Key Principles of Internal Models

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## Agenda

<table>
<thead>
<tr>
<th></th>
<th>What is an internal model?</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Development of internal models</td>
</tr>
<tr>
<td>3</td>
<td>Model design – what do you want out of your model?</td>
</tr>
<tr>
<td>4</td>
<td>Model calibration and testing</td>
</tr>
<tr>
<td>5</td>
<td>SCOR’s Group Internal Model (GIM)</td>
</tr>
<tr>
<td>6</td>
<td>Conclusions</td>
</tr>
</tbody>
</table>
What is an internal model

- An internal model is here to assess the risk of the economic balance sheet of the company.

Economic Balance Sheet at the end of the year $t_0$

- Own funds (Available Capital)
- Economic Value of the assets
- Economic value of the liabilities

Risk 1 (Market)
Risk 2 (Credit)
Risk 3 (FX)
Risk 4 (Life-UW)
Risk 5 (P&C-UW)
Risk 6 (Yield)
Risk 7 (Op. Risk)
Risk n (Retro)

Scenario 1
Scenario 2
Scenario 3
Scenario n

100,000 scenarios

Probability distribution of the capital at $t_1 = t_0 + 1y$

Gain
Loss

Mean

Solvency Ratio = \( \frac{\text{Own Funds}}{\text{SCR}^*} \)

*) Measured at $t_1$ but discounted at $t_0$
Aggregating risks means diversification

- The internal model allows to measure the diversification benefits
- In a simple example we show how the capital is reduced by combining risks

<table>
<thead>
<tr>
<th>Measure</th>
<th>Hurricane</th>
<th>Earthquake</th>
<th>Portfolio</th>
<th>Diversification Benefits(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected</td>
<td>62</td>
<td>16</td>
<td>78</td>
<td>0%</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>84</td>
<td>60</td>
<td>104</td>
<td>28%</td>
</tr>
<tr>
<td>VaR(99%)</td>
<td>418</td>
<td>332</td>
<td>544</td>
<td>27%</td>
</tr>
<tr>
<td>VaR(99.6%)</td>
<td>596</td>
<td>478</td>
<td>690</td>
<td>36%</td>
</tr>
<tr>
<td>TVaR(99%)</td>
<td>575</td>
<td>500</td>
<td>678</td>
<td>37%</td>
</tr>
<tr>
<td>TVaR(99.6%)</td>
<td>700</td>
<td>598</td>
<td>770</td>
<td>41%</td>
</tr>
</tbody>
</table>

\(^1\) Diversification benefit is measured as one minus the ratio between the capital of the portfolio over the sum of the capital of each risk standalone.
Internal models: development

Model (abstraction)

Model realization

Reality

Methodology

Conceptual Framework

Simplification

Data

Implementation Framework

Industrialization

Assumptions

Processes
Objectives of internal models

- Internal models should provide a way to assess the need for capital to cover the risk assumed.

- They should provide a unified way of communicating about risks within the company and with outside stakeholders (Solvency requirements, rating agencies, investors).

- They should set the framework for taking strategic decisions, balancing risk and return: “Flight Simulator”.

- They should allow the optimisation of both the asset and liability portfolios by modelling the diversification benefits.

- They should make it possible to measure the economic performance of the various lines of business.
Internal risk models: Applications and benefits

- Investment Strategy
- Profitability Analysis
  - RAC Allocation
  - "What-if" Analysis
- Rating Agencies
- Risk Mitigation, RI Optimization

- ALM
- Planning
- Solvency Management
- Solvency testing

Internal Risk Model
<table>
<thead>
<tr>
<th></th>
<th>Agenda</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>What is an internal model?</td>
</tr>
<tr>
<td>2</td>
<td>Development of internal models</td>
</tr>
<tr>
<td>3</td>
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</tr>
<tr>
<td>4</td>
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</tr>
<tr>
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</tr>
<tr>
<td>6</td>
<td>Conclusions</td>
</tr>
</tbody>
</table>
Why an internal model?

- At the heart of capital management the internal model gives answers to **how much capital is needed**. It is thus becoming an unavoidable instrument for the industry because:
  - Peak risks are growing
  - Regulators require them to assess the solvency of companies (Solvency 2, SST)
  - Shareholders are becoming more demanding & more attentive (Return on Equity ROE, new accounting rules)
  - The integration of world financial markets requires a more efficient use of capital (competition between various financial institutions) and increases the dependence between various risks
  - Insurers already have technically mature methods for risk analysis and capital allocation
Peak risks are growing

