhibits a right-skewed shape, reflecting the presence of asymmetric risk and the possibility of adverse outcomes with higher losses. The 80% VaR lies to the right of the deterministic *PVFCF*, indicating that the RA captures the additional compensation required to cover moderately adverse scenarios. The horizontal distance between these two points corresponds to the RA of 118,026 EUR. Although more extreme outcomes are possible, as shown by higher percentile levels, the selected confidence level reflects a moderate level of prudence consistent with IFRS 17 requirements.

4.2 Standard Formula (SF) results

The SF results presented in Table 5 illustrate the construction of fulfilment cash flows based on prescribed stress scenarios applied to the deterministic best estimate. The baseline *PVFCF* remains unchanged at -930,999 EUR, ensuring consistency with the internal model. After applying the SF stresses and aggregating the resulting stand-alone stressed liability impacts using the prescribed correlation matrix, the RA at the 80% confidence level amounts to 126,330 EUR. This corresponds to 13.5% of the deterministic *PVFCF*. Once the RA is added, fulfilment cash flows increase from -930,999 EUR to -804,669 EUR. Economically, this means that although the portfolio remains profitable after allowing for non-financial risk, the total insurance liability is increased once compensation for bearing uncertainty is included.

Table 5: Construction of FCFs under the Standard Formula approach

Item		Value (in EUR)
1.	PV premiums	6,347,474
2.	PV mortality benefits	380,018
3.	PV lapse/ surrender benefits	428,532
4.	PV maturity benefits	3,755,993
5.	PV total benefits = (2) + (3) + (4)	4,564,543
6.	PV expenses	851,931
7.	PVFCF = [(5) + (6)] - (1)	-930,999
8.	${RA^{SF}}_{0.80}$	126,330
9.	Fulfilment cash flows (FCFs) = (7) + (8)	-804,669
10.	RA%PVFCF = (8)/ | (7) | *100	13.5%

Source: Own work.

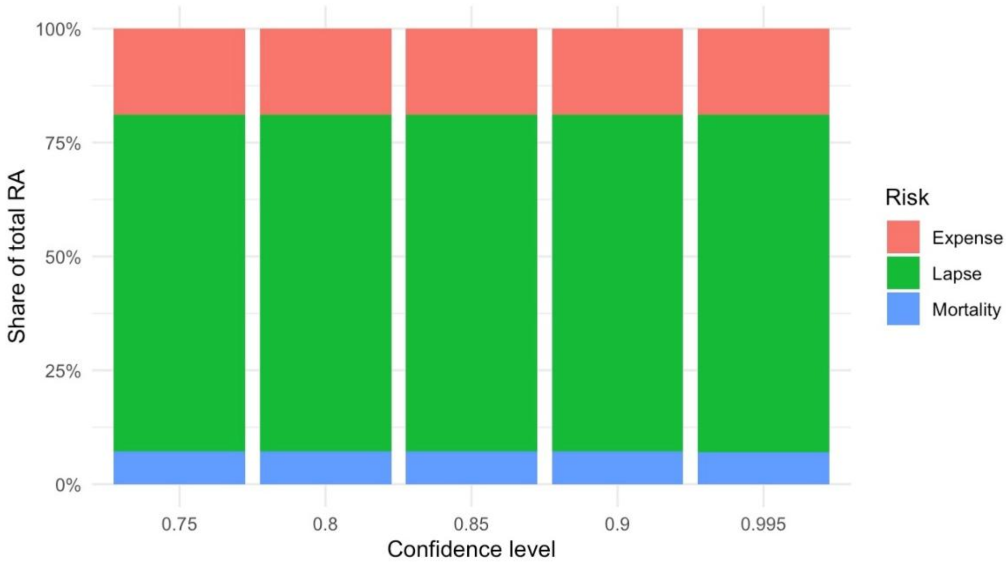
Table 6 presents the decomposition of the SF RA at the 80% confidence level. The total RA amounts to 126,330 EUR. At the 80% confidence level, the application of the SF stresses results in stand-alone impacts of 10,468 EUR for mortality risk, 109,057 EUR for lapse risk, and 27,836 EUR for expense risk. These values reflect the sensitivity of fulfilment cash flows to adverse movements in the underlying risk drivers under the prescribed stress scenarios. When considering each risk driver in isolation, the stand-alone increases in fulfilment cash flows for mortality, lapse, and expense risk sum to 147,361 EUR, which exceeds the aggregated portfolio RA. This difference reflects a diversification benefit of 21,031 EUR, corresponding to approximately 14.3% of the undiversified amount. This indicates that adverse developments in the individual risk drivers are not assumed to occur fully simultaneously, and therefore diversification reduces the overall level of required compensation for non-financial risk. After aggregation and allocation, lapse risk clearly emerges as the dominant contributor to the total RA, accounting for 84.0%, followed by expense risk at 14.8%, while mortality risk contributes only 1.1%. This indicates that, under the SF approach, the uncertainty in fulfilment cash flows is driven predominantly by policyholder behaviour. The strong impact of lapse risk reflects the sensitivity of the portfolio to changes in surrender patterns, which affect both future premium inflows and benefit outflows. Expense risk remains material but secondary, while mortality risk has only a limited impact on the overall variability of cash flows within this framework. Overall, the results indicate a portfolio where non-financial risk is concentrated in lapse risk, with moderate diversification effects across the remaining risk drivers.

