

**IAA Risk Book**  
**Chapter 13 - Asset Liability Management**  
**Techniques and Practices for Insurance Companies**  
**Charles Gilbert**

## **1. Executive Summary**

This chapter provides the reader with practical insights into ALM techniques and practices for insurance companies. Key messages include:

1. Insurance companies face various financial risks associated with assets backing liability cash flows. How these risks are managed vary by company and jurisdiction and are largely influenced by the regulatory environment.
2. Asset liability management (“ALM”) is a fundamental element of life insurer strategy and operations. It is also important to the operations of other types of insurers. The importance of ALM to insurers’ results from insurance being primarily a liability driven business with assets purchased to match<sup>1</sup>, in a risk efficient manner, the estimated insurance obligation cash flows, which may be uncertain for various reasons such as policyholder options.
3. Life insurance companies with long liability durations can be exposed to significant interest rate risk exposure. Inadequate ALM, ignoring the economic risk exposure and/or using only simple risk metrics such as duration has resulted in, and will continue to result in, insolvencies. For life insurance companies with long liability durations, it is important to understand the multiple dimensions of the interest rate risk exposure. P&C insurance companies with short liability durations have less exposure to interest rate risk and the focus is more on managing liquidity. P&C insurance companies with long-tailed liabilities can be exposed in a similar way to life companies.
4. One of the greatest challenges facing life insurance companies selling long duration contracts, and non-life companies with long-tailed liabilities, has been the prolonged

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<sup>1</sup> Note that it may not be necessary or even possible – as in the case of uncertain liability cash flows – to exactly match the asset and liability cash flows. ALM strategies oftentimes seek to match the sensitivity of the value of the assets to the value of the liabilities to changes in a given financial variable such as interest rates based on expected liability cash flows. It should be noted that on most long-tailed liabilities insurers can only match the expected cash flows. If and when the expectations change so the expected cash flows change this will result in the assets not being as well-matched as they were previously.

*This paper has been produced and approved by the Insurance Regulation Committee of the IAA  
on 24 October 2016*

extreme low interest rate environment<sup>2</sup>. Traditional guaranteed products with long durations have been difficult to immunize with available fixed income assets.

5. Many insurance company portfolios are suboptimal. There is an opportunity for insurance companies to improve the risk efficiency of their portfolios; in some cases, simultaneously increasing portfolio yield, increasing net income and adding positive convexity<sup>3</sup> to the portfolio while decreasing risk. Asset management approaches that manage assets separately against a benchmark rather than directly against the liabilities, or ignore the impact on capital requirements if they are risk-sensitive, do not support effective ALM.
6. Effective governance is a key part of ALM, one of the most vital functions related to many insurers' long term financial health. Effective governance provides a clear objective for the ALM function and ensures there is a framework in place for making decisions, the organizational structure supports effective ALM, there is accountability in respect of taking market views and that senior management and/or the board are aware of and fully understand the risk exposures and uncertainties, associated with the assets and liabilities.
7. ALM requires a variety of expertise and should be performed by professionals knowledgeable in the characteristics of both the assets and liabilities. Based on their expertise and knowledge of both, actuaries play key roles in ALM.

## 2. Introduction<sup>4</sup>

The aim of this chapter is provide the reader with practical insights into ALM techniques and practices for insurance companies. One of the first things a decision maker or risk professional comes to appreciate when first encountering ALM is that practices vary widely by company, by industry and by jurisdiction and that textbook theory does not provide the answers to many of the questions facing insurance companies implementing ALM.

Company culture, the nature of the liabilities as well as the regulatory and accounting regime all influence how the financial risks associated with the assets and liabilities are measured and managed. An important distinction must be made between ALM for property and casualty ("P&C") and life insurance companies. For life insurers with longer duration liabilities, while the scope of ALM includes all financial risks associated with the assets and liabilities, interest rate risk is often the focus of ALM. This has been mostly due to the fact that life insurer

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<sup>2</sup> The low interest rate environment is not as material a challenge for property/casualty insurers as witnessed by their continued profitability and satisfactory returns on equity. This is because their business model is not dependent on investment income – if investment return expectations are low then the price goes up accordingly. The low interest rate environment is only a risk to the extent that liabilities have longer tails than the available asset durations.

<sup>3</sup> See Appendix A for a definition of convexity and other technical terms.

<sup>4</sup> Definitions of various technical terms are provided in Appendix A.

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portfolios are often heavily weighted with fixed income securities because of the greater certainty in the asset cash flows.

P&C insurance companies, which generally have shorter term liabilities, have less exposure to interest rate risk and more exposure to catastrophes, mis-pricing and mis-estimating claim liabilities. For P&C insurers, ALM has historically tended to be very focused on maintaining a certain level of liquidity, given the uncertainty of the cash outflows (as to both amount and timing). With more long tail liabilities in jurisdictions such as the UK<sup>5</sup> and the advent of discounted liabilities and risk based capital requirements, ALM with a focus on interest rates is becoming more important in those jurisdictions.

## **I. Definition of ALM**

The Society of Actuaries ALM Principles Task Force provided the following definition for ALM.

*Asset Liability Management is the ongoing process of formulating, implementing, monitoring, and revising strategies related to assets and liabilities to achieve financial objectives, for a given set of risk tolerances and constraints<sup>6</sup>.*

While managing the risks associated with the assets and liabilities remains a key focus of ALM, the task force recognized that ALM had a more strategic role to achieve the financial objectives of an entity. This is in contrast to the view of ALM as solely a compliance exercise where the only goal is risk mitigation.

## **II. Relative Risk**

The risk exposure of an insurer is a function of the assets and the liabilities. ALM is less concerned with absolute risk than relative risk. Consider a highly volatile asset portfolio whose market value is subject to large swings. On a standalone basis, this portfolio may have a high absolute risk. However, if this portfolio is backing liabilities whose value changes by the same amount for a given change in a financial variable, then the relative risk associated with the assets and liabilities is what matters. This is the reason why an “asset-only” asset management approach for insurance portfolios is inappropriate. It is better to have a portfolio with a lower or even negative return on assets than a portfolio with a higher return on assets if in the former case the liabilities and possibly the capital requirements increased by less and in the latter case the liabilities and capital requirements increased by more.

One ALM strategy, which can be executed on many different bases, is immunization. The concept of immunization is to rebalance the asset portfolio as necessary so that the change in the value of the assets on some basis (economic, market value or book value) will be equal to the change in the liabilities within some tolerance level. Immunization is only possible for those

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<sup>5</sup> UK motor insurance exposes P&C insurers to the risk of Periodic Payment Orders – lifetime benefits for those permanently disabled as the result of an automobile accident.

<https://www.actuaries.org.uk/documents/periodic-payment-orders-revisited-paper>

<sup>6</sup> Principles Underlying Asset Liability Management © 2004 Society of Actuaries. All rights reserved.

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liabilities that are predictable and largely impacted only by the same financial variables that impact the assets.

### **III. Key Elements of ALM: Measurement and Management of Risk**

Two key elements of ALM include: 1) measurement of the risk exposure and 2) management of the risk exposure.

Measurement of the risk exposure can be done in a number of ways:

1. Calculating the sensitivity of the assets and liabilities<sup>7</sup> to changes in financial variables. This can be done using traditional ALM metrics such as duration and convexity, the greeks<sup>8</sup> or scenario testing.
2. Calculating the risk distribution of the assets and liabilities<sup>9</sup>. This is done using stochastic simulation and can be expressed using various measures such as value at risk (“VAR”) and conditional tail expectation (“CTE”).

In some jurisdictions where the capital requirements are risk-sensitive, the impact on the capital requirements would also be considered. This is not always intuitive as it may be that interest rate risk, or market risk, may diversify against the capital required to be held against other risks, and hence the aggregate capital required may be insensitive to increasing risk exposure until the diversification benefit is used up.

The above ways of measuring risk can be classified as either measuring the sensitivity to a change in financial variable at a point in time versus the sensitivity to a change in financial variable over time. For example, duration, convexity, delta, gamma and rho all measure the exposure to an immediate shock in the financial variable on the price of the underlying asset or present value of a series of cash flows and assumes that shock persists indefinitely into the future. Scenario testing and stochastic simulation can also look at future economic scenarios over time and test the impact under the ALM strategy or reinvestment assumption.

Monitoring of the risk can be performed intra-day, weekly, monthly or quarterly - often depending on how volatile the results are and the extent of surplus funds to absorb any mismatch. Measurement of the risk exposure and the impact of potential ALM strategies provides valuable decision support to an insurer.

Management of the risk exposure involves formulating and executing ALM strategies. Many companies use traditional ALM metrics such as duration and convexity to manage the risk exposure, set risk limits and rebalance the portfolio and then measure the resulting risk distribution using stochastic simulation.

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<sup>7</sup> This can refer to the market values, present value of cash flows or financial statement impact on reserves, net income, capital ratio, etc.

<sup>8</sup> See Appendix B for a description of the greeks.

<sup>9</sup> Note that calculating the risk distribution for some liabilities is problematic. E.g., no one yet has a reliable risk distribution for US asbestos liabilities.

