Thesis Proposal

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1 Thesis title

EVALUATION OF SOLVENCY CAPITAL REQUIREMENT MODELS FOR NON-LIFE INSURANCE BUSINESS
ตัวแบบการประเมินเงินทุนเพื่อความมั่นคงสำหรับธุรกิจประกันวินาศภัย

2 Introduction

The solvency capital of an insurance company guarantees the solvability of the latter during a financial distress. Regarding the importance of insurance to the society, economy and public welfare, the insurance company should have enough capital to overcome almost every crisis. In Solvency I the solvency capital requirement is calculated via a factor-based framework. This framework is easy to understand and easy to use, and it requires only some balance sheet values and the corresponding risk factors. The downside of a factor-based framework is that it does not reflect the actual risks. Solvency II, as a risk based framework, will provide a more sophisticated view on the risk taking of an insurance company. In the Solvency II framework, the amount of solvency capital has to be hold is in the broader sense defined as the amount of capital needed to survive a once in two hundred years crisis.

Solvency II is the new rule framework of the European Union for insurance and reinsurance companies. It replace the Solvency I and become effective in 2013. Under Solvency II, two capital level are determined: the minimum capital requirement, a threshold at which companies are no longer permitted to sell policies, and the Solvency Capital Requirement (SCR) which companies may need to discuss remedies with their regulator. The SCR is computed by means of a 99.5% Value-at-Risk (VaR).

One main feature of Solvency II is the calculation of the SCR, which is the amount of own funds that an insurance company is required to hold. For calculating the SCR, each company can choose between setting up its own internal model and using a provided standard formula.

Since Solvency II will have an important effect on the European insurance industry, many authors have discussed solvency capital requirements. For example, Devolder (2010) studied the capital requirement under different risk measurements, Eling et al. (2007) outlined the characteristics of Solvency II, Doff (2008) made a critical analysis of the Solvency II proposal in the standard formula and Holzmuller (2009) focused on the relation between the United States risk-based capital standards, Solvency II and the Swiss Solvency Test.

One of the most significant innovations of Solvency II is the possible use of internal, instead of standard, risk models to determine the target capital. An internal model is one constructed by the insurer for its specific needs; a standard model is designed by the regulator and used uniformly across insurers. Internal models are expected to result in more accurate analysis, control and management of the insurer's financial situation than do the more generic standard models. If an internal model is used, the resulting target capital should not be lower than the minimum capital requirements provided under Solvency I rules. Furthermore, regulators can require the use of an internal model if the insurer's particular conditions differ widely from assumptions made in the standard model. Many studies have focused on developing the SCR standard formula. For example, Ohlsson, E. and Lauzeningks, J. (2009) concentrated on clarifying the one-year concept, Christiansen, M., Denuit, M. and Lazar, P. (2012) developed a model supporting used in Solvency II to aggregate the modular life SCR and Levantesi, S. and Menzietti, M. (2012) developed a model for risk assessment in a portfolio of life annuities with long term care benefits. Alm, J. (2012) developed a general technique for constructing a simulation model which is able to generate the SCR. To cope with the problems more effectively, therefore, we need to develop and investigate the SCR formula.

Along with technical provisions, there are rules for determining the minimum capital required and the *target capital*. Conditions for internal and standardized risk models are included in this process, incorporating both asset and liability risks, although not necessarily including asset-liability matching. There are four controlling and monitoring-relevant risk categories specified for consideration; insurance risk, credit risk, market risk and operational risk.

The insurance risk is composed by risk of premium and claim reserves. Estimation of the loss (claim) reserving represents an important task for an insurance company to get the correct picture of its liabilities. Accurate estimation of the distribution of the outstanding claim and incurred but not reported (IBNR) claims reserve is required because of its impact on multiple aspects of the company; investment policy, dividend declaration, tax payment and so on. Here estimation of loss reserving is the important part to evaluate the SCR. With these relevant risk categories, we only consider the calculation of claims reserves. There are many methodologies to estimate claim reserving such as the Chain-Ladder (CL) method, Bounhuetter-Ferguson method and Poisson model. Since the CL method is popular and easy to practical, so we use CL for claim reserving in this research.

We now introduce the alternative, the support vector machine (SVM), for estimation the claim reserves. The SVM is developed by Vapnik, V. and his co-worker (1995) and is gaining popularity due to many attractive features, and promising empirical performance in a variety applications such as pattern recognition, regression estimation, time series prediction etc. So we try to use SVM to predict the claim reserves.