Table 6: Decomposition of the Standard Formula RA at 80% confidence level

Item		Value (in EUR)
1.	Total $RA^{SF}{}_{0.80}$	126,330
2.	Stand-alone mortality $RA^{SF}{}_{0.80}$	10,468
3.	Stand-alone lapse $RA^{SF}{}_{0.80}$	109,057
4.	Stand-alone expense $RA^{SF}{}_{0.80}$	27,836
5.	Sum of stand-alone $RA^{SF}{}_{0.80}$ = (2) + (3) + (4)	147,361
6.	Diversification benefit = (5) – (1)	21,031
7.	Allocated mortality $RA^{SF}{}_{0.80}$	1,444
8.	Allocated lapse $RA^{SF}{}_{0.80}$	106,161
9.	Allocated expense $RA^{SF}{}_{0.80}$	18,725
10.	Mortality share of total $RA^{SF}{}_{0.80}$ = (7)/ (1)	1.1%
11.	Lapse share of total $RA^{SF}{}_{0.80}$ = (8)/ (1)	84.0%
12.	Expense share of total $RA^{SF}{}_{0.80}$ = (9)/ (1)	14.8%

Source: Own work.

Figure 11: Composition of the RA by risk driver under the SF approach



Source: Own Work.

Figure 11 illustrates the composition of the RA across different confidence levels. The relative contributions of the individual risk drivers remain unchanged as the confidence level increases. This follows directly from the SF methodology, where stresses are obtained by rescaling a reference calibration at the 99.5% confidence level. As a result, both the stand-alone impacts and the aggregated RA increase proportionally, while their relative shares remain the same. Although this approach ensures consistency and transparency, it also reveals an important limitation. Because the composition of the RA does not adjust with the confidence level, the SF framework is unable to capture potential changes in the portfolio's risk profile under more severe scenarios. In particular, it does not reflect non-linear effects or changes in the interaction between risk drivers as the severity of shocks increases.

4.3 Quantitative comparison

The quantitative comparison in Table 7, shows that the two approaches produce similar total RA amounts. However, they have materially different insights into the underlying risk profile and the role of diversification. At the 80% confidence level, the SF produces a RA of 126,330 EUR, while the internal model produces 118,026 EUR. The difference of 8,304 EUR implies that the SF estimate of RA is approximately 7.0% higher than the RA in the internal model. Relative to the *PVFCF*, the internal model produces a RA equal to 12.67% of the *PVFCF*, compared with 13.57% under the SF. Generally, the results are not dramatically different. Both methods imply that a meaningful part of the expected margin in the endowment portfolio must be reserved as compensation for bearing non-financial uncertainty. However, once the total amount is decomposed, the models start to diverge. As shown in Table 8, the internal model produces relatively balanced distribution of risk across mortality, lapse and expense components. Mortality is the largest contributor, but lapse is only modestly lower and expense remains material. In contrast, the SF approach result is overwhelmingly concentrated in lapse risk, accounting for 84% of the total RA. This demonstrates that the choice of methodology affects not only the amount of the RA but also its economic interpretation.

Table 7: Quantitative comparison of total RA metrics

Item	Internal model (IM)	Standard formula (SF)	Difference (SF-IM)
PVFCF (in EUR)	-930,999	-930,999	0
RA (in EUR)	118,026	126,330	8,304
RA as % of |PVFCF|	12.67%	13.57%	0.81 pp
FCF (in EUR)	-812,973	-804,669	8,304
Stand-alone sum RA (undiversified) (in EUR)	163,026	147,361	-15,665
Diversification benefit (in EUR)	45,000	21,031	-23,969
Diversification as % of stand-alone sum	27.6%	14.3%	-13.3 pp

Source: Own work.

Two models can produce similar total RAs while telling very different stories about the underlying risk profile of the same portfolio. A key driver of this difference is the treatment of diversification. The internal model produces stronger diversification than the SF. Shown in Table 7, its diversification benefit equals 45,000 EUR, or 27.6% of the undiversified stand-alone sum. The SF diversification benefit is 21,031 EUR, or 14.3% of the undiversified amount. This difference is economically intuitive. In the internal model, diversification emerges from the simulated joint distribution of the risk drivers, which means it reflects the actual modelled interaction of mortality, lapse and expense shocks in the portfolio. In the SF, diversification is determined by the prescribed correlation matrix. The internal model is therefore more risk-sensitive and potentially more representative of entity-specific experience, whereas the SF is more standardised and less dependent on modelling judgement.