- Peak risks are growing due to:
  - **Demographic changes**: concentration of populations in hazardous areas, movement of populations favours the spread of disease (AIDS, SARS, A H1N1, etc…)
  - **Social & political changes**: better living standards, more demanding people (e.g. liability), evolution of legal systems, terrorism, political instabilities in oil rich regions, etc.
  - **New technologies** could bring new risks: nanotechnology, cell phones, new drugs (VIOXX) etc.
  - **New financial products** (especially in life insurance and credit). The financial crisis has shown the risk these instruments can bring to unprepared investors
The growth of peak risks is closely related to the growth of population in urbanized areas\textsuperscript{1)}

<table>
<thead>
<tr>
<th>Percentage Urban:</th>
<th>0-25%</th>
<th>50-75%</th>
<th>25-50%</th>
<th>75-100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>City Population:</td>
<td>$1 - 5$ million</td>
<td>$&gt; 10$ million</td>
<td>$5 - 10$ million</td>
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Urban populations concentrated in riskiest areas\textsuperscript{1)}

- The potential economic and human consequences of an event such as a pandemic or a natural catastrophe are increasing.

\textsuperscript{1)} Sherbinin, Shiller & Pulsipher (2007)
New risks are multiplying with varying levels of severity and probability

The 26 Core Global Risks: Probability with Severity by Economic Loss

- Retrenchment from globalisation (developed)
- Asset price collapse
- Slowing Chinese economy (6%)
- Oil and gas price spike
- Chronic disease, developed world
- Middle East instability
- Heatwaves & droughts
- Major fall in US$
- Retrenchment from globalisation (emerging)
- Failed & failing states
- International terrorism
- Loss of fresh water
- Collapse of NPT

Severity (in USD)

- More than 1 trillion
- 250 billion – trillion
- 50-250 billion
- 10-50 billion
- 2-10 billion
- below 1%

Probability

- below 1%
- 1-5%
- 5-10%
- 10-20%
- above 20%
Internal models: Historical evolution

Collection of sub models quantifying parts of the risks

Quantification of different risk types with portfolio effects

Risk types are combined to arrive at the company’s total risk

Modelling of underlying risk drivers and emphasize on the whole distribution

Slide inspired by Philipp Keller
Evolution of SCOR’s internal Model & Reports

- Reporting of Underwriting risk market outlook based on ESG
- Analyzes of invested assets including sensitivity tests
- Risk drivers, based on expected shortfall 5%
- Model integration including P&C Retro model in the Group Internal Model (GIM)
- Switch from Remetrica to Igloo
- Performance Review of Hedge Funds Investments
- First full run: Life model, Divisional split, Diversified interest-rate volatility of Liabilities / interest rate effects on net result, Measuring diversified FX-risk on net result
- First SST Report: One-Year Change, Risk Margin, CoCPIT project
- Adaptations to Solvency 2 (available capital) and use of 99.5% VaR
- Integration of TaRe portfolio in ILLAS (Life model)
- New method for calibrating dependencies for P&C risks: PrObEx

The model continuously evolves with improvements, adaptations, faster processes, better data control, better reporting...

We are finalising the internal model policies that allow flexibility in its implementation while satisfying the regulators’ need for stability
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
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</tr>
<tr>
<td>6</td>
<td>Conclusions</td>
</tr>
</tbody>
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Types of Models

- Models can be loosely grouped into:
  - **Deterministic models**: A number of factors are estimated and applied to volume measures (e.g. premium income etc.)
  - **Distribution-based models**: Probability distributions for different risks are determined and aggregated
  - **Scenario-based models**: A (frequently large) number of scenarios is generated to value the company in various countries around the world

- Most models are a mix of all three approaches

- Deterministic models present the danger that the underlying factors have to be regularly updated to take into account changing risk exposures

- Distribution and scenario-based models can be equivalent. Distribution-based models can be computationally efficient, whereas scenario-based models can be more intuitive and flexible
Should the internal model meet the requirements of all stakeholders?

- There are various points of view on the company and various models to assess the risks.
- Rating agencies, for instance, have their own capital model that does not coincide with the internal model.
- Regulators are fixing a certain number of principles concerning risk assessment that are not necessarily the same as those required to manage the company (yearly versus ultimate).
- The internal model should make it possible to satisfy all the requirements but should not depend on them.
- Companies need to design their internal model in order to steer their portfolio rather than to satisfy regulators or rating agencies.
SCOR internal model: Adapting GIM to Solvency 2 and Swiss Solvency Test

- For Solvency 2 and the SST, the relevant risk is the risk of the regulated legal entity and not the LoBs

- Thus, the model needs to split risks between legal entities as well as Lines of Business (multiplying the number of variables and parameters)

- The calendar year capital for Solvency 2 and the SST is based on the *yearly fluctuations of the reserves and other risks* and not on the ultimate losses

- Regulators are concerned about the company surviving one year and being able to run-off or sell its liabilities

- SCOR’s GIM needed to adapt to these constraints, without losing its generality and its application to capital management and ALM
Gap between regulatory requirements and company view on the risks: Example of P&C reserving