This research applies the SVM and CL methods to predicting the ultimate loss. After the ultimate loss is estimated, we evaluate the SCR standard formula and the SCR formula based on a fundamental concept to present the value of future cash flows (Alm ,J. (2012)). The main purpose of this present study is to investigate a new approach to the SCR standard formula. In addition, We compare these formulas and give a simulation example.

3 Research Objectives

With the main aspect of Solvency II, calculation of the SCR, our research will focus as follows:

1. Loss reserve
   - To estimate the loss reserve by using CL method and SVM.
   - To compare the loss reserve between CL method and SVM.
2. The SCR evaluation
   - To calculate the SCR standard formula and the SCR formula based on a fundamental concept to present value of future cash flows as currently declared by Alm, J.(2012).
   - To develop a new approach to the SCR standard formula.
3. To compare these SCR formulas; the SCR standard formula and the SCR formula based on a fundamental concept to present value of future cash flows as currently declared by Alm, J.(2012) and a new approach to the SCR standard formula.
4. Give a simulation example.

4 Scope and Limitations of the Study

- Loss reserve
  1. Claims arrivals happen at time T_i. The claim arrival process (T_i) constitutes claim arrivals satisfying $0 \leq T_1 \leq T_2 \leq ....$
  2. Let X_i be the claim size of the ith claim arriving at time T_i. The process (X_i) forms an independent identically distribution(iid) sequence of non-negative random variables. Assume that the process (X_i) and (T_i) are *mutually independent*.

3. The claim number process is the number of the claims having occurred by time t :

$$N_t = \#\{i \geq 1 : T_i \leq t\}, t \geq 0.$$

   Note that $N = (N_t)_{t \geq 0}$ is a counting process on $[0, \infty]$.

4. The ultimate claim can be estimated based on cumulative claim or incremental claim amount. Since generating sample data is based on the cumulative claim amount, it may provide a decreased amount, that is, the incremental claim amount has a negative value. To reduce this problem, we generate the claim amount based on incremental claim amount for this research.

- The SCR evaluation

  The insurance types studied in this paper relate to the lines of business (LoBs) defined in the Solvency II framework. In fact, there are many insurance types in LoB for non-life insurance, e.g., types of LoBs defined by European commission (Oct, 2009). The following shows the formal definition of three types of LoBs;

  - **Accident** : This line of business includes obligations caused by accident or misadventure but excludes obligations considered as workers' compensation insurance;
  - **Sickness** : This line of business includes obligations caused by illness, but excludes obligations considered as workersćompensation insurance;
  - **Motor** : This line of business includes obligations which cover all damage to or loss of land motor vehicles, land vehicles other than motor vehicles and railway rolling stock.

5 Knowledge and Terminology

5.1 Claim reserve

A non-life insurance policy is a contract among two parties: the insurer and the insured. It gives the insurer a fixed amount of money (called *premium*) and the insured a financial coverage against the random occurrence of well-specified events. The amount which the insurer is obligated to pay in respect of a claim is known as the claim amount (loss amount). The payments that make up this claim are known as claims payments (loss payments, paid claims, or paid losses).

Figure 1 shows the form of typical non-life insurance claim.

Normally, the insurance company is unable to pay a claim immediately, for three main reasons; there is a reporting day which can take several years, especially in liability insurance, after being reported to the insurer, several years may elapse before

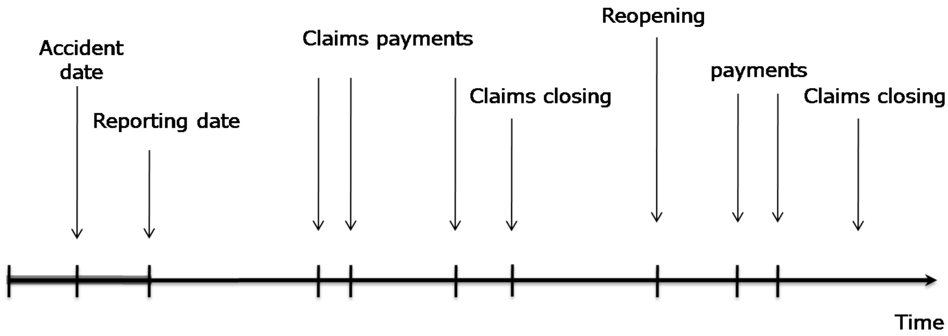

Figure 1: Typical time line of a non-life insurance claim

the claim is finally settled and it can also happen that a closed claim needs to be reopened due to (unexpected) new developments.