The comparison also highlights differences in how the two approaches respond to the tail of the loss distribution. The comparison also shows that the internal model reacts to the shape of the tail, while the SF mainly rescales a fixed shock structure. In the internal model, the composition of risk changes at higher confidence levels, with mortality becoming more dominant in the tail. This suggests that the model captures non-linearity and evolving severity as outcomes become more adverse. By contrast, the SF maintains the same composition at all confidence levels because the same prescribed stresses are simply scaled up or down. As a result, it does not reflect changes in the relative importance of risk drivers under more extreme scenarios. For IFRS 17, this distinction matters because the RA should reflect the entity's own compensation for uncertainty, and that compensation is conceptually linked not only to the centre of the distribution but also to the shape of its tail. From a methodological perspective, the modelling choices explain most of the differences between the two approaches. First, the internal model incorporates both process risk and parameter risk, while the SF does not explicitly estimate either from portfolio data. Second, the internal model derives uncertainty from entity-specific stochastic behaviour, while the SF relies on regulatory stresses calibrated for a representative insurer rather than the exact portfolio under study. Third, the diversification in the internal model is endogenous, whereas diversification in the SF is exogenous and formula driven. Fourth, the SF result at 80% is not a directly simulated 80% VaR but an approximation obtained by rescaling 99.5% solvency shocks. Each of these choices affects the amount, composition and interpretation of the resulting RA.

Table 8: Comparison of risk composition at 80% confidence level

Risk driver	Internal model (IM) share	Standard formula (SF) share	Interpretation
Mortality	41.9%	1.1%	Material in IM, almost negligible in SF
Lapse	35.9%	84.0%	Important in both, dominant under SF
Expense	22.2%	14.8%	Secondary but still material in both models

Source: Own work.

Although the total RA is relatively similar under both approaches, Table 8 shows that the underlying risk composition differs materially. The internal model produces a more balanced distribution across mortality, lapse and expense risk, while the SF is strongly concentrated in lapse risk. This reflects the methodological design of the SF, where prescribed stresses and fixed correlations assign a disproportionately larger stand-alone impact to lapse risk compared with the stochastic internal model.

From an actuarial perspective, the internal model provides a more informative view of the portfolio's risk profile. It explains how different risk drivers contribute to the total RA, how diversification arises, and how the composition of risk evolves across the distribution. This, however, does not automatically make it superior in all practical contexts. The SF approach remains valuable due to its transparency, operational simplicity, and ease of application, particularly when data are limited.

Taken together, these findings demonstrate that the choice of methodology affects not only the level of the RA, but also its composition and economic interpretation. While the SF can be adapted to produce a reasonable amount of an IFRS 17 RA, it provides a more standardised and less portfolio-sensitive representation of non-financial risk. The internal model, by contrast, offers a more detailed and entity-specific perspective, capturing both the underlying drivers of risk and their interaction across different scenarios.

4.4 Implications for insurers

The results obtained in the previous sections demonstrate that the choice of methodology for calculating RA has implications that go beyond the numerical value of the adjustment itself. While the internal model and the SF approach produce relatively similar total RA amounts for the analysed portfolio, they differ significantly in how risk is represented, how diversification is recognised, and how uncertainty is translated into financial reporting outcomes. These differences have direct implications for insurers in terms of balance sheet presentation, profit emergence, and the interpretation of risk.

From a balance sheet perspective, the RA forms part of the FCFs and therefore directly affects the measurement of insurance contract liabilities. A higher RA increases the carrying amount of liabilities and reduces equity, while a lower RA has the opposite effect. In this thesis, the SF produces a slightly higher RA than the internal model. Although the difference is not substantial in absolute terms, it illustrates that the chosen methodology can influence the reported financial position even when applied to the same underlying portfolio. Importantly, this difference is not driven purely by the level of prudence, but by the underlying structure of the methodology, including how shocks are defined and how dependencies between risks are treated.

From profit and loss perspective, the reported RA at initial recognition also affects the pattern of profit recognition over time. As established in Chapter 2, the RA is released over time as uncertainty is resolved during the coverage period. This means that the RA represents a source of future earnings that emerges gradually rather than immediately. Consequently, a higher RA at initial recognition leads to greater future release of insurance service result, while a lower RA results in earlier recognition of profit. The choice of RA methodology therefore implicitly determines the timing of profit emergence, even if total profitability over the lifetime of the contracts remains unchanged.

It is important to emphasise that the RA is determined independently of the CSM. The CSM is calculated as a residual at initial recognition, ensuring that no day-one profit is recognised. As a result, changes in the RA directly affect the CSM in the opposite direction, holding all other inputs constant. A higher RA reduces the CSM, while a lower RA increases it. Although the RA and CSM are released separately through the insurance service result, they jointly determine the timing and composition of profit emergence. Consequently, the choice of RA methodology influences not only the level of compensation for risk, but also how total profit is allocated between RA and CSM over the coverage period. This interaction is also relevant for the assessment of onerous contracts. Under IFRS 17, a contract is considered onerous when FCFs become positive, meaning that the discounted expected outflows including RA, exceed the discounted expected inflows at initial recognition. Since the RA forms part of these cash flows, a higher RA increases the likelihood that a contract is classified as onerous at initial recognition. In such cases, no CSM is established and the loss is recognised immediately in profit or loss. Therefore, the choice of RA methodology may affect not only the timing of profit recognition, but also whether profit is recognised at all at inception.