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#### **IV. Influence of Regulatory Regime on ALM practice**

Supervisory and financial reporting trends that value all elements of the balance sheet independently may not sufficiently consider ALM exposures. Accounting rules have sometimes encouraged mismanagement of risk as a result of a disconnect between the accounting treatment and economic reality.

Many of the large losses and failures suffered by insurance companies with long duration liabilities could have been avoided by applying basic ALM techniques. Failures and near failures of life insurance companies as a result of asset liability mismatches continue today. Accounting rules<sup>10</sup> in some jurisdictions have encouraged mismanagement by ignoring the economic risk exposure and rewarding companies for taking mismatch risk. In countries where the reserve and capital requirements do not reflect the interest rate risk exposure associated with a mismatch of the asset and liability cash flows, and/or where there is a large disconnect between the exposure on an accounting basis and risk exposure on an economic basis, insurers have had less motivation to implement effective ALM.

#### **V. Unique Considerations and Challenges for Insurance Companies in a Low Interest Rate Environment**

ALM for life insurers can be complex due to the long term nature of some product guarantees (e.g. for the lifetime of insured/annuitant) extending beyond the term to maturity of available fixed income assets, the presence of optionality in either or both of the asset and liability cash flows (e.g. resets, ratchets in variable annuities with guarantees), the presence of adjustable features in some products (e.g. participating insurance with dividends) and the dependence on demographic assumptions which can undermine the matching as assumptions change.

One of the greatest challenges facing life insurance companies has been the prolonged extreme low interest rate environment<sup>11</sup>. Life insurers who were short asset duration were not able to earn the returns assumed in pricing of the liabilities. This has resulted in lower earned rates on insurer portfolios, decreased investment income, higher reserves, spread compression on products offering minimum credited rate guarantees and reduced ability to support dividend scales. Even those insurers who were immunized on a duration basis and within their board approved risk limits for the maximum allowable mismatch between the duration of assets and duration of liabilities found themselves offside as a result of their convexity exposure (see appendix); as interest rates declined, the duration of liabilities increased by a greater amount than the duration of assets. Many of these insurers started chasing yield, decreasing the credit quality

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<sup>10</sup> In the US, accounting rules played major role in savings and loan crisis in the 1980's and 1990's. Assets were valued at cost and reinvestment risk associated with short term deposits backed by longer term mortgages was ignored. When interest rates increased in the 1980s the earned rate on the longer term mortgages was less than the rate paid on short term deposits. This was exacerbated by severe disintermediation and weakening of the portfolios consisting of assets that were held at book values higher than their market value. US GAAP does not capture the interest rate risk exposure of life insurance companies and economic losses due to interest rates are not immediately revealed.

<sup>11</sup> The sustained low interest rate environment has not hurt most P&C companies without long tail business as they can adjust prices for new business for the change in interest rates.

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of their portfolios and increasing the allocation to riskier asset classes. The resulting pressure for higher yield has resulted in more risk being taken.

Traditional guaranteed products with long durations have been difficult to immunize with available fixed income assets. Many insurers have assets backing liabilities that have a shorter duration either because longer duration fixed income assets are not available or because they do not want to invest in long low yielding bonds and lock in losses. Insurers who have taken a market view on the direction of future interest rate changes and have not lengthened their assets to match the duration of the liabilities have essentially taken a bet that interest rates will not fall further in the medium to long term.

Life insurers are faced with the prospect of having to rebalance their portfolios to lengthen the duration of their assets by purchasing longer term bonds and locking in unattractive yields in a low rate environment. Because of a growing disconnect in Canada between the accounting and economic results, some Canadian insurers were further penalized with an increase in reserves if they immunized their portfolio on an economic basis.

There have been three main ways that insurers have sought to increase the yield on their portfolios.

1. Add credit spread<sup>12</sup>. This is achieved by decreasing the credit quality of the portfolio and taking on more credit risk exposure, and often aiming to capture the illiquidity premium where they are intending to hold assets to maturity.
2. Increase expected return. This is achieved by increasing the allocation to riskier assets classes such as equities, real estate and other non-fixed income assets.
3. Increase yield to maturity in an upward sloping term structure. This is achieved by selling shorter assets that have a lower yield to maturity and buying longer assets that have a higher yield to maturity. In some cases, for life insurance companies that had assets shorter than the liabilities to begin with, this increases yield and decreases the interest rate risk. Albeit the insurance company is giving up both the downside risk if rates fall as well as the upside gain if interest rate rise.

European insurers have looked to transfer risk to new policyholders in this low rate environment by replacing sales of traditional guaranteed products with unit linked products. This has principally been driven by recognition of the cost of guarantees in Solvency II (as well as earlier versions of Risk Based Capital (RBC) in countries like UK), although the risk-based capital approach of Solvency II has typically resulted in the increased asset risk increasing capital requirements. Low interest rates have served to emphasize those costs.

Life insurance products with minimum crediting rate guarantees represent an embedded option in the liabilities. As interest rates fell, spread compression or margin squeeze resulted from the portfolio earned rate falling below the crediting rate plus the required margin. Few insurance

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<sup>12</sup> Companies may use risk-adjusted yields but may for example seek to exploit the illiquidity premium.

companies outside of the UK hedged these guarantees explicitly using dynamic hedging or purchasing interest rate floors. Once interest rates fell, the guarantees became prohibitively expensive to hedge. If the hedging of the guarantee is managed explicitly, it may be possible for the liabilities to be immunized as if the cash flows were fixed. Otherwise insurance companies will look to immunize the effective duration and effective convexity that take into account the interest rate sensitivity of the cash flows.

It should also be noted that there are ALM issues associated with high interest rates due to hyperinflation such as seen in Venezuela or Brazil.

### **3. Objectives for the ALM Function**

At its most fundamental level, the goal of ALM is to manage the financial risk exposure associated with the assets backing liabilities. While this seems straightforward enough, several basic questions need to be answered before ALM can be properly performed. For example:

- What sources of financial risk should fall within the scope of ALM?
- Which risk exposure matters and which does not?
- On what basis should risk be measured and managed?
- What assets and what liabilities should be included and which, if any, should be excluded?
- At what aggregation level should ALM be performed?

Getting any of these basic questions wrong can have disastrous results for a financial institution, potentially doing more harm than not doing ALM at all.

Once the insurer has defined what risk will be managed, it needs to determine how this will be done. Before this question can be answered, the objectives for the ALM function need to be determined. In some insurance companies, ALM is viewed as a risk mitigation exercise primarily and the objective is simply to ensure all risk exposures are within the board approved risk limits. Other insurers have integrated ALM within their broader Enterprise Risk Management ("ERM") to be executed as a strategic decision-making framework to run the company by formulating, implementing and executing investment strategies related to the assets and liabilities that achieve the financial objectives and setting this up as an optimization program. The objectives for the ALM function will determine how asset management is performed. Other objectives for the ALM function may include

- Demonstrating to internal and external stakeholders that the company is being well managed
- Minimizing capital requirements, especially RBC
- Determining how much interest should be credited to policyholders

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- Determining impact on account items which have immediate impact on earnings (e.g. FAS97 DAC and shadow DAC calculations in the US)

One complication that arises in RBC regimes, such as Solvency II, is that interest-rate and market capital requirements interact with the capital arising from other risks when they are aggregated. Hence the ALM function needs to work closely with the team responsible for overall capital management. Another complication is the increasing need to look at the future liability and capital requirements in the ORSA, rather than simply looking at the current balance sheet.

## I. Strategic Use vs. Mitigation Only

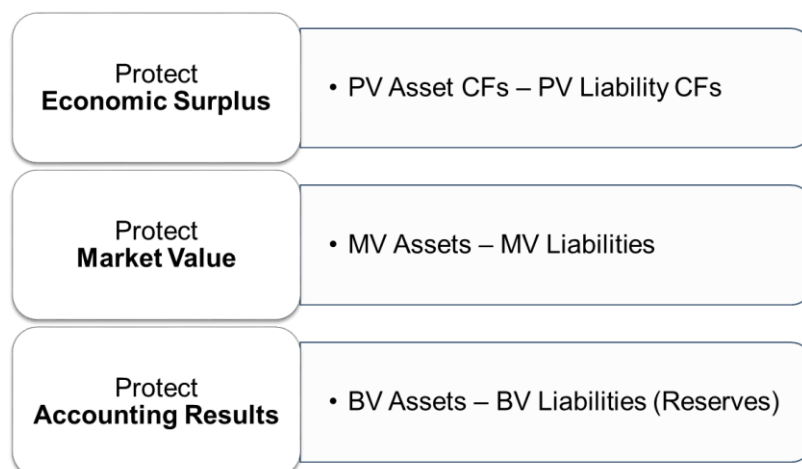
In practice, some insurance companies execute ALM as a risk mitigation exercise where the goal is simply to keep the risk exposure within the specified risk limits. For other insurance companies the goal is not to eliminate or minimize risk, the goal is to formulate ALM strategies to achieve the financial objectives subject to the risk tolerances and constraints.