Now we introduce the classical claims reserving notation and terminology. In most cases outstanding loss liabilities are studied in so-called *claim development triangles* which separate insurance claims into two time axes.

Below we use the notation as follows (see Figure 2):

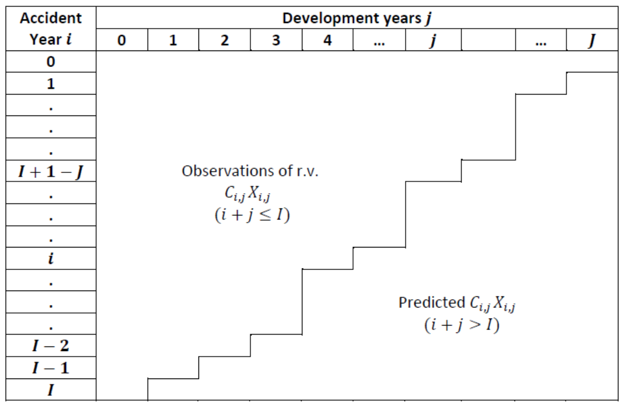

Figure 2: Triangles of claim development for outstanding loss

i = accident year, year of occurrence (vertical axis),

j = development year, development period (horizontal axis).

The most recent accident year is denoted by I while the last development year is denoted by J. That is, $i \in 0, \ldots, I$ and $j \in 0, \ldots, J$.

For explanatory purposes, we assume that $X_{i,j}$ denotes payments. Then $X_{i,j}$ denotes all payments in development period j for claims with accident year i. That is $X_{i,j}$ corresponds to the payments for claims in accident year i made in accounting year $i + j$. Cumulative payments $C_{i,j}$ for accident year i after j development years are then given by

$$C_{i,j} = \sum_{k=0}^{j} X_{i,k}.$$

Regularly, at time I, the claims development tables are split into two parts: the upper triangle containing observations $X_{i,j}, i + j \leq I$, and the lower triangle with predicted values of the outstanding payments $X_{i,j}, i + j > I$. This means that observations are available in the upper triangle

$$D_I = X_{i,j}; i + j \leq I, 0 \leq j \leq J$$

and the lower triangle $D_I^c = X_{i,j}; i + j > I, i < I, j \leq J$ needs to be estimated or predicted.

The accounting years are then given on the diagonals $i + j = k, k \geq 0$. The incremental claims in accounting year $k \geq 0$ are denoted by

$$X_k = \sum_{i+j=k} X_{i,j}$$

and are shown on the (k+1)th diagonal of the claims development triangle.

Incremental claims $X_{i,j}$ represent the incremental payments in cell (i, j), the number of reported claims with reporting delay j and accident year i, or the change of reported claim amount in cell (i, j). **Cumulative claims** $C_{i,j}$ may represent the cumulative payments, total number of reported claims, or claims incurred. $C_{i,J}$ is often called the **ultimate claim amount** of accident year i or the total number of claims in year i.

If the $X_{i,j}$ denote incremental payments then the **claim reserves** (outstanding loss reserves) for accident year i at time j are given by

$$R_{i,j} = \sum_{k=j+1}^{J} X_{i,k} = C_{i,J} - C_{i,j}$$

$R_{i,j}$ need to be predicted by so-called **claims reserves**.

5.1.1 Chain-Ladder (CL) method

The CL algorithm is seemingly the most popular loss reserving technique in theory and practice. The distribution-free derivation of the CL method links successive cumulative claims with appropriate link ratios, and is based on the following definition of model.

Assumption 1 *(distribution-free CL model)*

- *Cumulative claims $C_{i,j}$ of different accident years i are independent.*

- *There exist development factors* $f_0, ..., f_{J-1} > 0$ *such that for all* $0 \leq i \leq I$ *and all* $1 \leq j \leq J$ *we have*

$$E[C_{i,j}|C_{i,0}, \ldots, C_{i,j-1}] = E[C_{i,j}|C_{i,j-1}] = f_{j-1}C_{i,j-1} \tag{1}$$

In the following $D_I = C_{i,j}; i+j \leq I, 0 \leq j \leq J$ denotes the set of observations at time I (upper triangle; Figure 2).