These differences imply that the selection of methodology is not only a technical modelling decision, but also a strategic reporting choice. An internal model allows insurers to align the RA more closely with portfolio-specific characteristics, risk appetite, and observed experience. This results in a more risk-sensitive and economically meaningful measure of uncertainty. However, this comes at the cost of increased complexity, requiring stochastic simulation, statistical calibration, and high-quality data.

By contrast, the SF approach offers advantages in terms of simplicity, transparency, and operational feasibility. Its reliance on predefined stresses and aggregation rules makes it easier to implement, communicate, and justify, particularly in environments with limited data or modelling resources. However, this simplicity comes at the expense of risk sensitivity. The SF does not fully capture the portfolio-specific behaviour of risk drivers, nor does it reflect how the composition of risk may evolve across confidence levels. Instead, it produces a relatively stable and predetermined structure of risk contributions.

Importantly, the findings of the thesis suggest that an insurer may choose to build its own internal model not because it produces lower RA, but because it provides a richer and more informative explanation of risk. It captures the interaction between risk drivers, reflects the shape of the loss distribution, and allows the composition of risk to change across confidence levels. This is consistent with the objective of IFRS 17, which requires the RA to reflect the entity's own compensation for bearing non-financial risk. On the other hand, the SF approach, while producing a slightly higher overall RA, offers a more simplified, standardised and regulatory friendly balance sheet item.

4.5 Methodological strengths and limitations

The methodologies applied in this thesis combines a stochastic internal model and a Solvency II SF based approach within a consistent IFRS 17 valuation framework. This provides a structured basis for comparing alternative models for calculating the RA under the VaR approach and enables a clear assessment of how methodological choices influence both the level and composition of risk.

A key strength of the analysis in this master thesis is the use of consistent modelling framework used across both models. The same underlying portfolio, assumptions, and deterministic baseline valuation are applied in both the internal model and the SF approach. This ensures that any observed differences in the resulting RA are driven solely by the treatment of uncertainty rather than by inconsistencies in inputs. As a result, the comparison between the two approaches is transparent and analytically robust.

A further strength lies in the stochastic internal model, which explicitly captures uncertainty in mortality, lapse, and expense risk through Monte Carlo simulation. By incorporating both process risk and parameter risk, the internal model provides a detailed representation of the loss distribution and allows for a direct estimation of the RA at different confidence levels. This makes the analysis of tail behaviour, diversification effects, and the interaction between risk drivers possible in a way that is consistent with the IFRS 17. Furthermore, the methodology incorporates a decomposition and allocation of risk, allowing the total RA to be analysed in terms of individual risk drivers and product contributions. This provides valuable insight into the structure of non-financial risk within the portfolio and enhances the interpretability of the results.

Another strength lies in the adaptation of the Solvency II SF approach to an IFRS 17 context. By rescaling the SF stresses to different confidence levels, the thesis demonstrates how a regulatory capital framework can be transformed into a reporting-oriented risk measure of non-financial risk.

Despite these strengths, several limitations should be acknowledged. First, the analysis is based on a synthetic portfolio. While this allows for full control over modelling assumptions and ensures internal consistency, it does not fully capture the complexity and heterogeneity of real-world insurance portfolios. In practice, insurers operate with more diverse and complex products which may lead to different risk dynamics.

Second, the internal model relies on simplifying assumptions in the modelling of risk drivers. Although GLMs provide a flexible and widely accepted framework, they may not fully capture complex dependencies, extreme events, or structural changes in risk behaviour. In particular, the modelling of dependencies between mortality, lapse, and expense risk is implicitly rather than explicitly calibrated, which may affect the accuracy of diversification estimates. Future research could enhance the modelling framework by incorporating explicit dependence structures, for example through correlated risk factors, macroeconomic drivers, or copula-based approaches, allowing for a more realistic representation of joint risk behaviour.

Third, the use of VaR as the primary risk measure introduces well-known limitations. VaR captures risk at a specific percentile but does not reflect the severity of losses beyond that point and does not satisfy the property of subadditivity. As a result, it may underestimate tail risk and limit the robustness of risk allocation. Although VaR is widely used in practice and suitable for comparative purposes, alternative measures could provide a more comprehensive representation of extreme outcomes.

A further limitation arises in the SF approach, where the rescaling of stresses from a 99.5% confidence level to lower IFRS 17 confidence levels is based on a normal distribution approximation. This assumption simplifies the transformation but may not accurately reflect the true distribution of insurance risks, which are often skewed and heavy-tailed.

In summary, this master thesis provides a coherent and analytically robust framework for comparing RA methodologies under IFRS 17. However, the results should be interpreted in light of the simplifying assumptions and modelling choices made. The main strengths lie in the transparency, comparability, and ability to explain the drivers of risk. At the same time, the limitations highlight the challenges of capturing the full complexity of life insurance portfolio and risk within a modelling framework and suggest avenues for further research and model development.