The ALM definition presented in the previous section, contemplates that ALM will be executed as a strategic decision making framework to achieve financial objectives subject to risk tolerances and constraints.

## II. Economic vs. Accounting

The risk exposure can be measured on different bases. There is a wide range of practice within the insurance industry globally regarding the basis the risk should be managed on. One of the first steps in defining the ALM objectives is to determine what interest rate risk to manage. Is it the interest rate risk associated with the long term future cash flows, the market value of the assets and liabilities or the financial statement results? Figure 1 below lists these three objectives.

**Figure 1 - ALM Objectives<sup>13</sup>**



<sup>13</sup> It is possible for some companies to have other ALM objectives such as regulatory and/or economic capital.

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In general, it will not be possible to manage the risk exposure on all three bases perfectly. Insurance companies must choose on what basis the risk will be managed. Best practice is to measure the exposure on multiple bases and use this to inform decisions regarding risk / reward tradeoffs.

A challenge for insurance companies that can threaten solvency and the financial health of the company occurs when there is a disconnect between the economic and accounting or regulatory results. Many insurance company executives will say that they are focused on the long term economic value. However, they are reluctant to immunize the interest rate risk exposure on an economic basis (e.g. lengthening duration) when that creates losses on a financial statement basis. The accounting regime can encourage the whole industry to systematically take on interest rate risk.

The basis for managing interest rate risk will determine which yield curve<sup>14</sup> should be used for calculating present values of cash flows and the various ALM metrics such as duration, convexity etc.

One challenge facing insurance companies wishing to manage the economic risk exposure is that the very long term end of the yield curve may not be observable or be available for investment.

## **4. Scope**

### **I. Sources of Risk**

The scope of ALM varies from company to company. While historically, at least for the life insurance industry, ALM has been synonymous with interest rate risk management, there are many financial risks associated with the assets and liabilities including liquidity risk, credit risk, market risk, currency risk. For some insurers, the scope encompasses most if not all sources of financial risk associated with the assets backing the liabilities.

#### **A. Interest Rate Risk**

Interest rate risk manifests itself in many ways: market value risk associated with the market value of the assets, economic risk associated with the present value of the cash flows or accounting risk associated with the financial statement value of assets and liabilities. Ultimately the interest rate risk will be a function of the gains and/losses on reinvestment and disinvestment of the actual cash flows that are realized in future. This is what measuring the economic risk exposure by projecting best estimate cash flows and calculating economic surplus<sup>15</sup> seeks to capture. Best estimate cash flows may include investment expenses, expected asset defaults, margins for adverse deviations and future income taxes depending on various considerations<sup>16</sup>.

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<sup>14</sup> For example, government yield curve, swap curve, credit curve.

<sup>15</sup> Economic surplus or excess assets equals the difference between the present value of the asset cash flows and the present value of the liability cash flows.

<sup>16</sup> For example, whether the interest rate risk is managed on an accounting or economic basis, whether income taxes are paid from the corporate surplus account or the assets backing the liabilities, etc.

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Risk limits for interest rate risk can be expressed in terms of duration<sup>17</sup>, cash flow match analysis, and worst-case scenario testing.

As part of the ALM strategy for life insurance companies, the net dollar duration exposure may be managed at a total company level including surplus assets. Risk limits may include:

|                              |   |   |
|------------------------------|---|---|
| $DD_A - DD_L$                | < | X% of present value of assets                                     |
| Partial duration sensitivity | < | Y% of present value of assets at all points along the yield curve |
| Worst case scenario          | < | Z% of present value of assets                                     |

But even if a company were perfectly matched on both a first and second order basis, this would not be sufficient to protect against non-parallel shifts in interest rates<sup>18</sup>. It is possible for an insurance company to realize the same loss from a 7 basis point tilt in the yield curve (short rates up 7 basis points, long rates down 7 basis points) as from a 100 basis point decrease across the yield curve. Companies wishing to protect against non-parallel changes in the yield curve would immunize on a partial duration<sup>19</sup> basis. However, even being perfectly immunized on a partial duration basis would not be sufficient to protect against interest rate changes where there are embedded options in the assets or liabilities and/or other interest sensitive cash flows. Insurers wishing to protect against the interest rate risk associated with interest rate sensitive cash flows would either explicitly hedge the embedded option or immunize on an effective duration and effective convexity basis. Unfortunately, this too would not be sufficient to protect against all possible changes in interest rates. Other techniques including stochastic simulation, value at risk, economic capital and principal component analysis will measure the extent to which all the multiple dimensions of the interest rate risk exposure are effectively managed.

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<sup>17</sup> In North America, Dollar Duration is commonly used.

<sup>18</sup> If a company were perfectly matched on duration (i.e. first order) basis, this would only protect against small parallel shifts in the yield curve. If a company were perfectly matched on a convexity (i.e. second order) basis, this would protect against larger parallel shifts in the yield curve.

<sup>19</sup> Key rate duration, which measures the exposure to changes in the zero-coupon bond yields or spot rates rather than the changes in market yields, is a similar metric which is also used.

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**Figure 2 - Risk Metrics Measure Multiple Dimensions of Interest Rate Risk**

| Risk Metric                    | 1 <sup>st</sup> Order | 2 <sup>nd</sup> Order | Point in Time | Over Time | Embedded Options | Large Changes | Non-Level Shifts | Present Value | Market Value | Book Value | Earnings | Regulatory Capital | Economic Capital |
|--------------------------------|-----------------------|-----------------------|---------------|-----------|------------------|---------------|------------------|---------------|--------------|------------|----------|--------------------|------------------|
| Duration                       | ✓                     |                       | ✓             |           |                  |               |                  | ✓             | ?            |            |          |                    |                  |
| Effective Duration             | ✓                     |                       | ✓             |           | ✓                | ✓             |                  | ✓             | ?            |            |          |                    |                  |
| Dollar Duration                | ✓                     |                       | ✓             |           |                  |               |                  | ✓             | ?            |            |          |                    |                  |
| Partial Duration               | ✓                     |                       | ✓             |           |                  |               | ✓                | ✓             | ?            |            |          |                    |                  |
| Convexity (all)                |                       | ✓                     | ✓             |           | ✓                | ✓             |                  | ✓             | ?            |            |          |                    |                  |
| CALM C3                        | ✓                     | ✓                     |               | ✓         | ✓                | ✓             | ✓                |               |              | ✓          | ✓        |                    |                  |
| Deterministic Scenario Testing | ✓                     | ✓                     | ✓             | ✓         | ✓                | ✓             | ✓                | ✓             | ✓            | ✓          | ✓        | ✓                  |                  |
| Stochastic Modeling            | ✓                     | ✓                     | ✓             | ✓         | ✓                | ✓             | ✓                | ✓             | ✓            |            | ✓        | ✓                  | ✓                |
| Earnings at Risk               | ✓                     | ✓                     | ✓             | ✓         | ✓                | ✓             | ✓                |               |              |            | ✓        | ✓                  |                  |

## B. Liquidity Risk

Liquidity risk is the exposure to the illiquidity of the assets and liabilities. An insurance company could have no interest rate risk exposure if all the assets and liabilities were held to maturity but be exposed to loss in the event that illiquid assets needed to be sold to cover a demand liability or meet the mark-to-market cash flow requirements of a derivatives position.

Liquidity risk is managed by maintaining some level of liquid assets or cash so that liquidity risk exposure is not material or is tolerably low. This is commonly managed by the Treasury function.

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### C. Credit Risk

Credit risk is the exposure associated with the default of principal and/or coupon payments and/or the decrease in market value resulting from an increase in credit spread<sup>20</sup>. There are various approaches for taking into account the credit risk exposure in the asset cash flows. One approach is to adjust the cash flows for credit risk. If a best estimate is used for expected defaults however, the present value of the resulting risk adjusted cash flows discounted using a risk free interest rate curve will tend to be greater than the market value of the instrument. If the adjustment to the cash flows is solved for so that the resulting present value is equal to the market value, the cash flows will not reflect the actual expected asset cash flows. Another approach is to use an interest rate curve that reflects the credit spread for discounting. This will help ensure the present value of the cash flows equals the market value but ignores expected defaults in the cash flows. To the extent that the assets are matching liability cash flows, there is debate regarding how to adjust the cash flows for credit risk and take credit for the illiquidity premium.

The oversight of credit risk is sometimes a contentious issue for insurance companies. While the investment department has the expertise to analyze credit quality and credit risk exposure, a best practice is to have oversight of credit risk as part of the scope of ALM in order to ensure monitoring of the risk is independent from the area that is taking the risk.

### D. Market Risk

Market risk associated with equities and other non-fixed income asset classes – especially when these asset classes are backing insurance liabilities – includes not just the exposure to losses in market value but also the mismatch risk associated with backing insurance liabilities with non-fixed income assets. Market risk associated with variable annuity or segregated fund guarantees tends to be managed as part of an insurance company’s dynamic hedging program. In practice, these dynamic hedging programs tend to be separate functions and may or may not be considered part of the overall scope of ALM.