Lemma 2 *Under Model Assumptions 1 we have*

$$E[C_{i,J}|D_I] = E[C_{i,J}|C_{i,I-i}] = C_{i,I-i}f_{I-1} \ldots f_{J-1}$$

for all $1 \leq i \leq I$*.*

Lemma 2 gives an algorithm for predicting the ultimate claim $C_{i,J}$ given the observations D_I. For known CL factors f_j, the outstanding claims liabilities of accident year i based on D_I are predicted by

$$E[C_{i,J}|D_I] - C_{i,I-i} = C_{i,I-i}(f_{I-i} \ldots f_{J-1} - 1)$$

This corresponds to the 'best estimate' reserves for accident year i at time I (based on the information D_I and know CL factors f_j).

Unfortunately, in most practical applications the CL factors are not known and also need to be estimated. The CL factors $f_j, j = 0, \ldots, J-1$, are estimated in the following:

$$\widehat{f_j} = \frac{\sum_{i=0}^{I-j-1} C_{i,j+1}}{\sum_{i=0}^{I-j-1} C_{i,j}} = \sum_{i=0}^{I-j-1} \frac{C_{i,j}}{\sum_{k=0}^{I-j-1} C_{k,j}} \frac{C_{i,j+1}}{C_{i,j}}.$$

That is, the CL factors f_j are estimated by a volume-weighted average of individual development factors $F_{i,j+1} = C_{i,j+1}/C_{i,j}$.

Estimator 3 *(CL estimator)*
The CL estimator for $E[C_{i,j}|D_I]$ *is given by*

$$\widehat{C_{i,j}}^{CL} = \widehat{E}[C_{i,j}|D_I] = C_{i,I-i}\widehat{f}_{I-i} \ldots \widehat{f}_{j-1} \tag{2}$$

for $i+j > I$*.*

The algorithm that leads to the CL reserves can be derived from equation (2).

5.1.2 Support vector machine

We propose a machine learning technique for forecasting the ultimate loss, which relies on the popular technique of support vector machines (SVM). Using a historical set of generated financial time series, we examine the performance of different variants and parameter settings.

Basically, SVM use a hyperplane to separate two classes. For classification problems that can not be linearly separated in the input space, SVM finds a solution using a non-linear mapping from the original input space into a high-dimensional so-called *feature space*, where an optimally separating hyperplane is searched. Those hyperplanes are called *optimal* that have a maximal margin, where margin means the minimal distance from the separating hyperplane to the closest (mapped) data points (so-called *support vectors*). In this study, we estimate the future value using the theory of SVM in regression approximation.

Our study will contain a comparison of the ultimate losses by using the CL method and the SVM and use them to evaluate the SCR.

5.2 Solvency Capital Requirement

Before introducing the standard model of Solvency II we introduce the volume measure of insurance company and the combined standard deviation (per volume unit) as follows:

For an individual LoB, say ℓ, let $V_R^{(\ell)}$ be the volume of outstanding incurred claims that is computed by the best estimate of outstanding incurred claims,

$$V_R^{(\ell)} = \mathrm{BE}_R^{(\ell)},$$

and let $V_P^{(\ell)}$ be the volume of claims expected to arise in the future, computed by the best estimate of future claims multiplied by the estimated total cost to claim cost ratio $\gamma^{(\ell)}$,

$$V_P^{(\ell)} = \gamma^{(\ell)} \cdot \mathrm{BE}_P^{(\ell)}.$$

Let $V^{(\ell)}$ be the sum of these two volume measure. Then the volume measure of insurance company, denoted by V, concerning the LoB for non-life insurance is the sum of the all individual LoBs, for all ℓ,

$$V = \sum_{i=1}^{\ell} V^{(i)}.$$

The standard deviation (per volume unit) $\sigma^{(\ell)}$ of LoB ℓ is given by

$$\sigma^{(\ell)} = \frac{1}{V^{(\ell)}}\big((\sigma_R^{(\ell)} V_R^{(\ell)})^2 + 2\rho\sigma_R^{(\ell)}\sigma_P^{(\ell)} V_R^{(\ell)} V_P^{(\ell)} + (\rho_P^{(\ell)} V_P^{(\ell)})^2\big)^{\frac{1}{2}},$$

where $\sigma_R^{(\ell)}$ and $\sigma_P^{(\ell)}$ are the standard deviations for reserve risk and premium risk, respectively, for LoB ℓ, and ρ is the correlation between the reserve risk and the premium risk.