5 CONCLUSION

This master thesis examined the calculation of the RA under IFRS 17 for a life insurance portfolio and compared two alternative approaches: an internal stochastic model and an approach based on the Solvency II SF. The purpose of the analysis was not only to compare the numerical outcome of the two methods, but also to assess how each framework represents uncertainty, diversification, and the composition of non-financial risk.

The thesis first established the conceptual and regulatory background of IFRS 17 and Solvency II. While both frameworks address uncertainty in insurance liabilities, they do so for different purposes. IFRS 17 is a financial reporting standard that requires an entity-specific measure of compensation for bearing non-financial risk, whereas Solvency II is a solvency regime designed to ensure capital adequacy and policyholder protection. This distinction is important because it means that a methodology that is operationally convenient under Solvency II does not necessarily provide a fully appropriate representation of the RA under IFRS 17.

To evaluate this issue empirically, the thesis developed a stochastic internal model for a synthetic endowment portfolio. The model captured mortality, lapse, and expense risk through a Monte Carlo framework using GLM-based risk drivers and measured the RA with a VaR approach across several confidence levels. In parallel, the Solvency II SF was adapted to an IFRS 17 context by rescaling the prescribed life underwriting stresses from the original 99.5% calibration to lower confidence levels more consistent with IFRS 17 reporting practice.

The results showed that, at the selected 80% confidence level, the two approaches produced relatively similar total RA amounts. The internal model generated an RA of 118,026 EUR, while the SF approach produced 126,330 EUR. This indicates that, for the analysed portfolio, the SF can provide a reasonable amount of the overall level of compensation for non-financial risk. However, the similarity in total amount should not be interpreted as evidence that the two approaches are economically equivalent.

A more detailed comparison revealed significant methodological and interpretive differences. The internal model produced a more balanced distribution of risk across mortality, lapse, and expense risk, with mortality emerging as the largest contributor and diversification arising naturally from the simulated joint behaviour of the risk drivers. By contrast, the SF approach produced a highly concentrated risk profile in which lapse risk dominated the total RA, while mortality contributed only marginally. In addition, diversification under the internal model was materially stronger than under the SF, reflecting the fact that the internal model captures portfolio-specific interactions between risk drivers, whereas the SF imposes diversification externally through a fixed regulatory correlation matrix.

These findings suggest that the choice of methodology affects not only the level of the RA, but also its composition, interpretation, and usefulness for decision-making. The internal model is better aligned with the IFRS 17 principle that the RA should reflect the entity's own compensation for bearing non-financial risk. It provides richer information about the structure of uncertainty, the interaction between risk drivers, and the way the risk profile evolves across confidence levels. At the same time, this approach is more demanding in terms of data, modelling assumptions, calibration effort, and implementation complexity.

The SF approach, on the other hand, offers simplicity, transparency, and operational feasibility. It can therefore be a practical alternative, especially for insurers with limited data or modelling capabilities. However, its standardised design means that it is less sensitive to portfolio-specific risk characteristics and less able to reflect changes in risk composition under more adverse scenarios.

Overall, the thesis shows that an internal stochastic model does not necessarily produce a lower RA than the RA of the SF approach, but it does produce a more informative and entity-specific view of non-financial risk. The main contribution of the thesis is therefore to demonstrate that the methodological choice behind the RA is important not only quantitatively, but also conceptually. For insurers, this means that the decision between an internal model and the SF is not merely a technical one, but also a strategic reporting choice that affects how risk is understood, communicated, and reflected in the financial statements.

Finally, the thesis also highlights several limitations, including the use of a synthetic portfolio, simplifying assumptions in the modelling of dependencies, the reliance on VaR as the risk measure, and the normal approximation used to rescale SF stresses. These limitations provide a basis for future research. Further work could extend the analysis to real insurance portfolios, incorporate more explicit dependence structures, or compare VaR-based results with alternative techniques such as CTE or CoC approaches. Despite these limitations, the thesis provides a coherent framework for comparing RA methodologies under IFRS 17 and offers useful insights into the trade-off between risk sensitivity and operational simplicity.

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APPENDICES

Appendix 1: Slovenian life tables

Table A1 presents the Slovenian life tables for the year 2023, obtained from Eurostat. These unisex tables provide key mortality indicators, including the probability of death q_x and survival probability p_x by age. The life tables serve as the primary source for mortality assumptions used in this thesis. In particular, the values of $q_x$and $p_x = 1 - q_x$ are directly applied in the actuarial calculations and implemented in the R code for projecting expected cash flows and premiums calculation.