Variable products and associated dynamic hedging tend to be viewed separately and managed by a different team within an insurance company.

#### ***Non-Fixed Income Assets Backing Liabilities***

Many insurance companies in Canada back insurance liabilities with both fixed income and non-fixed income (“NFI”) assets. Backing insurance liabilities with NFI assets introduces mismatch risk arising from the market risk of the NFI assets and the interest rate risk associated with the liability cash flows. It can result in higher financial statement volatility or higher capital requirements, and reserves could be higher or lower. The expected return on NFI assets such as equities and real estate is generally thought to be higher than fixed income assets over the long

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<sup>20</sup> This latter item is a risk only if the asset would need to be liquidated before maturity. Credit risk is tied to liquidity risk and interest rate risk.

run. However, it is critical for insurance companies to explicitly measure their exposure including the effect on capital and have a strategy in place to appropriately manage this risk.

For any strategy involving NFI assets, accurate measurement of the interest rate risk exposure is complicated by the existence of NFI assets along with liability cash flows that may vary with interest rates and equity returns. The resulting exposure calculated is a function of the approximation methods and assumptions used. Companies need to take this into account when making ALM and trading decisions based on the duration of the assets and liabilities.

Some companies project cash flows for NFI assets corresponding to an assumed buy and hold strategy and will rebalance and immunize the portfolio based on the resulting interest rate sensitivity that is calculated for these assumed fixed cash flows. Some companies have modeled real estate and equities as 30 year strip bonds with a fixed equity risk premium when calculating duration. While the value of equities has some correlation to interest rates, assuming that equities have a duration other than zero can be misleading and can distort the duration results. Duration specifies the change in the price of an asset for a given change in interest rates. The change in the price of equities will not necessarily move in the direction predicted using duration.

Another practice is to assume NFI assets have no interest rate sensitivity (i.e. duration of zero), model the cash flows as cash and perform sensitivity analysis for various combinations of interest rate and equity return scenarios.

A third approach is to project the NFI assets and liability cash flows using a stochastic model that generates economic scenarios for all financial variables under question (e.g. yield curve, credit spreads, equity returns, real estate gains, etc.), and analyze the resulting risk distribution.

In contrast to notionally backing long term liability cash flows with NFI assets, many life insurance companies in Canada explicitly carve-out the long term liability cash flows after a certain number of years and back these with real estate and equity assets. An immunization or other matching strategy is typically used for the shorter term cash flows using fixed income securities.

### ***Carve-out Strategy***

A carve-out strategy whereby the long term liability cash flows after a certain number of years are carved out and backed with NFI assets will enable an insurer to explicitly measure and manage the risk exposure associated with using NFI assets to back insurance liabilities, and will enable the insurer to assess whether the company is comfortable with the associated mismatch and market risk to ultimately meet the future insurance obligations<sup>21</sup>.

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<sup>21</sup> This can be done using deterministic scenario testing or by performing a stochastic analysis for the NFIs backing the carved out liabilities, projecting both NFI returns and interest rates under a large number of future return and interest rate scenarios. A shortfall measure can be used to determine the amount of NFI assets that would be required to meet carved-out liability cash flows under a variety scenarios, and to measure the likelihood and severity of a shortfall. In addition to the ultimate risk of shortfall, companies need to also assess the volatility of the projected economic surplus for the carved out assets and liabilities over key projection horizons, such as one and five years.

The first step in a carve-out strategy is to determine the carve-out point and/or amount of NFI assets. In general, one of the following methods is used:

In the first method, the carve-out point is determined first, immunization is performed up to the carve-out point, and then the remaining amount of assets is invested in non-fixed income securities.

In the second method, the amount of equities or other NFI assets is determined first (either as a dollar amount or percentage of assets), the carve-out point is then determined based on how many years of cash flows the fixed income and NFI assets can support, respectively; and finally immunization is performed up to the carve-out point.

The amount of NFI assets backing insurance liabilities varies from company to company based on many factors including impact on reserves and capital ratio, potential earnings volatility, and overall comfort with the amount of equity and interest rate risk being assumed. Once the desired amount of NFI assets is determined, some companies use a stochastic approach to determine the confidence level at which the current amount of NFI assets will be sufficient to provide for the present value of the long term cash flows after the carve-out point.

In the first method described above, the carve-out point is typically determined by looking at the latest date where all of the liability cash flows up to that point can be effectively immunized using available fixed income assets. The remaining assets in the segment are then invested in NFI assets.

In the second method described above, the carve-out point is solved for based on the liability cash flows that can be immunized with the remaining amount invested in fixed income assets.

It is typical for the carve-out point determined above to be in the range of 30 to 45 years, depending on the amount of NFI assets and the liability cash flow profile.

Companies using carve-out strategies can perform stochastic analysis to assess the sufficiency of its NFI assets to meet the long term liability cash flows, as well as the ongoing risk associated with its allocation to NFI across various scenarios.

### ***Variable Annuities and Segregated Funds***

Risks associated with guaranteed minimum benefits provided by variable annuities and segregated funds are oftentimes managed using dynamic hedging programs. The aim of dynamic hedging is to rebalance the hedge portfolio so that the sensitivity of the embedded options in the liabilities to changes in financial variables such as 1) underlying stock price, 2) implied volatility surface and 3) term structure of interest rates are matched by the sensitivity in the hedge portfolio. This is done using price sensitivity metrics similar to those related to those used in ALM related to interest rates called greeks. See Appendix B for a definition of the greeks.

#### **E. Currency Risk**

Currency risk associated with backing liabilities with assets in a different currency has usually been avoided. It generally is not possible to “completely” hedge this risk unless the liability

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duration is short. Increasingly in the search for yield insurers do this and do hedge the foreign exchange rate risk as far as possible.

## 5. Governance and Framework

Governance is a vital part of effective ALM. Best practices with respect to ALM governance start with the organizational structure:

- The board and senior management demonstrate a strong commitment to ALM, are involved and actively promote risk management culture.
- The ALM Committee has a senior composition and is a forum for strategic decision making.
- The person responsible for ALM has the necessary professional expertise.
- There is an adequate level of resources and well-trained professionals dedicated to the ALM function.
- Roles and responsibilities are well-defined with clear accountability for the ALM function.
- The ALM policy statement and procedures are well documented and approved by the Board.
- Measurement and monitoring of exposure; reports clearly communicate the risk profile that supports decision making.
- Risk is consolidated at total company level and understood by board and senior management.

### I. Board of Directors

The board of directors is ultimately responsible for the risk management of an insurance company and ensures that key elements required for effective governance are in place including an organization structure that supports the execution of ALM, a senior level ALM Committee with a board approved mandate, a board approved ALM Policy with clearly defined roles and responsibility, risk limits and ALM Conceptual Framework. The board should also be satisfied that there is a strategic decision making framework in place for ALM and accountability for any management decisions to take market views or interest rate bets.

For life insurance companies where ALM issues are material, boards of directors and other decision-makers of insurance companies need to be well educated on ALM. Simplistic yet popular duration-matching strategies are not enough to protect and insurance companies writing long duration contracts from the multiple dimensions of the interest rate risk exposure they face. As interest rates have fallen, such insurance companies who may have been perfectly duration matched found themselves offside their risk limits because they had large convexity<sup>22</sup> exposure.

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<sup>22</sup> See Appendix A for a definition of convexity and other technical terms.

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Other life insurers who thought they did not have interest rate risk found themselves having to explain to equity analysts why they had such a loss due to interest rate when rates barely moved. The role of ALM is more important than ever in these conditions to provide effective decision support.

## **II. ALM Policy**

The ALM Policy that is reviewed and approved annually by the board is an important governance tool for the Board.

### **A. ALM Conceptual Framework**

This forms part of strong governance for the ALM function. Insurance companies who try to execute ALM without having a formal framework in place lack a proper decision making framework to manage the risk exposure and may position the company in an unintended direction.

Financial objectives, risk tolerances and constraints define the conceptual framework for ALM. This is part of a strategic decision making framework in which ALM serves as a tool to achieve the organization's financial objectives subject to its risk tolerances and constraints.

### **Financial Objectives**

Within an ALM framework, the financial objectives that are specified determine how risk is defined for the organization. Some examples of financial objectives include maximizing shareholder wealth, economic value, embedded value, earnings, Risk Adjusted Return on Capital ("RAROC"), Return on Equity ("ROE"), future earnings, etc. One of the key considerations in selecting the appropriate financial objectives is the balance between economic and accounting results (both regulatory accounting and shareholder accounting). Focusing on economic reality (i.e. the actual cash flows) ensures that the organization will ultimately realize superior earnings in future (on any basis). This tends to be a long term focus. Focusing on accounting results on the other hand tends to have a short term focus. However, these are the results that get reported to shareholders, policyholders, rating agencies, analysts, and regulators. Arguments against focusing on the long term economic results include

- Future long term economic earnings may not be realized due to forced actions caused by violating regulatory or rating agency constraints.
- Economic results depend on future projections that may not be reliable; economic valuations may be more susceptible to speculative assumptions than accounting valuations.
- Long term interest rates used to discount long term liability cash flows may not be observable.