The combined standard deviation (per volume unit) σ is given by

$$\sigma = \frac{1}{V}(\sum_{\ell}\sum_{m}\rho_{\ell m}\sigma^{(\ell)}\sigma^{(m)}V^{(\ell)}V^{(m)})^{\frac{1}{2}}$$

where $\sigma^{(\ell)}$ is the standard deviation of LoB ℓ and $\rho_{\ell m}$ is the correlation between LoBs ℓ and m.

5.2.1 The SCR - standard formula of Solvency II

In the standard model for non-life insurance, the formula of the solvency capital requirement based on the premium and reserve risk is given by

$$\mathrm{SCR}_{NL} := V \cdot g(\sigma), \tag{3}$$

$$\text{with } g(\sigma) := (e^{\mathcal{N}_{0.995}\sqrt{\log(\sigma^2+1)}})$$

where $\mathcal{N}_{0.995}$ is the 0.995 quantile of the standard normal distribution $\big(\mathcal{N}_{0.995} \approx 2.58\big)$, V is a volume measure and σ is the combined standard deviation per volume unit of the non-lift for the lines of business (LoBs) defined as before.

In the Solvency II framework, the amount of solvency capital an insurance company has to hold is in the broader sense defined as the amount of capital needed to survive a once in two hundred years crisis.

5.2.2 The SCR - based on a fundamental concept to present value of future cash flows

The approach to calculate SCR is based on a fundamental concept to present the value of future cash flows introduced by Alm, J. (2012). Here we simplify and modify it in accordance fashion.

The assets, Liabilities and SCR today and in one year shown in figure 3 and figure 4 shows the cash flow of outstanding loss liabilities of the insurance company.

Let $\mathbf{X} := \big(X_{I+1}, ..., X_{I+J+K}\big)^T$ be the cash flow of outstanding loss liabilities of the insurance company today, where X_t is the amount to be paid by the company at time t defined by

$$X_t = \sum_{n=1}^{N}\sum_{(i,j)\in S_t} X_{ij}^n, t = I+1, ..., I+J+K$$

where $S_t := \{(i,j) : \max(t-J, 1) \leq \min(t, I+K), j = t-i\}$.

Figure 3: Assets, liability and SCR in insurance company

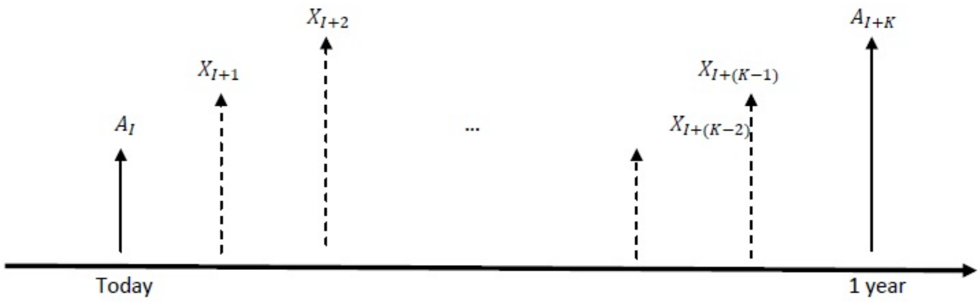

Figure 4: Cash flow of outstanding loss liabilities of the insurance company

Let $\mathcal{F}_I$ denote the information available at time t and B_{It} denote the price today of a zero-coupon bond with principal 1 maturing at time t.

An unbiased best estimator of the present value of the outstanding loss liability cash flows is given by

$$\text{BE} := X_t = \sum_{t=I+1}^{I+J+K} B_{It} \widehat{\mathbb{E}}[X_t \mid \mathcal{F}_I].$$

Assume that all assets of the insurance company are zero-coupon bonds maturing in one year, and that some of these bonds are sold during the coming year to pay off maturing liabilities.

Let A_t denote the value of the insurance company's assets at time t. The time $t = I$ and $t = I + K$ are at time of today and in one year respectively. Then the different between the value of the today's assets and the value of the coming year's maturing liabilities is that the assets value in one year calculated by

$$A_{I+K} = \frac{A_I}{B_{I,I+K}} - \sum_{t=I+1}^{I+K} \frac{X_t}{B_{I,I+K}}$$

Let L_t denote the value of the insurance company's liabilities at time t. The insurance company has enough assets to cover its liabilities if

$$\mathrm{VaR}_{0.005}\big(A_{I+K} - L_{I+K}\big) \leq 0,$$

which is the value-at-risk of the insurance company's portfolio in one year at the level 0.005.

