## **RIGA TECHNICAL UNIVERSITY** Faculty of Engineering Economics and Management Institute of Business Engineering and Management

# Darja Stepchenko

Doctoral Student of "Management Science and Economics" Study Programme

# RISK MANAGEMENT AND MEASUREMENT SYSTEM DEVELOPMENT AND ITS INFLUENCE ON BALTIC INSURANCE MARKET Doctoral Thesis

Scientific supervisor Dr.oec., Professor I.VORONOVA Scientific consultant Dr.math., Professor G.PETERE

#### ABSTRACT

The Doctoral Thesis is devoted to the field of risk management in insurance to ensure the solvency and financial stability of each insurance company in the European Union in line with the Solvency II framework. The present Doctoral Thesis covers the 2<sup>nd</sup> Pillar of the Solvency II regime, mainly risk management part.

The enhancement of the risk assessment should be performed through a more sophisticated and sensitive risk analysis in order to ensure the stability and solvency of insurance company's development and activity. During the research, the author has investigated the nature of risk, significance of the risk culture in insurance and importance of the System of Governance under the Solvency II framework.

However, the author has also applied the Analytic Hierarchy Process and Analytic Network Process to insurance in order to improve the risk assessment and decision making within an insurance company. In addition, the author has conducted the research in order to assess the capital to cover possible losses due to the occurrence of the operational risk events using the copula theory and approved the possibility of its usage for risk assessment.

**Keywords**: insurance, the Solvency II framework, risk management, risk assessment, risk measurement, risk culture, Analytic Hierarchy Process, Analytic Network Process, scenario planning, copula theory.

# LIST OF MAIN ABBREVIATIONS

ORSA	Own Risk and Solvency Assessment		
SCR	Solvency Capital Requirement		
CAR	Capital Adequacy Ratio or Capital to Risk		
NAIC	National Association of Insurance Commissioners		
CEIOPS	Committee of European Insurance and Occupational Pensions Supervisors		
OSFI	Office of the Superintendent of Financial Institutions		
RBS	Risk Based Capital		
SMI	Solvency Modernisation Initiative		
S&P	Standard & Poors rating		
GDV	German Insurance Association		
FTK	Financial Assessment Framework		
P&C	Property and Casualty Insurance		
FSA	Financial Supervisory Authority		
MCR	Minimum capital requirement		
SST	Swiss Solvency Test		
ALM	Asset Liability Management		
VaR	Value at Risk		
CRD	Capital Requirements Directive		
EU	European Union		
SCR	Solvency Capital Requirement		
SFCR	Solvency and Financial Condition Report		
Adj	Adjustment		
BSCR	Basic Solvency Capital Requirement		
Op	Operational Risk		
oppremiun	Operational risk premum		
opprovision	Operational risk provision		
CAT	Catastrophic Risk		
SLT	Similar to Life insurance techniques		
UW	Underwriting Risk		
CI	Consistency Index		
CR	Consistency Ratio		
RI	Random Index		
SWOT	Strengths, Weaknesses, Opportunities and Threats		
AHP	Analytic Hierarchy Process		
ANP	Analytic Network Process		
S — O	Strengths — Opportunities		
S — T	Strengths — Threats		
W — T	Weaknesses — Threats		
W — O	Weaknesses — Opportunities		
LR	Legal Risk		
OR	Organisational Risk		
IR	Informational Risk		

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#### **INTRODUCTION**

Insurance in one of the most explosive and important areas in every country's economy; therefore, it requires a more sophisticated and sensitive risk analysis in order to ensure stability and solvency of insurance company's development and activity.

Similar to the European Union trends, the Baltic insurance industry is one of the fastest developing industries with regard to its annual increase in the market volumes. The Estonian insurance market, Lithuanian insurance market and Latvian insurance market belong to the Baltic insurance market. This is mainly related to the improvement of the economic situation in the Baltics (i.e. Latvia, Lithuania and Estonia) after the recession and to the overall enhancement of citizens' knowledge in the field of insurance. In order to ensure further stable development and solvency of the Baltic insurance companies, thus protecting policyholders' interests, more sophisticated, sensitive and complex risk coverage and analysis should be provided.

The best option to achieve the solvency of every insurance company is to follow the requirement of the Solvency II Directive. The Solvency II Directive should establish economic risk-based solvency requirements across all European Union member states [46]. The point is that the Solvency II requirements should establish common risk management principles for every insurance company in the European Union.

The Solvency II Directive is based on a three-pillar approach where each pillar ensures the fulfilment of particular functions: quantitative requirements, qualitative and supervision requirements, disclosure requirements to secure prudential reporting and public disclosure. In fact, the requirements of the Solvency II Directive are planned to be more risk sensitive and more sophisticated than the requirements of the Solvency I Directive with the purpose to provide every individual insurance or reinsurance company's real risk better coverage [13]. The point is that Solvency II Directive is based on risk management and risk measurement, meanwhile each function plays crucial role in Solvency II Directive principles establishment in insurance company and should change the understanding of insurance business principles. The new Solvency II regime sets a lot of challenges to every insurance company, since it requires establishing new rules for risk evaluation that will change rapidly every insurance company's processes, systems, functions, organizational structure, and capital structure.

The requirements of the Solvency II Directive, which are in force from 1<sup>st</sup> January 2016, set a lot of challenges to every insurance company of Baltic states in relation to the

establishment of more sensitive and sophisticated risk coverage in order to ensure solvency and the safety of policyholders. However, the requirements of the Solvency II Directive have set many challenges to the Baltic insurance companies since not only enormous financial and human resources are required, but also there is a need for a change in the management mind and decision-making process within a company. Also, the Baltic insurance companies should educate key-employees in relation to risk evaluation and understanding of risk nature, improve and establish processes in line with the new regime requirements and ensure independence of each function under the new framework. The Baltic insurance market is rather small and developing compared to other countries in European union therefore Solvency II Directive requirements should be established in insurance companies through another approach.

Based on the requirements of the Solvency II Directive, the insurance companies should hold the appropriate amount of reserves that could ensure safety of policyholders and beneficiaries. The Solvency II Directive's requirements could require to increase level of reserves of Baltic insurance companies that could influence the amount of participants in the Baltic insurance market.

Under the Solvency II regime, appropriate risk management and risk measurement system should be introduced to ensure sophisticated and appropriate insurance company's risk coverage. All in all, the Solvency II regime requires implementing, improving and putting the risk culture into the heart of insurance company's business processes. Risk culture involves all processes, human resources of an insurance company since it sets norms and traditions of employees' (particularly the management board) behaviour within an organisation that determine the way of risk nature understanding, risk profile and risk strategy setting.