Arguments against focusing on the accounting results include

- Short term focus.

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- Accounting treatment and emergence of earnings may mask interest rate and other financial risks.
- Changes to accounting rules may give a very different financial picture and risk exposure.
- Focusing on accounting results can run counter to capital objectives in some regimes.

ALM strategies are formulated to achieve the financial objectives that are specified. It is possible to have more than one financial objective. A risk adjusted measure would ensure the financial objectives are defined relative to the amount of risk assumed.

## **Risk Tolerances**

Financial institutions such as insurance companies are in the business of assuming risks. In general, only those risks that help the company achieve its financial objectives and for which the company is fairly compensated should be assumed (e.g. if the risk profile is desirable). All other risks should be eliminated or minimized to the extent possible.

Risk for the insurer is the exposure of its stated financial objectives to changes in financial or other variables. For example, interest rate risk for a company whose financial objective is to maximize economic value is the exposure of that economic value to a change in interest rates. This is also the case when the financial objectives are based on accounting measures, except that the economic impact of a change in a financial variable may be masked or altered by the accounting rules.

The company's risk tolerance is used to establish specific risk limits for each material financial variable. These risk limits should be defined in terms of appropriate risk metrics and analyses that properly capture the true risk exposure on the desired basis (i.e. economic or accounting).

There may be times when an insurer may find itself in breach of these limits, for example, if the cost of eliminating or minimizing an existing risk is too great (e.g. locking in a loss, hedging when implied volatility is trading high, etc.) compared to the risk exposure.

## **Constraints**

In addition to an insurer's risk tolerances, there may be a number of internal or external constraints that must be considered (e.g. minimum capital ratio, maximum volatility of earnings, various investment guidelines, debt covenants<sup>23</sup>, etc.)

## **Surplus Management Philosophy**

Depending on the ALM objectives, not all assets and liabilities will be included in managing the interest rate risk and/or will be treated differently. In some cases only general account assets and liabilities are included for purposes of ALM. Separate account assets and liabilities such as

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<sup>23</sup> Debt covenants may be triggered by regulatory accounting results that are not severe enough to cause regulator action.

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segregated fund and variable annuities are managed separately<sup>24</sup> and have separate hedging programs. Some insurance companies include all assets backing interest bearing liabilities only. Aside from these two decisions, insurance companies must decide whether the interest rate risk that will be managed is

1. the interest rate risk associated with only the assets backing the liabilities,
2. the total interest rate risk that the company is exposed to including all the assets, i.e. including surplus assets, and /or
3. the interest rate risk associated with the capital requirements.

Many insurance companies manage the interest rate risk associated with the assets backing liabilities only and manage surplus on a total return basis. I.e. any interest rate risk exposure associated with the surplus assets is ignored. A key question for ALM for P&C and other insurers is the treatment of net assets (i.e. surplus) as final cash payments will be higher or lower than the estimate and new / renewal business may lead to payments higher than premium income for some period. Some insurers do not segment their assets and have one asset portfolio. In this case, the interest rate risk associated with fixed income assets relative to the liabilities is managed. Other objectives/metrics are used to manage NFI assets.

There are two ALM issues that arise in practice that relate to the surplus management philosophy of the company: 1) how to treat excess assets<sup>25</sup>, and 2) what to do with margins for adverse deviations that are included in the projected liability cash flows for valuation purposes.

Some companies implement ALM by requiring that the book value of assets equal the book value of liabilities in each segment (and do not allocate required surplus to the lines of business). In this case, the present value of the asset cash flows will generally be greater than the present value of the liability cash flows<sup>26</sup>. These excess assets in the line of business represent economic surplus. If the strategy is to match the modified duration of the assets and liabilities, the economic surplus in the line will be exposed to changes in interest rates<sup>27</sup>. On the other hand, if the strategy is to match the dollar duration of the assets and liabilities, the present value of the assets and liabilities will change by the same absolute amount for a given change in interest rates and the economic surplus will be immunized. This approach has been described as equivalent to

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<sup>24</sup> Segregated funds and variable annuities are not always managed separately. Some insurers have internal hedging arrangements to reduce external hedging costs.

<sup>25</sup> Excess assets or economic surplus equals the difference between the present value of the asset cash flows and the present value of the liability cash flows. Or could be net of capital requirements

<sup>26</sup> This is because the interest rate risk provision and the Provisions for Adverse Deviations ("PfADs") under CALM are non-cash flow items.

<sup>27</sup> This is because the present value of the assets and liabilities will change by the same percentage amount when their (modified or Macaulay) durations are the same. Since the present value of the assets is greater than the liabilities, the assets will experience a greater change in absolute terms.

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immunizing the present value of assets that are equal to the liabilities and investing the excess assets (or economic surplus) in cash (i.e. with a duration of 0)<sup>28</sup>.

As an example, in the same way that European companies would be required to hold more capital for an interest rate mismatch, Canadian life insurance companies are penalized under the Canadian Asset Liability Method (“CALM”) if they do not match asset and liability cash flows with Margins for Adverse Deviations (“MfADs”) included because the interest rate risk provision required under CALM is calculated with MfADs included in the cash flows.

An argument that has been put forth by some practitioners that matching with MfADs in the cash flows ensures smoother emergence of earnings. This argument asserts that to the extent that the release of MfADs represents the emergence of earnings, including the MfADs in the cash flows immunizes future earnings. This argument treats MfADs as if they were a real cash flow item and actually increases the company’s exposure to interest rate changes.

The surplus management philosophy becomes an important driver of how interest rate risk will be managed. Appendix C provides an example illustrating this.

#### **B. Organization Structure**

Within an insurance company, where ALM resides is often a function of the organizational structure, the expertise of personnel and what area within the company they work. It is not uncommon for the ALM function to reside within Actuarial, Investments, Finance or to report to the Chief Risk Officer.

#### **C. ALM Committee**

Some insurers have a formal, board approved, ALM Committee Mandate that sets out the terms of reference for the ALM Committee, which in many cases includes oversight for the risks associated with the assets and liabilities.

#### **D. Roles and Responsibilities**

A best practice for insurers is having clearly defined roles and responsibilities in respect of ALM.

#### **E. Asset Management within an ALM Framework**

It is not uncommon within insurance companies for internal conflicts to arise between the execution of ALM and asset management when assets are managed separately and the portfolio manager’s performance is measured against a benchmark. Executing an ALM strategy to achieve the financial objectives or performing a risk optimization will be met with resistance and the role of the asset manager versus ALM will be called into question. Many life insurance company CEOs have been dissatisfied that although the company has bright investment managers who achieve the investment objectives, beat the benchmark, and stay within the risk

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<sup>28</sup> Because of the shape of the yield curve, investing the assets in a lower average duration may result in a higher yield since the YTM of a 30 year bond is lower than the YTM of a 25 year bond, for example.

limits and constraints; they destroy value against the company's financial objective (e.g. the resulting increase in actuarial reserves was greater than the increase in investment income).

There are two general approaches used in the insurance industry to manage insurance company assets. One approach is to manage the assets separately against a benchmark within specified risk limits to achieve a specified investment objective. In the other approach, asset management is executed within an ALM framework. ALM drives the investment process. The assets are managed directly against the liability cash flows rather than a benchmark in such a way as to achieve the financial objectives rather than the investment objectives. For some companies, especially P&C, the ALM process may also include liquidity targets (both for the simplistic approaches and the more sophisticated approaches).

## **6. Measurement of Risk Exposures**

### **I. Risk Metrics**

ALM metrics for longer duration portfolios include various duration and convexity measures that capture the first and second order sensitivity of the present value of the asset and liability cash flows to changes in the level of interest rates, the shape of the term structure of rates and the corresponding change in the cash flows to changes in interest rates. These metrics may or may not correspond to the interest rates risk exposure the financial institution wishes to manage. Appendix A provides a description of various risk metrics used in ALM.

### **II. Scenario Testing**

In addition to risk metrics, deterministic scenarios are used to measure the impact of either 1) an instantaneous shock to the yield curve or other financial variable, or 2) a change in interest rates or other financial variable over time - along with the impact of other aspects of the scenario and in particular their capital impacts.

### **III. Stochastic Analysis**

Stochastic simulation is used to generate a risk distribution for the assets, liabilities, and capital requirements using stochastically generated scenarios for interest rates, equity returns and other financial variables.

### **IV. Decision Support**

ALM is a powerful tool to help run an insurance company. Beyond risk mitigation, ALM can provide valuable decision support to help insurers determine whether they are taking an appropriate amount of risk and whether they are sufficiently compensated for the risk they are taking. Ensuring that the portfolio is risk efficient is the first step. A portfolio is said to be risk efficient if the financial objective is maximized for the level of risk taken. The next step is to assess whether the level of risk is appropriate. The amount of risk taken needs to be consistent with the insurer's risk appetite. Taking too little risk may be inconsistent with the risk capacity and risk strategy of the company.