The last equation is equivalent to

$$A_I \geq L_I + \mathrm{VaR}_{0.005}(\Delta) \tag{4}$$

where the random variable Δ is the change of the difference between assets and liabilities of the insurance company over the coming year defined by

$$\Delta := A_{I+K} - \frac{A_I}{B_{I,I+K}} - (L_{I+K} - \frac{L_I}{B_{I,I+K}}).$$

We define the minimum amount that the present asset value must exceed the present liability value to be the SCR. From equation (4) then the definition of the SCR is

$$\mathrm{SCR} := \mathrm{VaR}_{0.005}(\Delta) := B_{I,I+K} F_{-\Delta}^{-1}(1 - 0.005), \tag{5}$$

where $F_{-\Delta}^{-1}$ is the quantile function of $-\Delta$.

We construct the loss statistic defined by

$$U := \frac{-B_{I,I+K}\Delta}{\mathrm{BE}},$$

to set the change in balance (i.e., profit or loss) in relation to the size of the insurance company's liability portfolio. Then from the definition of SCR (5), another form of SCR is

$$\mathrm{SCR} = B_{I,I+K} F_{-\Delta}^{-1}(1 - 0.005) = B_{I,I+K} F_{\frac{\mathrm{BE}\cdot U}{B_{I,I+K}}}^{-1}(0.995) = \mathrm{BE} \cdot F_U^{-1}(0.995). \tag{6}$$

In order to compare the standard model of solvency II capital and Alm' s model (4), let a loss per volume unit $\tilde{U}$ be a random variable with mean zero and variance σ^2 and $g(\sigma)$ is the 0.995 quantile of $\tilde{U}$. Rewriting equation(3) as

$$\mathrm{SCR} = V \cdot F_{\tilde{U}}^{-1}(0.995)$$

which is very similar to the equation (6)

$$\mathrm{SCR} = \mathrm{BE} \cdot F_U^{-1}(0.995).$$

If $\tilde{U}$ is normally distribution, then $g(\sigma) = \mathcal{N}_{0.995}\sigma \approx 2.58\sigma$. However, in the standard model, with g defined as in equation(1), we have $g(\sigma)$ between 2.7σ and 3.1σ for standard deviation σ in the appropriate range. This mean that in the standard model, the insurance data has heavier tails than the normal distribution.

6 Research Procedure

The research procedure of this thesis is as follows:

(1) Generating sample data of the claim amounts.

(2) Loss reserve

- Estimate the LoBs reserves by using CL.
- Modify SVM and estimate the LoBs reserves by using SVM.

(3) The SCR evaluation

- Computing the SCR by using the standard SCR of solvency II.
- Computing the SCR by using the SCR formula based on a fundamental concept to present value of future cash flows as currently declared by Alm, J.(2012).
- Investigation and computing a new approach to the SCR standard formula.

(4) Comparison and discussion

- Compare the loss reserves between the results using CL method and SVM.
- Compare and discuss the SCR values which are evaluated by the standard SCR of solvency II ,the SCR formula based on a fundamental concept to present value of future cash flows as currently declared by Alm, J.(2012) and a new approach to the SCR standard formula.

7 Expected Results

(1) The SCR values, using the standard model of solvency II and the SCR formula based on a fundamental concept to present value of future cash flows as currently declared by Alm, J.(2012), are evaluated.

(2) A new model of SCR is developed and evaluated.

8 References

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9 Research Plan

Year	2012		2013		2014
Activities	Apr-May	Jun-Dec	Jan-May	Jun-Dec	Jan-Apr
1. Literature survey and study the non-life insurance mathematics.	$\leftrightarrow$	$\leftrightarrow$			
2. Criticism and possible extensions of Solvency II.		$\leftrightarrow$	$\leftrightarrow$		
3. Investigation of the claims reserving method.		$\leftrightarrow$	$\leftrightarrow$		
4. Investigation of the solvency capital requirement(SCR).			$\leftrightarrow$	$\leftrightarrow$	
5. Investigation the applicability of 1, 2 and 3 into the non-life insurance company in Thailand.				$\leftrightarrow$	
6. Thesis preparation.				$\leftrightarrow$	$\leftrightarrow$

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(Miss Nawarat Ekkarntrong)
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