The **goal** of the Doctoral Thesis is the development of risk management and measurement system, identifying its influence on the Baltic insurance market, using risk management and risk measurement approaches. In order to achieve the goal set, the following **objectives** should be fulfilled:

- to analyse and clarify the main problems and challenges of the Baltic insurance market in order to evaluate its possible influence on the solvency of an insurance company;
- to study the solvency models in general and the requirements and challenges of the Solvency II Directive and their possible impact on the Baltic insurance market development in particular;
- to analyse in detail the insurance risk management system, including operational risk management framework as part of the Solvency II framework;

- to study the scenario planning and apply it to the risk management system in insurance in order to improve decision making and ensure the solvency and financial stability of the Baltic insurance company.
- to propose the practical possibilities in order to improve the risk evaluation system within the Baltic insurance company in line with the requirements of the Solvency II Directive:
  - to enhance the risk culture applying the Analytic Hierarchy Process and the Analytic Network Process to improve risk management in insurance in line with the Solvency II regime;
  - to study and apply the copula theory in order to improve operational risk measurement in insurance in line with the Solvency II regime and evaluate its impact on the Baltic insurance company development.

#### The Object, Subject, Hypothesis and Limitations of the Doctoral Thesis

The **object** of the research is the Baltic insurance companies as participants of Baltic insurance market. The **subject** is the improvement of risk management and measurement system and assessing its influence on the Baltic insurance company's development.

The **hypothesis** of the research is the risk management and measurement system based on a copula approach in terms of risk measurement and hierarchy methods applied to risk management ensures solvency and financial stability of the Baltic insurance companies.

The **limitations** of the research are mainly related to the author's concentration on operational risk management for the non-life insurance market; thus, the aspect of a reinsurance and life insurance company has not been studied. The authors' research is limited to the risk analysis and risk assessment in terms of the process of risk management. The author defines risk management in a similar way as under the Solvency II framework. The research is based on the rational choice theory since it is more appropriate for insurance. However, the risk management is not investigated in terms of "risk society". In addition, in the empirical study for operational risk measurement it is limited with the usage of the skew *t*-copula. Statistical data are available only until September 2014 due to the research timing. In the research, technical reserves are not investigated under the Solvency II framework. The author's research is concentrated on risk culture investigation; thus , other aspects of culture are not studied (for example, organisational culture).

#### Main Thesis Statements to Be Defended:

- Risk culture is the basis for implementation and development of risk management system within the Solvency II regime.
- In order to ensure the solvency and stability of an insurance company, the interconnection between the risk model and decision-making process in an insurance company should be established.
- Development and implementation of risk management and measurement system provide the opportunity of improving business results and solvency.

The Theoretical and Methodological Foundation of the Research is based on theoretical and empirical findings of the following foreign and Latvian scientists and researchers as well as organisations:

The issue of financial analysis and measurement of concentration has been considered in the studies performed by (8): Theil, Dalton, Stanford, Kramaric, Kitic, Rauch, Wende and Voronova.

Risk management has been examined on the basis of the studies performed by (28): Ernst&Young<sup>1</sup>, PricewaterhouseCoopers International Limited<sup>1</sup>, Towers Watson<sup>1</sup>, Manion, Daykin, Bennstein, Coutts, Wyman, Chandrashekhar, Kumar, Warrier, O'Shea, KPMG<sup>1</sup>, Lloyd's<sup>1</sup>, Bokans, Pinsent, Lavelle, O'Donnell, Pender, Roberts, Tulloch, Henschel, Comité Européen des Assurances<sup>1</sup>, International Association of Financial Engineers<sup>1</sup>, Deloitte<sup>1</sup>, Wilson, O'Brien, Sesma.

Risk culture has been examined on the basis of the studies performed by (15): The Institute of Risk Management<sup>1</sup>, Hofstede, MCKinsley<sup>1</sup>, Schein, Goffee, Jones, Sheedy, Griffin, Trickey, Financial Stability Board<sup>1</sup>, Farrell, Hoon, O'Donavan, Boseman, Kingsley.

Ranking methods, Analytic Hierarchy Process and Analytic Network Process have been examined on the basis of the studies performed by (67): Hovanov, Baron, Barrett, Potapov, Evstafjeva, Aron, Pareto, Zadeh, Roy, Keeney, Ralph, Tihomirova (Тихомирова), Sidorenko (Сидоренко), Saaty, Sharma, Moon, Marpaung, Bae, Rauch, Kangas, Pesonen, Kurttila, Kajanus, Wickramasinghe, Takano, Heinonen, Masozera, Alavalapati, Jacobson, Shrestha, Leskinen, Stewart, Mohamed, Daet, Shrestha, Alavalapti, Kalmbacher, Shinno, Yoshioka, Marpaung, Hachiga, Dehghanan, Khashei, Bakhshandeh, YaniIriani, Lee, Walsh, Poursheikhali, Kord, Varandi, Yüksel, Dağdeviren, Kandakoglu, Celik, Akgun, Gallego, Juizo, Wang, Yang, Smolakova, Šestakovs, Karpics, Romaskina (Ромашкина), Tatarova (Татарова).

<sup>&</sup>lt;sup>1</sup> The group of authors

In the Baltics, those methods were applied to risk management field in energy and trading industries by Rivža, Zeverte-Rivža [155] and Jansone.

Scenario planning (theoretical and practical aspects) has been investigated on the basis of the studies performed by (22): Axson, Bentham, Brigham, Houston, Ringland, Lindgren, Bandhold, Linneman, Malins, Torsten, Brands, Meissner, Wulf, Meißner, Stubner, Schwartz, Bryant, Lempert, Cherlkasova, Fadeeva, Fahey, Randall.

Risk measurement has been examined on the basis of the studies performed by (38): Embrechts, Hofert, Dutta, Perry, El-Gamal, Inanoglu, Stengel, Puccetti, Chavez-Demoulin, Targino, Shevchenko, Peters, Frachot, Georges, Roncalli, Strelkov (Стрелков), Sklar, Nelsen, Pfeifer, Nešlehová, Sempi, Pradier, Cheburini, Luciano, Vecchiato, Angela, Bisignani, Masala, Micocci, Smith, Gan, Kohn. In the Baltic States, copula theory application to risk measurement was studied by the following researchers: Kollo, Pettere, Kozlovskis, Lāce, Jansons and Kuzmina.

Within the research, the author has used the statistical base of the Baltic insurance companies (Quarterly and Annual Reports), Financial Supervisory Authorities, Central Statistical Bureau, Central Bank. Moreover, the author has studied normative documentation of the National Association of Insurance Commissioners, the Committee of European Insurance and Occupational Pensions Supervisors, the Office of the Superintendent of Financial Institutions, Latvian Actuarial Association, United Kingdom Financial and Supervisory authorities, American Institute of Certified Public Accountants in order to investigate the theoretical and legal aspects of the Solvency Directives in insurance and banking. Due to the Solvency II Directive requirements, the Latvian Supervisory Authority has made the changes in the insurance law by adding the requirements about the System of Governance [156] and also has translated the Own Risk and Solvency Assessment document [157].

In order to achieve the goal set, the author uses the theoretical and methodological analysis of the scientific literature, analytical, mathematical, statistical, comparative, priority charts, Analytic Hierarchy Process, and Analytic Network Process **methods**. Calculations are basically performed in MS Excel and MatCad.