Table A1: Slovenian life tables by age

	TIME	2023							
GEO (Labels)	AGE	Mx	ex	dx	qx	px	Lx	lx	Tx
Slovenia	0	0,00179	82,0	179	0,00179	0,99821	99.857	100.000	8.200.965
Slovenia	1	0,00011	81,2	11	0,00011	0,99989	99.815	99.821	8.101.108
Slovenia	2	0,00005	80,2	5	0,00005	0,99995	99.807	99.810	8.001.293
Slovenia	3	0,00005	79,2	5	0,00005	0,99995	99.802	99.805	7.901.486
Slovenia	4	0,0001	78,2	10	0,0001	0,9999	99.795	99.800	7.801.683
Slovenia	5	0,	77,2	0	0,	1,	99.790	99.790	7.701.889
Slovenia	6	0,00019	76,2	19	0,00019	0,99981	99.780	99.790	7.602.099
Slovenia	7	0,	75,2	0	0,	1,	99.771	99.771	7.502.319
Slovenia	8	0,00005	74,2	5	0,00005	0,99995	99.768	99.771	7.402.548
Slovenia	9	0,	73,2	0	0,	1,	99.766	99.766	7.302.780
Slovenia	10	0,00009	72,2	9	0,00009	0,99991	99.762	99.766	7.203.014
Slovenia	11	0,00013	71,2	13	0,00013	0,99987	99.751	99.757	7.103.252
Slovenia	12	0,00004	70,2	4	0,00004	0,99996	99.742	99.744	7.003.502
Slovenia	13	0,	69,2	0	0,	1,	99.740	99.740	6.903.760
Slovenia	14	0,00022	68,2	22	0,00022	0,99978	99.729	99.740	6.804.020
Slovenia	15	0,00009	67,2	9	0,00009	0,99991	99.714	99.718	6.704.291
Slovenia	16	0,00034	66,2	33	0,00034	0,99966	99.692	99.709	6.604.578
Slovenia	17	0,0004	65,3	40	0,0004	0,9996	99.656	99.676	6.504.885
Slovenia	18	0,00026	64,3	26	0,00026	0,99974	99.623	99.636	6.405.230
Slovenia	19	0,00042	63,3	42	0,00042	0,99958	99.589	99.610	6.305.607
Slovenia	20	0,00026	62,3	25	0,00026	0,99974	99.555	99.568	6.206.018
Slovenia	21	0,00025	61,3	25	0,00025	0,99975	99.530	99.543	6.106.463
Slovenia	22	0,00034	60,4	33	0,00034	0,99966	99.501	99.518	6.006.932
Slovenia	23	0,00038	59,4	38	0,00038	0,99962	99.466	99.485	5.907.431
Slovenia	24	0,00029	58,4	28	0,00029	0,99971	99.432	99.447	5.807.966
Slovenia	25	0,00018	57,4	18	0,00018	0,99982	99.409	99.418	5.708.533
Slovenia	26	0,00045	56,4	44	0,00045	0,99955	99.378	99.400	5.609.124
Slovenia	27	0,00031	55,5	31	0,00031	0,99969	99.340	99.355	5.509.746
Slovenia	28	0,0008	54,5	79	0,0008	0,9992	99.285	99.325	5.410.406
Slovenia	29	0,00031	53,5	31	0,00031	0,99969	99.230	99.245	5.311.121
Slovenia	30	0,00057	52,5	57	0,00057	0,99943	99.186	99.215	5.211.891
Slovenia	31	0,00055	51,6	54	0,00055	0,99945	99.131	99.158	5.112.705
Slovenia	32	0,00036	50,6	36	0,00036	0,99964	99.086	99.104	5.013.574
Slovenia	33	0,00047	49,6	46	0,00047	0,99953	99.045	99.068	4.914.488
Slovenia	34	0,00063	48,6	62	0,00063	0,99937	98.990	99.021	4.815.443
Slovenia	35	0,00081	47,7	80	0,00081	0,99919	98.919	98.959	4.716.453
Slovenia	36	0,0005	46,7	49	0,0005	0,9995	98.855	98.879	4.617.533
Slovenia	37	0,00063	45,7	62	0,00063	0,99937	98.799	98.830	4.518.679
Slovenia	38	0,00075	44,8	74	0,00075	0,99925	98.731	98.768	4.419.880
Slovenia	39	0,00074	43,8	73	0,00074	0,99926	98.657	98.694	4.321.149
Slovenia	40	0,00095	42,8	94	0,00095	0,99905	98.574	98.621	4.222.492
Slovenia	41	0,00092	41,9	91	0,00092	0,99908	98.482	98.527	4.123.917
Slovenia	42	0,00093	40,9	91	0,00093	0,99907	98.391	98.437	4.025.435