- In a P&C reserving triangle the difference between our internal model and the regulatory requirements is clear:

![Diagram showing risk for end of next calendar year and next period risk compared to ultimate risk for ultimate risk.](image-url)

- We use currently this for ALM

- This is what the regulator requires for the Solvency Capital Requirement (plus market value margin)
Impact of Transition to Solvency 2 Capital Requirement

- Transition from the 2010 Reported Capital Requirement ("Risk Adjusted Capital" with risk measure $\text{xtVaR } 99\%$) …

- … to "Solvency Capital Requirement" with the risk measure $\text{VaR } 99.5\%$

Steps:
  - Subtract Risk Margin (RM) (€385m for Life)
  - Subtract Profit (€391m)
  - Change risk measure (€207m)

- Note the RM and Profit are subtracted from the Available Capital

- Result:
  - $\text{RAC} = €3,530 \text{ million}$
  - $\text{SCR} = €2,547 \text{ million}$
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<table>
<thead>
<tr>
<th></th>
<th>1</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
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</tr>
<tr>
<td></td>
<td>3</td>
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<tr>
<td></td>
<td>4</td>
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</tr>
<tr>
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<td>5</td>
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</tr>
<tr>
<td></td>
<td>6</td>
<td>Conclusions</td>
</tr>
</tbody>
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How to Calibrate Dependences?

Dependences can hardly be described by one number such as a linear correlation coefficient

We just saw that it is possible to use the **copulas** to model dependences

In insurance, there is often not enough liability data to estimate the copulas

Nevertheless, copulas can be used to translate an opinion about dependences in the portfolio into a model:

- Select a copula with an appropriate shape
  - *increased dependences in the tail*  
    - this feature is observable in historic insurance loss data

- Try to estimate conditional probabilities by asking questions such as “What if a particular risk turned very bad?”
  - Think about *adverse scenarios* in the portfolio
  - Look at *causal relations* between risks
Is it possible to statistically test internal models?

- RAC is computed for a probability of 1% or 0.5%, which represents a 1/100 or 1/200 years event.
- In most of the insured risks, such an event has never been observed or has been observed only once.
- This means that the tails of the distributions have to be inferred from data from the last 10 to 30 years in the best cases.
- The 1/100 years RAC is thus based on a theoretical estimate of the shock size.
- It is considered more as the rule of the game than as a realistic risk cover.
- It is a compromise between pure betting and not doing anything because we cannot statistically estimate it.
Stress testing the models is crucial

- Bakounine used to say: “Reality is always wider than any doctrine”, in other words, a model is only a simplification of reality

- Testing the output of internal models is thus a must to gain confidence in its results and to understand its limitations

- We just saw that it is difficult, or even impossible, to statistically test the model. We can only stress test it

- There are at least four ways of stress testing the models
  1. Test the sensitivity to parameters (sensitivity analysis)
  2. Test the predictions against real outcomes (historical test)
  3. Test the model against scenarios
  4. Study the reasonableness of the extreme scenarios of the Monte-Carlo simulations (reverse stress-test)
Testing stochastic models with scenarios

- Scenarios can be seen as thought experiments about possible future world situations
- Scenarios are different from sensitivity analysis where the impact of a (small) change to a single variable is evaluated
- Scenario results can be compared to simulation results in order to assess the probability of the scenarios in question
- By comparing the probability of the scenario given by the internal model to the expected frequency of such a scenario, we can assess whether the internal model is realistic and has really taken into account enough dependencies between risks
- By studying the extreme outcomes of the Monte-Carlo simulations, it is possible to determine their plausibility
Scenario-based simulation vs. distribution-based simulation

**Scenario-based**

**Pro**
Risk is modelled at its source. When more random variables are modelled on the same scenarios, their dependence is recorded automatically:

- E.g. economic scenarios with impact on random variables “asset value $A$” and “value of liabilities $L$”

**Con**
For many risks, the random variable cannot be modelled or it is extremely difficult to calibrate the models.

**Distribution-based**

**Con**
The source of the risk is forgotten. Appropriate dependencies more difficult/ impossible to incorporate:

- the different scenarios cannot be distinguished anymore. The dependence of another risk (with different outcomes) cannot be recorded properly in this way.