The **Novelties** of the Doctoral Thesis are the following:

- Developed and proposed the financial stability evaluation model for the Baltic insurance company and evaluated its influence in risk management in order to ensure the financial health of an insurance company.
- Development of risk management system for the Baltic insurance company based on identified practical and theoretical interconnection between specifics of the Baltic

insurance market and the requirements of the Solvency II framework and assessment of its impact on the Baltic insurance market development.

- Development of model for risk strategy establishment in the Baltic insurance company in terms of operational risk management based on identified Baltic insurance market's risk key elements and functions, and the requirements of the Solvency II framework.
- Investigated and defined risk culture's effect on proper risk management establishment in the Baltic insurance company to ensure its solvency and stability in line with the Solvency II regime.
- Approved the scenario-planning role in relation to risk management and its impact on insurance market development that allows modelling uncertainty of the business improving governance of the process and risk culture within an insurance company, developed the scenario-planning algorithm to ensure scenario planning integration in Baltic insurance company's processes.
- Development of the algorithm of the risk culture enhancement and algorithm for decision-making improvement in the Baltic insurance company based on hierarchy methods, to improve decision making and risk assessment.
- Development of the mathematical model of operational risk measurement based on the copula theory (using skew *t*-copula) that allows assessing the capital to cover possible losses due to the occurrence of the risk events without over-reserving and putting gap capital to other needs of the Baltic insurance company.

#### The Approbation and Practical Use of Research Results

The results of the research have been presented and discussed in several conferences in Austria, Lithuania, Estonia, Latvia and in the 30<sup>th</sup> International Actuarial Congress in the USA. The presented studies have also been published in scientific proceedings. The research presented in the 30<sup>th</sup> International Actuarial Congress was awarded the "Best Research" in the field of Financial and Enterprise Risk.

Educational process: the results of research of the financial/actuarial analysis have been implemented in the educational process at Riga Technical University, by reviewing Master and Bachelor Theses as well as supervising the Master Theses at the Foreign Students Department.

The results were also presented, discussed and partially implemented in an insurance company of Baltics.

#### **Scientific Papers**

The results of the research have been presented in 15 scientific papers published in the Latvian, English and Russian languages.

- Stepchenko, D., Voronova, I. Assessment of Risk Function Using Analytic Network Process. In: *Engineering Economic Journal*, 2015, 26 (3), pp. 264–271 (ISI Web of Science).
- Stepchenko, D., Pettere, G., Voronova, I. Improvement of Operational Risk Evaluation under the Solvency II Framework. In: *Risk Governance & Control: Financial Markets* & *Institutions*, Vol. 5, Issue 2, 2015, pp. 135–141 (Scopus).
- Stepchenko, D., G., Pettere, Voronova, I. Application of the Stochastic Models in Operational Risk Modelling In: 16<sup>th</sup> ASMDA Conference Proceedings, Greece, 2015, pp. 801–812 (Scopus).
- Stepchenko, D., Voronova, I., Pettere, G. Investigation of Insurance Company Financial Stability: Case of Baltic Non-life Insurance Market. In: 8th International Scientific Conference "Business and Management 2014" Conference Proceedings, 2014, pp. 336–344 (ISI Web of Science).
- Stepchenko, D., Voronova, I., Pettere, G. Operational Risk Effect on Insurance Market. In: *International Actuarial Congress Proceedings*, 2014, pp. 1–9 https://cas.confex.com/cas/ica14/ webprogram/Session5820.html
- Stepchenko, D., Voronova, I. Insurance Company's Performance Risk Evaluation. In: *RTU ZR "Datorvadības tehnoloģijas"*, Vol. 14, 2013, pp. 115–122 (EBSCO).
- Stepchenko, D., Voronova, I. Scenario Planning Role: Case of Baltic Non-life Insurance Market. In *Economics and Management Journal*, Vol. 19, No. 1, 2014, pp. 36–43. doi:10.5755/j01.em.19.1.6303 (EBSCO).
- 8. Stepchenko, D., Voronova, I. Метод сценарного планирования в страховании. In: *Rusian web-conference "Проблемы управления государственными и частными финансами в России, Центральной и Восточной Европы"*, 2013, pp. 1–4. http://sdo.rea.ru/cde/conference/9/viewFiles.php
- Stepchenko, D., Voronova, I., Pilatova, M. Business Planning Problems in Risk Situation in Non-financial Industry. In *RTU IEVF scientific proceedings "Ekonomiskie pētījumi uzņēmējdarbībā"*, Vol. 11, 2013, pp. 73–80.
- Stepchenko (ex. Kalinina), D., Voronova, I. Risk Management Improvement under Solvency II. In: *RTU Publisher "Economics and Management Journal"*, 2012, pp. 29– 36. ISBN 9789934103605 (EBSCO).

- Stepchenko (ex. Kalinina), D., Voronova, I. Risk Management as a Tool to Improve the Reliability: Case of Insurance Company. In: *The 8<sup>th</sup> Annual International Scientific Conference. "Sustainable Development in Regions: Challenges and Perspectives" Klaipeda, Lithuania. September* 27–28, *Journal of Social Science, No* 2(7), 2012, pp. 48–56. http://www.ku.lt/leidykla/files/2012/09/Regional\_formation\_27.pdf (EBSCO).
- Stepchenko (ex. Kalinina), D., Voronova, I. Ways of Improving Risk Management Function in Insurance Companies. In: *Business and Management 2012. Selected papers*. Vilnius: VGTU Press "Technika", pp. 92–99. Doi 10.3846/bm.2012.013. ISBN 978-609-457-116-9 (ISI Web of Science).
- 13. Stepchenko (ex. Kalinina), D., Voronova, I. Роль государства в регулировании деятельности латвийских страховых компаний. In: *the web-conference "Российский финансовый рынок: проблемы и перспективы развития"*, Moscow, Russia, 23 April –11 June, 2012, pp. 109–115. sdo.rea.ru/cde/conference/3/file.php?fileId =42
- Stepchenko (ex. Kalinina), D., Voronova, I. Riska vadības funkcijas nodrošināšana apdrošināšanā. In: *RTU IEVF scientific proceedings "Ekonomiskie pētījumi uzņēmējdarbībā"*, Vol. 10, 2012, pp. 39–47, ISSN 16910737.
- 15. Stepchenko (ex. Kalinina), D., Voronova, I. Risku vadības funkcijas pilnveidošanas dzīvības apdrošināšanā. In: *RTU IEVF scientific proceedings "Ekonomiskie pētījumi uzņēmējdarbībā"*, Vol. 9, Rīga: RTU Izdevniecība, 2011, pp. 70–79.

The research results have been published in peer reviewed conference theses:

- Stepchenko, D., Voronova, I. Assessment of Risk Function Using Analytical Network Process. In the 2<sup>nd</sup> European Actuarial Journal (EAJ) Conference, pp. 20–20, Online: http://www.fam.tuwien.ac.at/events/eaj2014/EAJ2014\_abstracts\_conf.pdf
- Stepchenko (ex. Kalinina), D., Voronova, I. Risk Management Improvement under Solvency II. In: Riga Technical University, *Series 3 "Ekonomika un uzņēmējdarbība"*, Vol. 24, 2013, pp. 538–538, ISSN 1407-7337.
- Stepchenko (ex. Kalinina), D., Voronova, I. Scenario Planning Role: Case of the Baltic Non-Life Insurance Market. In: *The 18<sup>th</sup> International Scientific Conference on Economics and Management (ICEM-2013): Collected Abstracts*, Lithuania, Kaunas, 24–25 April, 2013. Kaunas: KTU, 2013, pp. 58–58. ISSN 2335-8025.