Table continues

continued

Slovenia	**43**	0,00119	39,9	117	0,00119	0,99881	98.287	98.345	3.927.044
Slovenia	**44**	0,00089	39,0	87	0,00089	0,99911	98.185	98.228	3.828.758
Slovenia	**45**	0,00145	38,0	143	0,00145	0,99855	98.070	98.141	3.730.573
Slovenia	**46**	0,00185	37,1	181	0,00185	0,99815	97.908	97.999	3.632.503
Slovenia	**47**	0,00152	36,1	149	0,00152	0,99848	97.743	97.817	3.534.595
Slovenia	**48**	0,00218	35,2	213	0,00218	0,99782	97.562	97.669	3.436.852
Slovenia	**49**	0,00241	34,3	235	0,00241	0,99759	97.338	97.456	3.339.290
Slovenia	**50**	0,00275	33,3	267	0,00275	0,99725	97.087	97.221	3.241.952
Slovenia	**51**	0,00254	32,4	246	0,00253	0,99747	96.831	96.954	3.144.864
Slovenia	**52**	0,0028	31,5	270	0,00279	0,99721	96.573	96.708	3.048.033
Slovenia	**53**	0,00328	30,6	316	0,00327	0,99673	96.280	96.438	2.951.460
Slovenia	**54**	0,00352	29,7	338	0,00351	0,99649	95.954	96.123	2.855.179
Slovenia	**55**	0,00347	28,8	331	0,00346	0,99654	95.619	95.785	2.759.225
Slovenia	**56**	0,00414	27,9	395	0,00413	0,99587	95.256	95.453	2.663.606
Slovenia	**57**	0,0047	27,0	446	0,00469	0,99531	94.836	95.059	2.568.350
Slovenia	**58**	0,00516	26,1	487	0,00514	0,99486	94.370	94.613	2.473.514
Slovenia	**59**	0,00588	25,3	552	0,00586	0,99414	93.851	94.127	2.379.144
Slovenia	**60**	0,00627	24,4	585	0,00625	0,99375	93.282	93.575	2.285.293
Slovenia	**61**	0,00727	23,6	673	0,00724	0,99276	92.653	92.990	2.192.011
Slovenia	**62**	0,00742	22,7	682	0,00739	0,99261	91.976	92.317	2.099.358
Slovenia	**63**	0,00826	21,9	754	0,00823	0,99177	91.258	91.635	2.007.382
Slovenia	**64**	0,00962	21,1	870	0,00958	0,99042	90.446	90.881	1.916.124
Slovenia	**65**	0,01057	20,3	946	0,01051	0,98949	89.538	90.011	1.825.678
Slovenia	**66**	0,01151	19,5	1.019	0,01145	0,98855	88.555	89.064	1.736.141
Slovenia	**67**	0,01314	18,7	1.149	0,01305	0,98695	87.470	88.045	1.647.586
Slovenia	**68**	0,013	18,0	1.122	0,01291	0,98709	86.335	86.896	1.560.116
Slovenia	**69**	0,01533	17,2	1.305	0,01521	0,98479	85.122	85.774	1.473.781
Slovenia	**70**	0,01648	16,4	1.381	0,01635	0,98365	83.779	84.469	1.388.659
Slovenia	**71**	0,0182	15,7	1.499	0,01804	0,98196	82.339	83.088	1.304.881
Slovenia	**72**	0,01972	15,0	1.593	0,01953	0,98047	80.793	81.590	1.222.542
Slovenia	**73**	0,02179	14,3	1.724	0,02156	0,97844	79.134	79.996	1.141.749
Slovenia	**74**	0,02161	13,6	1.674	0,02138	0,97862	77.435	78.272	1.062.614
Slovenia	**75**	0,02492	12,9	1.885	0,02461	0,97539	75.656	76.598	985.179
Slovenia	**76**	0,02927	12,2	2.155	0,02884	0,97116	73.636	74.713	909.523
Slovenia	**77**	0,0303	11,5	2.166	0,02985	0,97015	71.475	72.558	835.888
Slovenia	**78**	0,0323	10,9	2.238	0,03179	0,96821	69.274	70.393	764.412
Slovenia	**79**	0,04155	10,2	2.774	0,04071	0,95929	66.768	68.155	695.139
Slovenia	**80**	0,04462	9,6	2.854	0,04365	0,95635	63.953	65.380	628.371
Slovenia	**81**	0,04775	9,0	2.916	0,04664	0,95336	61.069	62.527	564.418
Slovenia	**82**	0,05805	8,4	3.363	0,05641	0,94359	57.929	59.611	503.349
Slovenia	**83**	0,06785	7,9	3.691	0,06563	0,93437	54.402	56.248	445.420
Slovenia	**84**	0,07307	7,4	3.705	0,07049	0,92951	50.704	52.556	391.018
Slovenia	**85**	0,14355	7,0	48.852	1,	0,	340.314	48.852	340.314

Source : Eurostat (2023).

Appendix 2: Premium calculation for the endowment portfolio

Table A2 summarises the actuarial basis used to determine premiums for the endowment portfolio. The actuarial present value of premium and benefits are defined using the commutation functions. First, the expected present value of endowment benefits and the expected present value of future premium payments are calculated. The gross annual premium is then derived using the actuarial equivalence principle, under which the expected present value of gross premium income is set equal to the expected present value of benefits and expenses (Dickson et al., 2013). Finally, an additional pricing margin is applied to obtain the premium used for each policy in the portfolio.