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It is important for an insurer to know how much a particular ALM strategy and/or risk limits are costing. A horizon matching strategy whereby cash flows are matched for the first 10 or 15 years may be taking on more risk and giving up more yield than an immunization strategy that is less constrained.

But even if a risk is within an insurer's risk appetite, it may not be advisable if the insurer is not being compensated for the amount of risk taken. ALM can quantify how much additional income / value can be added for some measure of additional risk.

Insurance companies have a choice in how they implement ALM. ALM can be implemented primarily as a risk mitigation function. Alternatively, ALM can be executed as part of a strategic decision making framework by formulating ALM strategies to control risk and achieve the company's financial objectives.

**Figure 3 - ALM Executed As Part of a Strategic Decision Making Framework**



## 7. Execution of ALM Strategies

Most ALM strategies will involve rebalancing of the asset and/or hedge portfolio as needed. Rebalancing can be performed as frequently as daily in real time or as infrequently as monthly or quarterly. The objective of periodic rebalancing is to ensure that the risk exposure associated with the assets backing the liabilities is kept within some target or risk limit. There are transaction costs associated with buying and selling assets which are sometimes taken into account when deciding how frequently to rebalance the portfolio. Hedging costs are also a function of rebalancing. Delta hedging, for example, is a buy high sell low strategy whose cost stems from the realized volatility and frequency of rebalancing. In periods of illiquidity, it may be difficult or expensive to rebalance as required. The accounting and tax treatment of realized gains and losses oftentimes influences rebalancing decisions.

### I. Segmentation

Portfolio segmentation is used to explicitly back a block or segment of liabilities with certain assets. This can be helpful for profitability measurement and pricing. As noted above, not all P&C insurers have multiple segments.

Segmentation is suboptimal from an ALM perspective. In the early days of ALM implementation many North American life insurance companies started by immunizing certain

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lines of business separately. While they increased in sophistication and succeeded in reducing the interest rate risk exposure on those lines of business they actually increased the interest rate risk for the company overall as the interest rate risk exposure that was eliminated was offsetting interest rate risk of another line of business. A best practice is to aggregate risk exposures and manage at a total company or group level.

## **II. Dedication and Horizon Matching**

Dedication and horizon matching are both forms of cash flow matching strategies. Insurance companies project the liability cash flows and, usually working backwards, find bonds with maturity and coupon payments to match the projected liability cash flows. Complete cash flow matching is not possible for portfolios with long duration liabilities. Some insurance companies will match cash flows within some tolerance level over some shorter term horizon period such as 5 or 10 years.

## **III. Immunization**

For life insurance companies, the concept of ALM has been around since the 1950's when Frank Redington wrote his seminal paper on immunization theory. The basic principle was that if what insurance companies were most interested in was protecting economic surplus, then it was not necessary to exactly match the asset and liability cash flows. For P&C companies in the US there was no concern with interest risk until the late 1970s, when rates increased drastically after a long period of relative stability. Many insurers before then had longer asset durations than liability durations to take advantage of higher yields.

## **IV. Portfolio Replication**

A replicating portfolio is a portfolio of capital market instruments that seeks to replicate either the cash flows or market value of the liabilities for a given set of stochastic scenarios. Instead of re-running an insurer's actuarial models to project the liability cash flows, the replicating portfolio is used as a proxy to predict the change in the value of insurance liabilities under different economic conditions. The goal is for the replicating portfolio to equal the value the liabilities would have under a wide range of economic conditions. If close replication is achieved, then an estimate for liabilities can be calculated more quickly under changing market conditions, stress testing or other deterministic scenarios. The behavior of insurance liabilities will be easier to understand by investment managers and the insurer will avoid the need to re-run actuarial models and dramatically improve the speed of calculations.

## **V. Carve Out Strategy**

The extent to which mismatch risk can be mitigated depends on the available assets as well as the reliability and accuracy of the projected future liability cash flows. Increasingly, following the quest for yield, insurers are using alternative non-fixed income assets<sup>29</sup> to increase the

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<sup>29</sup> This is not the case for P&C insurers in the US, as equity investments are usually restricted to a fraction of the insurer's equity. Use of equities may be a function of the available asset markets in the subject currency. Equity investments are more common in the US P&C market for mutuals and others without ready access to capital markets – hence not because of the liabilities.

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expected return of the assets backing the liabilities. A robust ALM framework will allow companies to understand how best to reach their financial objectives and maintain portfolio risks within set limits given the assets available.

## **VI. Interest Rate Swap Overlay**

Interest rate swaps are an effective tool to execute ALM strategies and facilitate risk optimization of a portfolio. An interest rate swap overlay can be used to adjust the interest rate risk exposure and extend the duration beyond what could be achieved using cash assets.

## **VII. Reinsurance**

Reinsurance is used by some insurers to manage the risks associated with both the liabilities and the corresponding assets.

## **VIII. Taking Market Views**

Many insurers have made a management decision not to lengthen an asset portfolio that has a duration shorter than the duration of the liabilities. One reason is that the insurer is taking a view on the market and does not want to lock in rates in a low interest rate environment. In some cases companies have taken large interest rate bets with no accountability surrounding the decision. One best practice is to measure the gains or losses that result over time from taking any market view / interest rate bet and report this at each ALM Committee meeting.

## **IX. Risk Optimization**

Many insurance company portfolios may be risk inefficient. Financial objectives are not maximized for the amount of risk being taken. In some cases financial objectives are not well defined. As a result it is not clear what risk should be managed.

A portfolio is risk efficient if the financial objective is maximized for a given level of risk and set of constraints.

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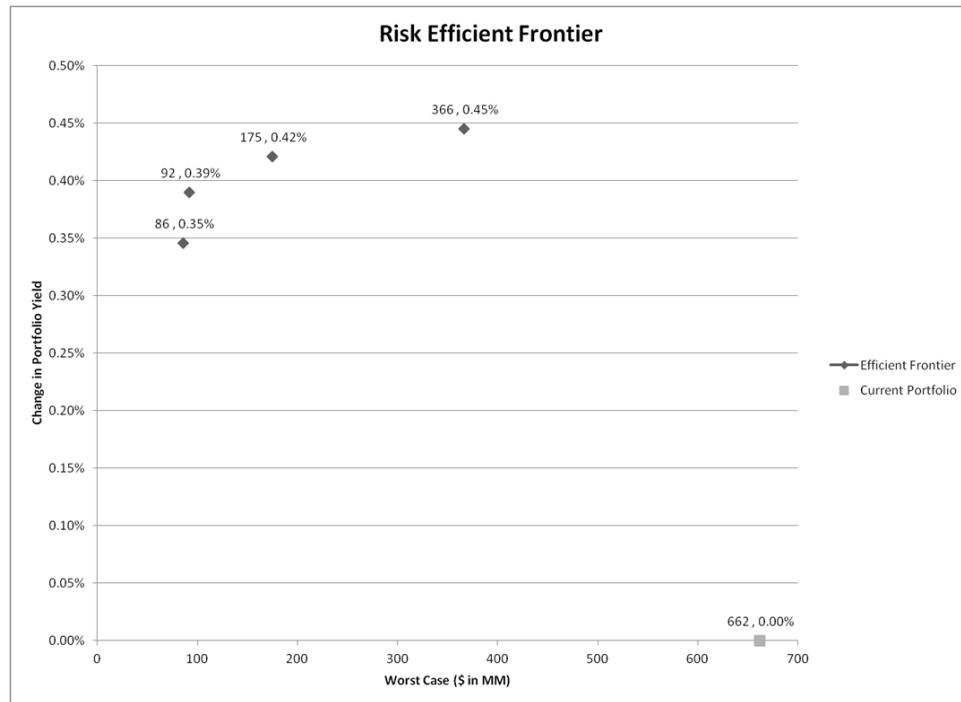
**Figure 4 - Three Ways to Optimize a Portfolio Include**

| Optimization Basis | Object          | Value Added  |
|--------------------|-----------------|--|
| Asset Mix          | Expected Return | <ul style="list-style-type: none"><li>• Actual return not necessarily maximized</li><li>• High dependency on assumptions</li><li>• Mismatch risk</li></ul>       |
| Credit Spreads     | Portfolio Yield | <ul style="list-style-type: none"><li>• Credit risk premia front ended</li><li>• No free lunch – higher credit risk taken in order to get higher yield</li></ul> |
| Yield Curve        | Portfolio Yield | <ul style="list-style-type: none"><li>• Yield maximized on default-free basis</li><li>• Real value added</li></ul>   |

Figure 5 below illustrates the risk efficiency frontier of an insurance company. The frontier measures the increase in portfolio yield above the current portfolio for various levels of risk. Risk can be measured using CTE, VAR, worst case loss, etc. The current portfolio is shown in the gray box.

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**Figure 5 - Risk Efficiency Frontier**



In the example above the insurer can decrease risk (in this case the worst case scenario) from 662 million to 366 million and increase portfolio yield by 45 basis points. This is accomplished by buying and selling government bonds. Alternatively, an interest rate swap can be used. In either case, the rebalancing is done on a credit neutral basis.