The research results have been presented in the international scientific conferences:

1. Participation and presentation of the paper "Роль государства в регулировании деятельности Латвийских страховых компаний", International scientific web-

conference "Российский финансовый рынок: проблемы и перспективы развития", 23 April–11May, 2012, Moscow, Russia.

- Participation and presentation of the paper "Ways of Improving Risk Management Function in Insurance Companies", the 7<sup>th</sup> International Scientific Conference "Business and Management 2012", 10 May–12, 2012, Vilnius, Lithuania.
- Participation with the paper "Risk Management as a Tool to Improve the Reliability: Case of Insurance Company", the 8<sup>th</sup> Annual International Scientific Conference "Sustainable Development in Regions: Challenges and Perspectives", 27–28 September, 2012, Klaipeda, Lithuania.
- Participation and presentation of the paper "Risk Management Improvement under Solvency II Framework", the 53<sup>rd</sup> International Scientific Conference of Riga Technical University, 11–12 October, 2012, Riga, Latvia.
- Participation and presentation of the paper "Scenario Planning Role: Case of the Baltic Non-life Insurance Market", the International Scientific Conference "Economics and Management 2013", 24–26 April, 2013, Kaunas, Lithuania.
- Participation and presentation of the paper "Метод сценарного планирования в страховании", International Scientific Web-conference "Проблемы управления государственными и частными финансами в России, странах Центральной и Восточной Европы", 7–15 October, 2013, Moscow, Russia.
- Participation and presentation of the paper "Insurance Company's Performance: Risk Evaluation", the 54th International Scientific Conference of Riga Technical University, 14–17 October, 2013, Riga, Latvia.
- Participation and presentation of the paper "Operational Risk Effect on Insurance Market's Activity", the 30<sup>th</sup> International Congress of Actuaries (awarded the "Best Paper" in the section "Financial and Enterprise Risk"), 30 March–4 April, 2014, Washington DC, USA.
- Participation and presentation of the paper (not published yet) in the 2<sup>nd</sup> European Actuarial Journal (EAJ) Conference, 8–12 September, 2014, Vienna, Austria.
- Participation and presentation of the paper "Assessment of Operational Risk Based on Copula Approach", the 56<sup>th</sup> International Scientific Conference "Scientific Conference on Economics and Entrepreneurship (SCEE'2015)" of Riga Technical University, 14– 15 October, 2015, Riga, Latvia.

**Chapter 1** is devoted to the research of main challenges and problems of the Baltic insurance market. During the present research, the financial assessment of the Baltic insurance market is performed in order to evaluate its financial stability. However, the author also presents the possible core structure of monthly financial assessment and the performance evaluation model for the Baltic non-life insurance company to ensure the stability, solvency and understanding of financial results of an insurance company. In addition, the level of the Baltic insurance market concentration is measured since it plays a special role in the improvement of risk assessment in an insurance market. The author performs a study of the main features of the Solvency I Directive and the Solvency II Directive, identifying the main similarities and differences, to emphasise the necessity and main challenges of the Solvency II Directive. Furthermore, the risk self-assessment of the Baltic insurance market is investigated since it is the transitional risk management tool from the Solvency I Directive to the Solvency II framework.

**Chapter 2** covers the research and theoretical aspects of historical solvency models and their use in risk management. The author also investigates the Solvency II Directive's structure, significance, role and requirements. In addition, the System of Governance, also including Own Risk and Solvency Assessment, is studied since it is the main challenge of the Solvency II regime. However, the author also investigates the theoretical aspects and role of the risk culture in insurance under the Solvency II framework, by investigation of main risk culture's dimensions in insurance. The author's study on the theoretical aspects of copula theory and its influence on risk assessment in insurance is also presented in this Chapter. Chapter 2 is also devoted to the detailed analysis of risk nature under the Solvency II Framework and the author's research of the practical and theoretical aspects of the structure of risk management system and its main components; in particular the operational risk management system is analysed.

**Chapter 3** presents theoretical aspects of new quantitative and qualitative approaches of risk assessment enhancement in insurance. The author has investigated the risk culture role in risk assessment in Baltic insurance company. This Chapter is also devoted to the theoretical aspect of the scenario planning and its role in risk management system. In addition, the author investigates and proposes the practical application of the scenario planning integration in insurance company's processes as part of risk management system with the aim to ensure the solvency and financial stability and improve the decision making of an insurance company.

**Chapter 4** is devoted to the models of risk assessment improvement, created by the author. The author presents the case studies to prove the application of ranking methods, Analytic Hierarchy Process and Analytic Network Process to insurance with the aim to improve

the risk management function through enhancement of the risk culture in an insurance company. However, the author investigates the possible application of copulas in operational risk measurement with the aim to improve the assessment of the capital that is required for this risk.

The **final Chapter** summarises main conclusions and findings of the present Doctoral Thesis, also proving the usage and importance of introduced novelty of the research. Besides, the author also emphasises several proposals of risk management and measurement improvement.

The Doctoral Thesis comprises abstract, acknowledgments, introduction, 4 chapters, conclusions and proposals, bibliography, and appendices. The Doctoral Thesis is based on 157 reference sources included in the bibliography. It has been illustrated by 33 tables, 61 figures and 39 equations. The volume of the Doctoral Thesis is 160 pages, including appendices.

#### **1. BALTIC INSURANCE MARKET PROBLEMS AND CHALLENGES**

#### **1.1. The Analysis of Baltic Insurance Market Development**

#### 1.1.1. The Identification of Baltic Insurance Market Concentration

In order to analyse the development of the Baltic non-life insurance market, the volumes and concentration should be analysed. The Baltic non-life insurance market development in terms of volume is presented in Fig. 1.



<sup>\*</sup> The data is for 9M 2014



Based on Fig. 1, the author can conclude that the development of the Baltic non-life insurance market has heavily been affected by the economic downturn, and in recent years the non-life insurance has been recovering, particularly quickly in Lithuania. The largest non-life insurance market is in Lithuania; however, the market volumes in Latvia and Estonia are almost similar. However, it is important to mention that Baltic insurance market is rather narrow compared to other countries in European union, therefore macroeconomical factors have significant influence on Baltic insurance company's development.

The author has investigated the development of Baltic non-life insurance market in terms of its structure. The summary of the research is presented in Fig. 2.