**Pro**
For many risks the random variable may be difficult or impossible to model, but the distribution can be estimated using statistics.
Capital Buffer to absorb single worst case scenarios

<table>
<thead>
<tr>
<th>Event Description</th>
<th>Probability in years</th>
<th>In € million, net of retro</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major Fraud in largest C&amp;S exposure</td>
<td>1 in 100</td>
<td>150</td>
</tr>
<tr>
<td>US hurricane</td>
<td>1 in 100</td>
<td>200</td>
</tr>
<tr>
<td>EU windstorm</td>
<td>1 in 100</td>
<td>200</td>
</tr>
<tr>
<td>Japan earthquake</td>
<td>1 in 250</td>
<td>200</td>
</tr>
<tr>
<td>Terrorism Wave of attacks</td>
<td>1 in 100</td>
<td>445</td>
</tr>
<tr>
<td>Long term mortality deterioration</td>
<td>1 in 200</td>
<td>520</td>
</tr>
<tr>
<td>Global pandemic</td>
<td>1 in 200</td>
<td>650</td>
</tr>
<tr>
<td>Severe adverse development in reserves</td>
<td>1 in 500</td>
<td>700</td>
</tr>
</tbody>
</table>

Capital Buffer: 1 in 100

Expected Change in Economic Capital: 1 in 500
Protecting the company against model shortcomings

- To protect the company against the inevitable shortcomings of the model is to set *exposure limits for each extreme scenario*.

- For instance, one can decide not to allow any scenario to consume more than 15% of the company’s available capital.

- One can add a certain *buffer to the capital* that is strictly required from the model.

- Another good measure is to *limit capital exposure to particular risks*. For instance, the company would not allow more than 5% of its available capital to be exposed to terrorism.

- Develop accumulation control system and give limits purely to the sum of exposures.
### Agenda

<table>
<thead>
<tr>
<th></th>
<th>What is an internal model?</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
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</tr>
<tr>
<td>6</td>
<td>Conclusions</td>
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SCOR’s main model principles

Risk is modelled at the origin

- Data is entered and signed-off by the people who are in charge of the corresponding business (P&C for Norma and Life for ILIAS)
- Models are developed in their related divisions (NORMA and ILIAS) in close cooperation with the FinMod team who is the ultimate responsible for the GIM and the integration of all risk models
- The responsibility of the parameterization and the life cycles of the partial models lies in the divisions

Strong focus on dependency modelling

- Non-linear treatment by mirrored-clayton copulas to ensure strong dependence in the tails
- The Economic Scenario Generator (ESG) uses bootstrapping to conserve historical dependencies between economic variables and to produce consistent scenarios
- Dependencies are calibrated using also expert judgments within the PrObEx framework, which is scientifically sound

Full balance sheet approach

- From the current balance sheet a stochastic one-year projection of future balance sheets is calculated
- All risks are considered, such as underwriting, market, yield, credit, foreign and exchange risks
- All valuation is done on a market consistent basis

Capital allocation via Euler principle

- Fully change in economic value distribution is produced
- Expected profit and capital requirements at the different thresholds and for different risk measures are computed
- Capital allocation is calculated by the marginal contribution to the TVaR (Euler principle) and preserve RoRaC compatibility
Integrating all models in the approach

Assets
Innovations
- Cash & Short term investments
- Fixed Income
- Equities
- Real Estate
- Alternative Investments

Liabilities
Lines of business (LoB)
- LoB1
- LoB2
- LoB3
- LoB4

Economic Indicator

Cash flow
Accounting

Economy
Equity indices
GDP
Yield curves
Forex

Intenrnal Model
Michel M. Dacorogna
IAJ, Tokyo, Feb. 17, 2014
Conclusion on SCOR’s Group Internal Model

**GIM at level of best peers**
- SCOR is through the publication of the “Blue Book”¹) and various (research) papers at the forefront of the (re)insurance discussion on quantitative risk management
- With development of the ESG, Norma and Ilias SCOR fulfils industry leading standards in stochastic modelling

**GIM is fully embedded in SCOR’s strategy**
- The group internal model is fully aligned with our strategy to be a capital driven company
- Together with CaDeT it was used to calculate key figures for our “Strong Momentum”- Plan
- It is used for M&A activities (Transamerica RE)

**GIM is embedded in the company**
- Numerous departments and around 100 individual people contribute data, assumptions or analysis to the operational run
- The produced results are used in a lot of activities of SCOR, ranging from sharing our experience on risk modelling with clients to the presentation to our investors

**The GIM is fully operational**
- With around 30-40 model runs in the last months the group internal model is fully operational and can deliver additional value to the business
- The internal model is well established in SCOR and contributes with diverse analyses to the understanding of our business (M&A activities, retro optimization, investment strategy, planning)

¹) From Principle-Based Risk Management to Solvency Requirements
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</tr>
<tr>
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Conclusions

- The development of internal models helps to improve risk awareness and anchors risk management and governance deeper in industry practices.
- Internal models provide valuable assessments, especially in relative terms, as well as guidance in business decisions.
- They facilitate reasonable discussions about strategic choices and their possible consequences.
- They will be playing an increasingly important role and already have a material impact on transforming the business models of insurers and reinsurers.
- The challenge for the future is to create a fully dynamic model with adaptive strategies.