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## Appendix A – Interest Rate Risk Metrics and Analytics

This section defines risk metrics and analytics used in measuring the exposure to interest rate risk.

**Macaulay Duration** is the time weighted present value of cash flows divided by the present value of the cash flows. Macaulay Duration gives an indication of the interest rate sensitivity of the present value of a future stream of cash flows but is rarely used in practice.

**Modified Duration** provides a provides a measure of the interest rate sensitivity in percentage terms of the present value of a series of fixed cash flows assuming a level term structure for a parallel change in interest rates. For example, if the Modified Duration of an asset is 10, then for a 1 basis point increase in interest rates the market value of the asset will decline by approximately 0.1%. Modified Duration can be calculated by dividing Macaulay Duration by  $1 + i^{(n)} / n$ , where  $n$  is the compounding frequency.

**Effective Duration** provides a measure of the interest rate sensitivity in percentage terms of the present value of a series of interest rate sensitive cash flows assuming a parallel shift in the yield curve. Effective Duration can be calculated by shocking the yield curve up and down by some change in interest rates, projecting the cash flows under the shocked yield curves and using a central difference approximation.

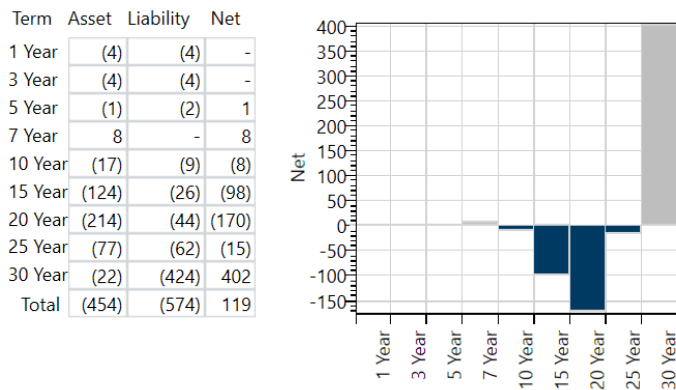
**Dollar Duration** provides a measure of the interest rate sensitivity in dollar terms of the present value of cash flows for a parallel change in interest rates. For example, if the dollar duration of assets is \$100,000,000 greater than the dollar duration of liabilities, then for a 1 basis point increase in interest rates for all terms to maturity across the yield curve, the present value of assets will decrease by approximately \$10,000 more than the present value of liabilities.

**Partial Duration** provides a measure of the interest rate sensitivity in percentage terms of the present value of a series of fixed cash flows for a change in the yield for a given term to maturity. Partial Duration can be calculated by partitioning the yield curve by term to maturity and for each term to maturity shocking the yield to maturity up and down, linearly interpolating to the next term to maturity and the prior term to maturity.

The partial duration sensitivity analysis shown in figure 6 below measures the impact on economic surplus for a 1 basis point change in interest rates at each term to maturity along the term structure. This is a valuable tool as interest rates seldom move in a parallel fashion.

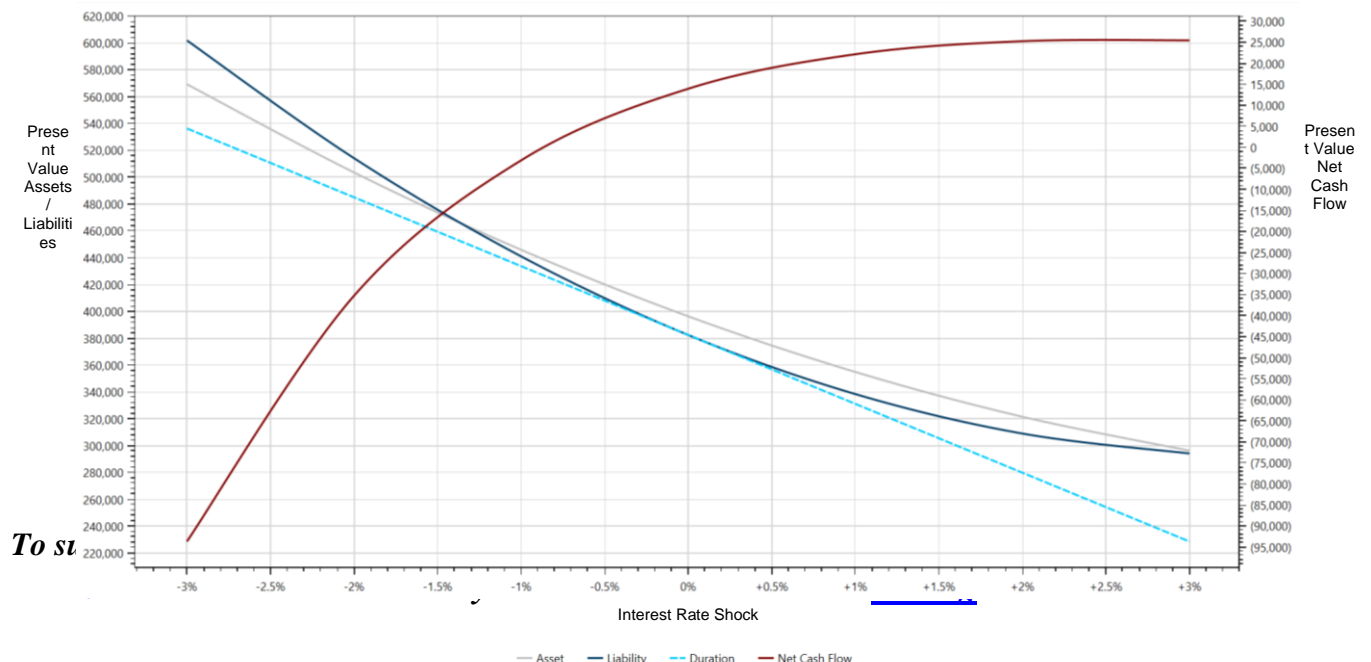
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**Figure 6 - Partial Duration Sensitivity Analysis**



**Convexity** measures the rate of change of duration. Duration only provides an approximation of the price sensitivity to changes in interest rates. The precision of the approximation deteriorates as the change in interest rates increases. Including convexity improves the approximation. In general, assets with greater convexity are more desirable than assets with less convexity. This is because as interest rates decrease the increase in the market value of the assets increase at a faster rate. Conversely, as interest rates increase the decrease in the market value of the assets decreases. It is therefore desirable to have assets that have higher convexity than the liabilities. Convexity is a second-order sensitivity measure to changes in interest rates. It is the rate of change in duration for a change in interest rates. In general, duration provides a good first-order approximation to a small parallel shift in the yield curve. As the change in interest rates increases, duration will understate the increase in present value of cash flows as rates decrease and overstate the decrease in present value of cash flows as rates increase. Positive convexity results in a higher present value of cash flows than duration alone would predict for an increase or decrease in rates. Negative convexity results in a lower present value of cash flows than duration alone would predict for an increase or decrease in rates.

**Figure 7 - Convexity Exposure**



**Scenario testing** involves measuring the sensitivity of economic surplus to both parallel and non-parallel yield curve shifts both at a point in time and out into the future. Deterministic scenario testing is a valuable tool to analyze “what if” type scenarios.

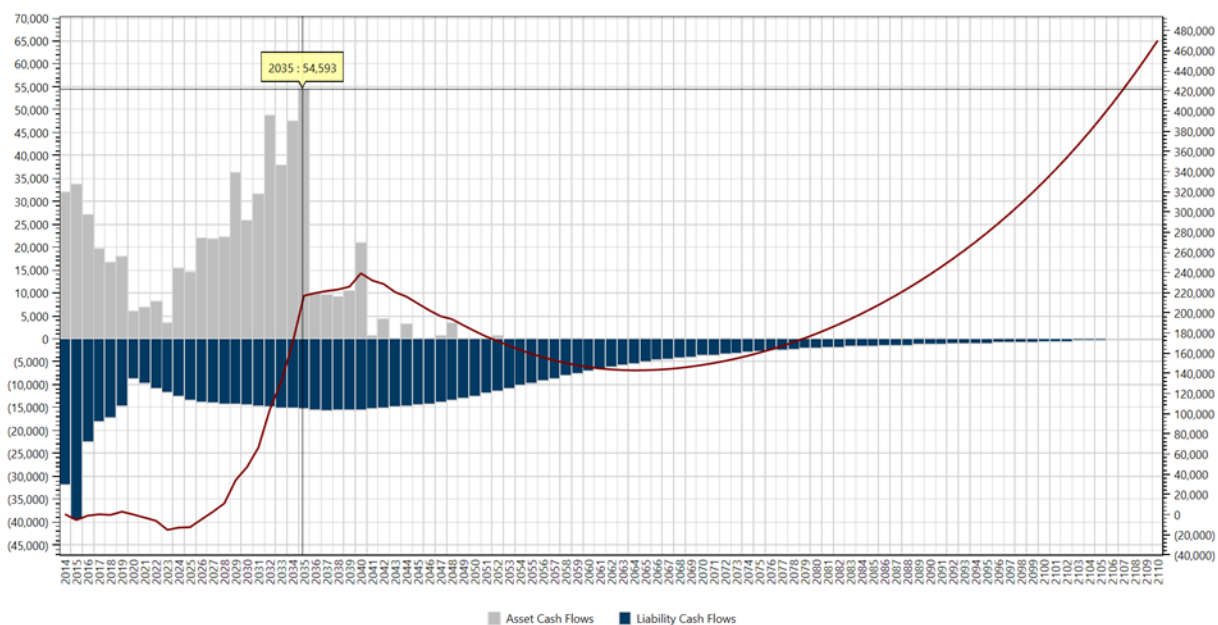
**Figure 8 - Deterministic Scenario Testing**