Fig. 2. The development of the Baltic non-life insurance market (compiled by the author)

Based on Fig. 2, the author can conclude that in recent years the number of Baltic nonlife companies has grown quite significantly due to the several reasons: (1) to establish proper, transparent and unified processes in one organisation among all three Baltic countries; (2) to improve the efficiency of the processes that would help to decrease the cost level of a non-life insurance company; (3) to improve the level of employees' knowledge through the exchange of experience among all three Baltic countries. In order to create a more appropriate approach to the analysis of Baltic non-life insurance companies, the author has investigated the concentration of the non-life insurance market in each Baltic country. The research of the concentration of the non-life insurance market is based on  $7^2$  (seven) Baltic non-life insurance companies using three main indices: concentration index, Herfindahl-Hirschman index, Theil's entropy index [9, 10; 11]. In fact, market concentration is related to return on equity or return on CAR capital. Dalton and Levin (1977) have concluded that market shares and profit rates are directly related only in the high concentration subgroups. When concentration is low, market share and rates of return are not related. The evaluation of the market concentration plays a special role in the improvement of risk assessment in an insurance market and for its participants. The research has been conducted both for each Baltic country separately and for the total Baltic market. The concentration analysis using the concentration index is presented in Figs. 3, 4, 5, 6.

<sup>&</sup>lt;sup>2</sup> The author has selected only non-life insurance companies that operate in all three Baltic countries since those companies could significantly influence the solvency of the non-life insurance within the Baltic States.



**Fig. 3.** The analysis of the Latvian non-life insurance market using the concentration index (created by the author based on [1]–[8])

According to Fig. 3, the concentration of the Latvian insurance market has grown by 14 percent over the last 11 years that proves the tendency that the dominance of leading Baltic companies is growing.



**Fig.** 4. The analysis of the Estonian non-life insurance market using the concentration index (created by the author based on [1]–[8])

According to Fig. 4, the concentration of the Estonian insurance market has grown by 11 percent over the last 11 years and there is particularly high dominance of the leading Baltic companies.



**Fig. 5.** The analysis of the Lithuanian non-life insurance market using the concentration index (created by the author based on [1]–[8])



**Fig. 6.** The analysis of the Baltic non-life insurance market using the concentration index (created by the author based on [1]–[8])

However, Fig. 5 demonstrates that the concentration of the Lithuanian insurance market has grown by 12 percent over the last 11 years that shows the highest growth of concentration among all three Baltic countries.

Based on Fig. 6, the author can draw the conclusion that the concentration of the Baltic non-life insurance market has grown by 12 percent over the last 11 years and reached 82% in 2013. The concentration growth of the Baltic non-life insurance market could be explained by strengthening of the solvency requirements because of tough market conditions due to the financial crisis that pushed out weaker non-life insurance participants.

The Herfindahl–Hirschman index that is close to 100% characterises monopoly markets, meanwhile the Herfindahl–Hirschman index between 1000 and 1800 means average concentration of the market, wherein an index that exceeds 1800 characterises a high level of concentration of the market [11]. The concentration analysis of the Baltic market using the Herfindahl–Hirschman index is presented in Table 1.

Table 1

Years	Country			
	Latvia	Estonia	Lithuania	The Baltics
2003	1054	2325	1479	1070
2004	1147	2597	1224	1071
2005	1244	2525	1550	1172
2006	1363	2339	1637	1212
2007	1309	2056	1837	1173
2008	1299	1674	1680	1157
2009	1308	1577	1583	1129
2010	1365	1617	1604	1174
2011	1196	1568	1387	1109
2012	1137	1535	1450	1161
2013	1255	1474	1428	1178

The Analysis of the Baltic Non-life Insurance Market Using the Herfindahl–Hirschman Index (compiled by the author based on [1]–[8])

On the basis of the Herfindahl–Hirschman index, the author has come to the conclusion that the market concentration corresponds to the medium competitive level. The decrease in market concentration in 2011 in the Baltics was due to recession in economics that led to lower gross written premium volumes for the leading non-life insurance companies.

The fact is that Theil's entropy index is derived from the notion of entropy in the information theory [9]. The concentration analysis performed by the author using the Theil's entropy index is depicted in Fig. 7.



**Fig. 7.** The Analysis of the Baltic non-life insurance market using Theil's entropy index (compiled by the author based on [1]–[8])

Based on Fig. 7, the author can conclude that the Theil's entropy index demonstrates that the Baltic non-life insurance market is medium concentrated; the lowest concentration is characteristic of the Lithuanian non-life insurance market. Medium concentration level of the Baltic insurance market enables one to use a common approach to assessing the solvency and financial health of each non-life insurance company in the three Baltic countries.

All in all, market concentration is directly related to risk management since leading insurance companies are responsible for the solvency of the total insurance market. Thus, the author can conclude that it is important to evaluate the concentration of an insurance market in order to improve risk assessment in a particular market.

#### 1.1.2. The Analysis of Stability and Solvency of the Baltic Insurance Market

The main purpose of insurance financial indicators is to evaluate an insurance company's performance, identify and eliminate possible risk affecting an insurance company's development.

In order to assess an insurance company's financial health, different financial ratios of solvency and stability should be used [12]–[14]. The author can conclude that financial evaluation is part of risk management framework. Traditionally, all insurance financial ratios are grouped into 4 (four) groups:

- operating ratios that characterise the operational performance of an insurance company;
- profitability ratios that give the overview of financial performance of an insurance company;
- leverage or capitalisation ratios that measure the exposure of insurance company's surplus to various operating and financial practices;
- liquidity ratios that measure the ability to meet insurance company's short-term financial obligations.

For example, Irina Voronova [14] in her paper distinguishes three main groups of financial ratios that can be used in non-life insurance companies to evaluate their financial stability:

- solvency ratios that mainly characterise the operational performance of an insurance company;
- safety ratios that mainly focus on an insurance company's ability to undertake the risks;
- competitiveness ratios that characterise the competitiveness and commercial potential of an insurance company.

The Baltic non-life insurance market is rather young and its volume is rather small compared with other European Union member states. Over the last 7 (seven) years, the number of market participants has been quite stable, only a few non-life insurance companies have left the market due to lack of technical reserves resulting in the inability to fulfil their obligations to policyholders and beneficiaries.

The bankruptcy of several market participants highlights the necessity for an in-depth financial analysis to be performed on a daily basis with the aim to ensure financial stability of a non-life insurance company. The author has investigated the existing system of evaluation of non-life insurance company's financial results (see Fig. 8).

According to Fig. 8, in order to evaluate the company's basic activity the insurance financial ratios are mainly used that assess the solvency of an insurance company. However, the main indicators are usually compared with plan estimates and the outcome of previous periods.



**Fig. 8.** Actual analysis of insurance company's performance evaluation in the Baltic countries (created by the author based on [12]–[14])

The Solvency II framework requires more sensitive and sophisticated risk evaluation for ensuring the solvency of insurance companies and protecting the interests of policyholders. Therefore, it is crucial to ensure the market stability using a more appropriate and complex evaluation scheme of financial stability of an insurance company performance.

In order to prepare the universal model for the performance assessment of each Baltic non-life insurance company, the author has investigated the financial situation of the Baltic non-life insurance market. The author has analysed the Baltic insurance market's financial stability and solvency using the following financial ratios since they fully represent the non-life insurance company's ability to get financial benefit from an insurance activity, thus ensuring positive underwriting results:

- risk ratio that shows the relation between claims incurred (excluding claims handling costs) and net earned premiums;
- cost ratio that is the net operating expense, including claims handling proportion in net earned premiums;
- combined ratio that shows claims incurred and operating expense proportion in net earned premiums or the sum of risk ratio and cost ratio.