Table A2: Premium calculation basis for the endowment portfolio

Component	Formula	Short description
Expected present value of endowment benefits	$A_{x:\overline{n}\rceil} = \sum_{t=0}^{n-1} v^{t+1} \, {}_tp_x q_{x+t} + v^n \, {}_np_x$	Benefit payable on death or at maturity.
Expected present value of temporary life annuity-due	$\ddot{a}_{x:\overline{n}\rceil} = \sum_{k=0}^{n-1} v^t \, {}_tp_x$	Premium payments at the beginning of each year while in force.
Gross annual premium	$P^g_{x:\overline{n}\rceil} = \frac{A_{x:\overline{n}\rceil} + \alpha + \gamma \, \ddot{a}_{x:\overline{n}\rceil}}{(1-\beta) \, \ddot{a}_{x:\overline{n}\rceil}}$	EPV of premium income equals EPV of benefits and expenses.
Final premium per policy	$P^{\text{final}}_{x:\overline{n}\rceil} = 1.08 \, P^g_{x:\overline{n}\rceil}$	Premium including 8% pricing margin.
Notation	n denotes the policy term, $v(t)$ the discount factor at time t, ${}_tp_x$ the probability that a life aged x survives for t years, and q_{x+t} the one-year probability of death for a life aged $x + t$, with probabilities derived from the Slovenian life tables (2013).	

Source: Adapted from Anderson (1999) and Dickson et al. (2013).

Appendix 3: Prescribed life underwriting shocks under the Solvency II SF

The table A3 reports the European Commission Delegated Regulation (EU) 2015/35 for life underwriting shocks, calibrated to a 99.5% VaR over a one-year horizon in line with the Solvency II SF.

Table A3: Prescribed life underwriting shocks under the Solvency II SF

Submodule	Shock at 99.5%
Mortality	15.00%
Longevity	-25.00%
Disability / Morbidity	
Year 1	50.00%
Year 2+	25.00%
Lapse	
Up	50.00%
Down	-50.00%
Mass	40.00%
Expense	
Nominal	10.00%
Inflation	1.00%
Revision risk	3.00%
Life CAT	0.15%

Source: Adapted from European Commission (2015).

Appendix 4: Complete calculation results for the internal model and SF model

According to EIOPA report (2024), insurers would typically select confidence level between 70% and 85%, depending on the risk appetite. The results at higher percentiles shown in Table A4 and Table A5 are not intendent to represent practical reporting choices, but rather to illustrate the sensitivity of the RA to the selected confidence level and to highlight the tail behaviour of both models. The following appendix presents the numerical results of the RA under both the internal model and the Solvency II SF across multiple confidence levels. Table A4 and Table A5 provide a consistent breakdown of total RA, stand-alone components, diversification effects, and allocated contributions for each risk driver.

Table A4: Internal model RA results by confidence level

Confidence level	$PVFCF_0$	**FCFs**	RA^{IM}_{total}	RA^{IM}_{mort}	RA^{IM}_{lapse}	RA^{IM}_{exp}	$RA^{IM}_{sum\_sa}$	**Diversification**	$Alloc\ RA^{IM}_{mort}$	**Alloc** RA^{IM}_{lapse}	**Alloc** RA^{IM}_{exp}
75.0%	- 930,999	- 828,709	102,290	57,068	49,151	28,445	134,664	32,374	43,349	37,335	21,606
80.0%	- 930,999	- 812,973	118,026	68,235	58,547	36,243	163,026	45,000	49,401	42,387	26,239
85.0%	- 930,999	- 792,838	138,161	84,525	70,796	44,169	199,490	61,329	58,540	49,031	30,590
90.0%	- 930,999	- 770,395	160,604	105,139	85,262	55,329	245,729	85,125	68,717	55,725	36,162
99.5%	- 930,999	- 569,154	361,845	327,183	149,705	118,924	595,812	233,967	198,703	90,918	72,224

Source: Own work.

Table A5: Standard Formula RA results by confidence level

Confidence level	$PVFCF_0$	**FCFs**	RA^{SF}_{total}	RA^{SF}_{mort}	RA^{SF}_{lapse}	RA^{SF}_{exp}	$RA^{SF}_{sum\_sa}$	**Diversification**	$Alloc\ RA^{SF}_{mort}$	**Alloc** RA^{SF}_{lapse}	**Alloc** RA^{SF}_{exp}
75.0%	- 930,999	- 829,756	101,243	8,393	87,400	22,308	118,101	16,858	1,158	85,079	15,007
80.0%	- 930,999	- 804,669	126,330	10,468	109,057	27,836	147,361	21,031	1,444	106,161	18,725
85.0%	- 930,999	- 775,428	155,571	12,885	134,301	34,279	181,465	25,894	1,777	130,735	23,059
90.0%	- 930,999	- 738,637	192,362	15,922	166,063	42,386	224,371	32,009	2,195	161,655	28,512
99.5%	- 930,999	- 544,379	386,620	31,895	333,775	85,193	450,863	64,243	4,388	324,928	57,304

Source: Own work.