| Change in PVCF              | Assets   | Liabilities | Net     |
|-----------------------------|----------|-------------|---------|
| Parallel Shift + 50 bps     | (21,732) | (23,815)    | 2,083   |
| Parallel Shift - 50 bps     | 23,753   | 27,458      | (3,705) |
| Flattening to 15Y rate      | 2,402    | 3,571       | (1,170) |
| Flattening (short + 50 bps) | (7,773)  | (2,557)     | (5,216) |
| Steepening (short - 50 bps) | 8,144    | 2,665       | 5,480   |
| Steepening (long + 50 bps)  | (14,423) | (21,590)    | 7,167   |
| Inversion (+ 100 / - 50)    | 15,187   | 23,948      | (8,761) |
| Steepening (- 50 / + 50)    | (14,884) | (21,495)    | 6,611   |

**Cash flow analysis** examines how well matched the asset and liability cash flows are and provides insight into the liquidity exposure.

Net cumulative cash flows can also be studied after reinvestment under different interest scenarios.

**Figure 9 – net cash flow**



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## Appendix B – The Greeks

The greeks are price sensitivity metrics similar to those related to those used in ALM related to interest rates.

| Bonds             |  | Options       |   |
|-------------------|--|---------------|---|
| <b>Duration:</b>  | $\frac{\Delta \text{ Bond Price}}{\Delta \text{ Interest Rate}}$ | <b>Delta:</b> | $\frac{\Delta \text{ Option Price}}{\Delta \text{ Underlying}}$ |
| <b>Convexity:</b> | $\frac{\Delta \text{ Duration}}{\Delta \text{ Interest Rate}}$   | <b>Gamma:</b> | $\frac{\Delta \text{ Delta}}{\Delta \text{ Underlying}}$        |
|                   |  | <b>Vega:</b>  | $\frac{\Delta \text{ Option Price}}{\Delta \text{ Volatility}}$ |

|              | Greeks Measure Sensitivity With Respect To |                |                    |                    |
|--------------|--|----------------|--------------------|--------------------|
|              | Spot Price (S)                             | Volatility (v) | Risk Free Rate (r) | Time to Expiry (t) |
| First Order  | Delta                                      | Vega           | Rho                | Theta              |
| Second Order | Gamma                                      | Vomma          | Rho Convexity      |                    |
| Third Order  | Speed                                      | Ultima         |                    |                    |

|       | Second Order And Cross Greeks |                     |                    |                      |
|-------|-------------------------------|---------------------|--------------------|----------------------|
|       | Spot Price (S)                | Volatility (v)      | Risk Free Rate (r) | Time to Expiry (t)   |
| Delta | Gamma                         | Vanna<br>DdeltaDvol | DdeltaDr           | Charm<br>DdeltaDtime |
| Vega  | Vanna<br>DvegaDspot           | Vomma               | DvegaDr            | DvegaDtime           |
| Rho   | DrhoDspot                     | DrhoDvol            | Rho Convexity      | DrhoDtime            |

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## Appendix C – Surplus Management Philosophy

Consider a company matches the modified duration of the assets and liabilities. This strategy exposes economic surplus to interest rate risk. Figure 10 below shows how an increase in interest rates of 1% results in the same percentage change in assets and liabilities and a resulting decrease in economic surplus from 10 to 7.5 due to the excess present value of assets backing the liabilities.

**Figure 10 - Immunization on a Modified Duration<sup>30</sup> Basis**

|             | Book Value | Present Value | Modified Duration |
|-------------|------------|---------------|-------------------|
| Assets      | 100        | 105           | 25                |
| Liabilities | 100        | 95            | 25                |
| Difference  | 0          | 10            | 0                 |

A 1% increase in interest rates results in a 2.5 decrease in economic surplus

|             | Book Value | Present Value |
|-------------|------------|---------------|
| Assets      | 100        | 78.75         |
| Liabilities | 100        | 71.25         |
| Difference  | 0          | 7.5           |

A company wishing to immunize economic surplus would immunize on a dollar duration<sup>31</sup> basis. Figure 11 below shows how an increase in interest rates of 1% results in the same dollar change in assets and liabilities and therefore no change in economic surplus.

**Figure 11- Immunization on a Dollar Duration Basis**

|             | Book Value | Present Value | Modified Duration | Dollar Duration |
|-------------|------------|---------------|-------------------|-----------------|
| Assets      | 100        | 105           | 22.6              | 2375.0          |
| Liabilities | 100        | 95            | 25.0              | 2375.0          |
| Difference  | 0          | 10            | -2.4              | 0.0             |

A 1% increase in interest rates results in no change in economic surplus

|             | Book Value | Present Value |
|-------------|------------|---------------|
| Assets      | 100        | 81.25         |
| Liabilities | 100        | 71.25         |
| Difference  | 0          | 10            |

<sup>30</sup> Modified duration measures the first order sensitivity of the present value of cash flows to a change in interest rates.

<sup>31</sup> Dollar duration equals the modified duration times the present value of the cash flows.

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The reader may be tempted to observe that immunizing on a dollar duration basis is equivalent to investing economic surplus or excess present value of assets in cash or some other asset with duration zero and question whether that is how surplus should be invested. In fact, depending on the shape of the yield curve and the asset liability profile, immunizing on a dollar duration basis in this example could increase portfolio yield. But the underlying question remains, what should the duration of surplus be?

Insurance companies are exposed to significant interest rate risk which has multiple dimensions. As we saw in the example above, immunizing on a duration basis is not sufficient to protect economic surplus against a change in interest rates if the present value of assets is greater than the present value of liabilities. Immunizing on a dollar duration basis is also not sufficient. Many life insurance companies with long duration liabilities were immunized on a first order, dollar duration basis and were not protected against large changes in interest rates. As a result second order, convexity exposure these companies found themselves offside of their board approved risk limits as the duration of the liabilities increased at a greater rate than the duration of assets as interest rates fell.

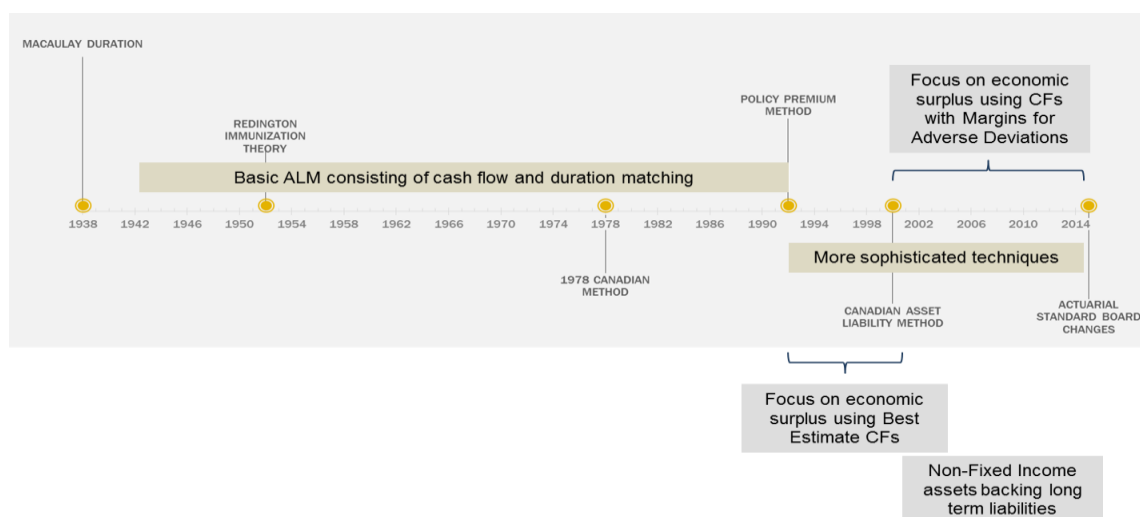
#### Appendix D – Evolution of ALM Practices

Interest rate risk remains a significant challenge for many insurance companies with long duration liabilities. Long bond rates have been decreasing for the past two decades. For the last 10 years, we have been in a prolonged low interest rate environment with interest rates below what used to be considered an overly conservative ultimate reinvestment rate of 5%.

The decrease in interest rates has caused a number of life insurance companies with long duration liabilities to be outside of their interest rate risk limits, some with still large duration mismatches.

Convexity exposure, prevailing view on interest rates since the early 1990s has been that interest rates will increase.

**Figure 12 - Historical Timeline for Life Insurance Companies in Canada**



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