The author proposes using the above-mentioned ratios since they fully represent the financial stability of a non-life insurance company. The analysis of the solvency and financial stability of the Baltic non-life insurance is presented in Fig. 9.



**Fig. 9.** The solvency analysis of the Baltic non-life insurance market (compiled by the author based on [1]–[8])

Fig. 9 demonstrates that the Baltic market solvency is quite stable and less than 100% in almost all periods. Basically, the most profitable is the Estonian non-life insurance market with the lowest combined ratio over the last six years. Besides, the Estonian market is characterised by the highest average insurance premium among the Baltic countries.

All in all, risk ratio and cost ratio of the Baltic non-life insurance market are recognised to be at a normal level, but the Latvian and Lithuanian non-life insurance markets' results should be more carefully managed with the control and risk management functions. In order to ensure the fulfilment of the requirement of the Solvency II Directive, particularly in terms of the risk management, the appropriate financial follow-up should be established. The fact is that within the research the author concentrates on the following issues of insurance financial ratios:

- to discover and evaluate significant differences between fair value of investments and their costs or amortised costs;
- to check the equity section for unrealised gains (losses);
- to check for a deferred policy acquisition cost build-up;

- to check that loss reserves grow adequately with insurance in force;
- to identify the main risk that can impact non-life insurance company's development in the short term;
- to identify the weaknesses of cost management.

The financial model to follow the financial results of an insurance company proposed by the author is based on the following main principles:

- no additional high workload to employees;
- no additional high financial resources required;
- easy to understand, apply and integrate into processes;
- a common approach that is easy to implement and integrate into daily processes of an insurance company.

The core structure of monthly financial assessment of the Baltic non-life insurance company performance, developed by the author, is presented in Fig. 10. This model is developed to ensure the stability, solvency and understanding of financial results of an insurance company.



Fig. 10. Core structure of monthly financial assessment (created by the author)

The core structure of monthly financial assessment model fully describes and presents the overview on the non-life insurance company's performance. The author also emphasises that monthly financial assessment should be performed using vertical and horizontal analysis principles. The performance evaluation model for the Baltic non-life insurance company is presented in Fig. 11.



\*The arrow's width represents the importance of evaluation



According to the performance evaluation model for the Baltic non-life insurance company (see Fig. 11), the assessment should start with the monthly activity analysis and end with possible future development evaluation and the creation of probabilistic models.

The first stage is to establish the core financial analysis on a monthly basis using vertical and horizontal analyses. It is also important to follow up costs development (one of the operational ratio components) and try to optimise the cost structure of an insurance company. The second stage is to prepare the liability adequacy test to ensure the adequacy of reserve level in an insurance company. The third stage is to implement a strategic organisational planning tool — scenario planning — as one of the possible solutions to evaluate and assess possible short-term outcomes of an insurance company activity. The fourth stage is to test the possible future outcomes of an insurance company activity forecasted using scenario planning through critical stress testing, which allows conducting the sensitivity analysis of external factors'

influence on the possible development of an insurance company. The fifth stage is to integrate probabilistic models to ensure appropriate risk measurement in an insurance company.

The performance evaluation model for the Baltic non-life insurance company should also improve the reliability of an insurance company. In fact, the introduced model is part of risk self-assessment that increases every insurance company's reliability by means of risk monitoring at each business unit level.

### 1.2. The Analysis of Risk Management System in the Baltic Insurance Market

### 1.2.1. The Identification of Problems and Challenges of Risk Management System of the Baltic Insurance Market

Insurance is one of the most important constituents of every country's economy as it provides possibilities of increasing national prosperity.

The Solvency I Directive was established to ensure the solvency of an insurance company using more realistic capital requirements. The development of the necessary legislative framework began in the 1970s with the first generation Insurance Directives, but was only completed in the early 1990s with the third generation Insurance Directives. The third generation Insurance Directives established an "EU passport system" (single licence) for insurers based on the concept of minimum harmonisation and mutual recognition. The Directives required the Commission to conduct a review of the solvency requirements. A limited but expedited reform — Solvency I — was agreed in 2002, following that review [15]. The author of the Doctoral Thesis has performed the study [15]–[23] in order to investigate main weaknesses of the Solvency I Directive:

- lack of risk sensitivity and risk correlation;
- insufficiency of international and cross-sectorial convergence;
- restrictions on the proper functioning of a single market due to additional rules at a national level;
- orientation towards the past (based on a cut-off date);
- restrictions on the composition of an insurance company's portfolio;
- wrong incentives created by the premium index;
- limited and inadequate consideration given to reinsurance;
- undifferentiated consideration of insurance company's capital investments;
- sub-optimal arrangements for the supervision of insurance companies.

Comparison between the Solvency I Directive and the Solvency II Directive by Pillars (compiled by the author based on [15]–[23])

	The Solvency I Directive	The Solvency II Directive
1 <sup>st</sup> Pillar	Accounting view	Economic view
	No internal model used	Increase of market value
	Minimal capital requirements	Total capital requirements: solvency capital requirements and prudence margin
	Local accounting standards: IFRS/GAAP reporting	Minimal capital requirements inside solvency capital requirements
	Minimal capital required	Solvency capital requirements include minimal capital requirements
	Free surplus	Increased free surplus
	Technical provisions	Technical provisions
	No internal model	Possibility of internal model usage with acceptance of management board
		Basic and ancillary own funds
		Economic value of liabilities
llar	Supervisory	Supervisory
	Non-harmonisation in principles across the European Union	Based on unified principles
	Group capital assessment without diversification benefit	Group capital assessment with diversification benefit
id bi		Capital add-ons
5		Implementation of the System of Governance and risk management
		Implementation of risk culture
		Own risk and solvency assessment
<sup>1</sup> Pillar	Some public disclosure	Public disclosure
	Regulatory return	Private reporting
3 <sup>rt</sup>		More regular disclosure

The author has analysed the differences and similarities between the Solvency I Directive and the Solvency II Directive and summarised them by pillars in Table 2.

Thus, the decision of necessity in new solvency requirements was taken due to weaknesses of the Solvency I Directive. The core structure of the Solvency II Directive is presented in Section 2.1. Also, the author has defined the most important differences between the Solvency I Directive and the Solvency II Directive:

- in the Solvency II Directive the main focus is on proper implementation and improvement of risk function;
- risk sensitivity is not included in the Solvency I Directive; therefore, in the Solvency II Directive risk sensitivity sets a special role;
- the Solvency I Directive is based on the required minimum reserve (basically, on quantitative requirements), but the Solvency II Directive is based on qualitative and quantitative requirements;
- the requirements of the Solvency I Directive could not sufficiently ensure the supervision of insurance companies; therefore, under the Solvency II framework the System of Governance was introduced;
- internal model could be used under the Solvency II regime; however, there is no such a possibility under the Solvency I Directive;
- the requirements of the Solvency II Directive are harmonised across the European Union;
- establishment and strengthening of an insurance company's risk culture play a special role in the Solvency II Directive;
- improvement of public disclosure and reporting is a core element of the Solvency II Directive;
- different approaches to technical requirements and standards.

Unfortunately, the Solvency I Directive did not reflect the true risk of an insurance company to ensure the sophisticated analysis of an insurance company's financial and solvent situation in relation to current development, risk assessment, monitoring, financial policy and international financial statements that was crucial in a changing market situation.

The fact is that the requirements of the Solvency II Directive are not just about capital of an insurance company but about risk assessment through the implementation and enhancement of risk measurement and risk management.

Also, the Solvency II regime requires higher required capital compared with the requirements of the Solvency I Directive that should ensure the solvency and financial stability of each insurance company.

However, the biggest challenge to the insurance industry is the System of Governance since it asks for prudent and efficient management. The structure of the System of Governance is presented in Fig. 12.



**Fig. 12.** The System of Governance under the Solvency II Framework (compiled by the author based on [15]–[24])

The author has investigated the core principles of the System of Governance and presented them in Fig. 13:



**Fig. 13.** The core principles of the System of Governance under the Solvency II framework (compiled by the author based on [15]–[24])

Based on the requirements of the Solvency II Directive, the insurance companies should hold the appropriate amount of reserves that could ensure safety of policyholders and beneficiaries. The author can conclude that the Solvency II framework poses a lot of challenges to the insurance industry.

All in all, the author can conclude that the Solvency II framework poses a lot of challenges to the insurance industry. Thus, some insurance companies can face the problems with the new regime requirement that can negatively influence the stability of the insurance market.

#### 1.2.2. The Risk Analysis of the Baltic Insurance Market

The Baltic insurance market is rather narrow; therefore, the development of the risk management system is a complicated process. The point is that due to the Baltic insurance market every insurance company's reliability and activity depend on the risk management system. The first step to improve every insurance company's reliability within the establishment of risk management system is to develop and integrate the risk self-assessment tool. Baltic insurance companies have started to report on risk self-assessment in quarterly and annual reports since 2005 [1-8]; thus, it can be regarded as the acknowledgment of the insurance companies' concentration on the implementation and improvement of risk self-assessment. The regulation rule of risk self-assessment elements can also be defined as the transition period from the Solvency I regime to the Solvency II framework. The non-life insurance companies mainly report in their quarterly and annual reports about the following risks:

- operational risk that can be defined as the financial losses occurred due to incorrectly defined systems or processes; failures in IT system, human mistakes or other external processes;
- insurance risk that is the insurance company's financial losses that occur due to insurance operations;
- reinsurance risk that is the insurance company's financial losses caused by reinsurance operation;
- financial risk that is the possible financial losses of an insurance company that occur due to the company's main activity like investment policy, credit etc.

The risk self-assessment tool is based on the main positions and principles presented in Table 3.

No.	Heading	Description
1	Number	Number of the line
2	Main risk identified	Description of the identified risk: situation analysis, risk factors that increase risk occurrence probability and possible losses
3	Control system	Description of the exiting control system to avoid risk occurrence probability
4	Assessment result of risk occurrence probability according to the scale of 1–5	1 — rare (less than 1%); 2 — unlikely (1.1% –%); 3 — moderate (10.1% – 50%); 4 — almost possible (50.1% – 80%); 5 — possible (80.1% – 100%).
5	Assessment result of risk possible losses according to the scale of 1–5 (direct and indirect expenses)	1 — insignificant (<1000 EUR); 2 — low (1000 – 5000 EUR); 3 — average (5 000 – 20 000 EUR); 4 — significant (20 000 EUR – 100 000 EUR); 5 — maximum (> 100 000 EUR).
6	Assessment of the existing risk final result (scale of 1–25)	Estimated risk occurrence probability multiplied by estimated risk possible losses
7	Risk trend (increasing, stable, decreasing)	Give indication or compare with the previous year assessments
8	Risk ranking	20–25 points — very critical risk with the necessity of the immediate actions towards managing and controlling the risks; 12–19 points — critical risk with the necessity of managing and controlling; Less than 12 points — normal risk with the minimum impact on company's activity; therefore, it is necessary to pay attention to its future development
9	Evaluation of risk control system according to the scale of 1–5	<ol> <li>1 — risk control system is implemented and provides maximum security;</li> <li>2 — risk control system is implemented but provides security at an average level;</li> <li>3 — risk control system is implemented but provides a low security level;</li> <li>4 — risk control system is in the implementation process;</li> <li>5 — risk control system is not implemented.</li> </ol>
10	Assessment of the exiting risk control system (scale of 1–25)	Estimated risk occurrence probability multiplied by evaluation of risk control system
11	Risk control ranking	<ul> <li>20–25 points — risk control system needs to be improved immediately;</li> <li>12–19 points — risk control system needs to be improved as soon as possible;</li> <li>Less than 12 points — normal risk control system, but it is necessary to pay attention to future development</li> </ul>

According to the requirements of the Solvency II Directive, a more sophisticated analysis of risk should be performed in order to ensure better risk coverage. The risk self-assessment is the transitional risk management tool from the Solvency I Directive to the Solvency II framework. The risk self-assessment tool is also used to evaluate and map the most significant insurance company's risks and their occurrence probability and possible losses. The main company's risks should be included in the risk self-assessment process. The risk self-assessment is the risk management tool that increases every insurance company's reliability by means of risk monitoring at each business unit level.

Therefore, the risk self-assessment process is an excellent opportunity for every insurance company to coordinate risk management efforts and generally improve the understanding of risk management strategy. The most convenient and cheap way is to implement risk self-assessment tool using MS Excel.

The aim of the risk self-assessment framework is to identify, assess, control and mitigate insurance company's risks and to maintain effective reporting of risk and emerging risk issues.

Risk self-assessment can be performed and reviewed for every insurance company's business line according to organisational structure on a monthly, quarterly or annual basis.

Risk self-assessment is an excellent tool for Baltic insurance companies to improve their risk management system according to the Solvency II Directive with the aim to increase reliability and solvency.

# 2. INVESTIGATION OF RISK MANAGEMENT SYSTEM IN INSURANCE

## 2.1. Development of Solvency Assessment Models and Their Impact on Risk Management in Insurance

2.1.1. Theoretical Aspects of the Solvency Assessment Models

Insurance relates to risk management as the main aim is to ensure the insured person safety and to pay to an insurant or beneficiary, or insured legatee the necessary claim sum in case of risk event occurrence. Therefore, insurance offers the sense of protection to the clients.

The fact is that many different solvency models have been developed and implemented by insurance companies in different countries with the main aim to protect policyholders' and beneficiaries' interests by ensuring the financial stability and solvency of an insurance company. In general, all solvency models include strict requirements in relation to the fulfilment of commitments to policyholders and beneficiaries ensuring correct pricing of insurance products. Thus, the aim of the solvency models is to ensure proper amount of own capital that should be held by the companies to cover all possible obligations to the policyholders and beneficiaries in a certain period of time.

Historically, many different solvency models have been developed by leading key employees of the insurance companies such as Daykin, Bernstein, Pentikainen, Rantala etc [34]–[37] in England, Europe, USA, Switzerland etc. The fact is that each solvency model is based on common principles and deals with the modelling of particular risk to ensure the solvency and stability of an insurance company.

Basically, financial authorities supervise the activity of insurance companies across the world: NAIC in the USA, CEIOPS in the European Union, OSFI in Canada etc. However, the author has investigated the basis and nature of different solvency models, and the summary of the research is presented in Fig. 14.

Presented in Fig. 14 solvency models was developed in different time periods and some are still under the development stage. For example, the German insurance industry has developed GDV-model from 1997 till 2002 in order to model market risk in insurance model; Australia Model Insurance Reform Act was developed in 1973.



Fig. 14. The summary of historical solvency models (prepared by the author based on [35]-
Fig. 14 fully describes the nature, basis as well as approaches of the historical solvency models. The solvency models are divided into the two main groups: statistical or accounting models that are based on strict rules defined in advance and dynamic or cash flow models that are based on principles or specific risk scenarios. For example, the Solvency I Directive is a statistical model, but the Solvency II Directive is a dynamic model since it is based on particular principles to ensure the financial health and solvency of an insurance market in the European Union.

In the USA, the solvency of insurance companies is guided using the RBS (Risk Based Capital) developed under the SMI (Solvency Modernisation Initiative). The comparison between the Solvency II Directive risk measurement and the RBS is presented in Fig. 15.

- MethodologyBasis
- Risk measure
- Time period
- Market vs book value
- Classification of available capital
- Cosideration of offbalance sheet items
- Correlation among risk
- Establishment of risk management

# RBS

- Static factor modelRule-based except variable annuities
- No risk measure
- 1 year
- Book value
- No
- No
- No, only for credit and reserve risk
  No, partially is in SMI
- No, partially is in SMI

## Solvency II

- Dynamic cash-flow model
- Principle-based
- Value at Risk at a 99.5% confidence level
- 1 year (with ORSA planning cycle)
- Market value
- Yes, economic value of liabilities and assets
- Yes
- Yes, between and within risk
- Yes
- Fig. 15. The comparison of the Solvency II Directive and the RBS (based on [37], [39] with the author's changes)

In order to thoroughly study new challenges of the European Union's insurance industry, the author has compared the Basel II Directive and the Solvency II Directive in order to investigate main similarities.

The Basel Accord was implemented in the European Union via the Capital Requirements Directive (CRD), which was designed to ensure the financial soundness of credit institutions (banks and building societies) and certain investment firms. The CRD came into force on 1 January 2007, with firms applying the advanced approaches from 1 January 2008

[40]. The analysis of banking sector can be performed because of the reason that the requirements of the Solvency II Directive were based on the rules of the Basel II framework. The main difference is the sectors' unique features.

The main similarities between the Basel II framework and the Solvency II regime are the following [40]–[41]:

- a three-pillar approach;
- renewal of relatively outdated regulations;
- ambitious in terms of the improvement;
- requirements for development of employee new skills;
- more risk-sensitive regulatory capital requirements;
- more sophisticated risk analysis;
- establishment and improvement of risk management;
- the change of business control;
- the change of risk management principles;
- the change of financial analysis approaches.

The author has investigated not only the similarities between the Basel II framework and the Solvency II Directive but also analysed the key areas and problems of risk management using the survey results of the Basel II regime.

The author investigates risk appetite and most critical risks in the banking sector based on the Basel II framework. The author presents the Ernst&Young company's survey that was held in 2012 among 75 banks in 38 countries about the most critical risks of banking sector (see Figs. 16–18).

Fig. 16 demonstrates that the most critical risks in the banking sector are liquidity, credit and market risks as well as operational risk. Basically, the author recognises the possibility of having similar critical areas under the new regime in insurance. The operational risk is identified as the most critical of core risks by 36% of respondents. The author investigates operational risk assessment under the Solvency II framework in Chapter 4.

The point is that it is critically important to agree on the metrics that will be used to set and monitor the risk appetite. However, in order to set risk appetite several key qualitative issues should be considered. The author presents the survey among banks about key qualitative issues in setting risk appetite in Fig. 17.



Fig. 16. The most critical risks in the banking sector [42]



Fig. 17. Survey on the key qualitative issues in setting risk appetite [42]

Based on Fig. 17, the author can conclude that key qualitative issues in setting risk appetite are related to business planning and drilled down into almost all processes of a bank.

Risk appetite defines the amount of total risk that an organisation accepts to hold. Moreover, risk appetite is an important figure for every insurance company and is expressed in qualitative units using key metrics and forms that are based on the risk management function. Furthermore, the quantitative metrics for setting and monitoring risk appetite in order to set a target risk profile are presented in Fig. 18.



Fig. 18. Survey of quantitative metrics for setting and monitoring risk appetite [42]

On the basis of Fig. 18, the author can conclude that the banks in most cases use such quantitative metrics for settings and monitoring risk appetite as capital buffers, limits, capital ratios, concentration limits, possible loss estimation, Tier 1 ratio, stress testing results and VaR.

However, the risk profile in practice could be defined using risk mapping, including the risk of the 1<sup>st</sup> Pillar under the Basel II framework as well as under the Solvency II regime. The point is that it is critically important to agree on the metrics that will be used to set and monitor the risk appetite. The fact is that the risk profile includes all the risks that the company is exposed to, considering the specific features of each insurance company.

Therefore, both key qualitative and quantitative issues in setting risk appetite are related to business planning and drilled down into the organisation.

The special role under the Solvency II framework similar to the Basel II regime is played by risk culture that is one of the most important focus areas of the management board. The definition of risk culture will be studied in Section 2.1.3.

#### 2.1.2. The Application of the Solvency Assessment Models to Insurance

Historically, the supervisor authorities introduce to insurance companies different approaches, methods and models to ensure the solvency of insurance companies, thus securing the interests of policyholders and beneficiaries.

Solvency II is an EU legislative programme to be implemented in all 27 Member States, including the UK. It introduces a new, harmonised EU-wide insurance regulatory regime. The legislation replaces 13 existing EU insurance directives [43]. The European Solvency II Directive establishes the ground rules for good governance as a complete system composed of functions and rules used by regulators and models for appropriate decision-making procedures [44]. Solvency II will set out new, stronger EU-wide requirements on capital adequacy and risk management for insurers, with the aim of increasing protection for policyholders. The strengthened regime should reduce the possibility of consumer loss or market disruption in insurance [45].

The fact is that the new solvency framework will consist of three main thematic areas, or "pillars", of regulation which are designed to be mutually reinforcing. Pillar 1<sup>st</sup> consists of the quantitative requirements (i.e. how much capital an insurer should hold). Pillar 2<sup>nd</sup> sets out requirements for the governance and risk management of insurers, as well as for the effective supervision of insurers. The focus of Pillar 3<sup>rd</sup> is on supervisory reporting and transparency requirements [46].

The Solvency II Directive's requirements are planned to be more risk sensitive and more sophisticated than the Solvency I Directive requirements with the purpose to provide every individual insurance or reinsurance company's real risk better coverage [47]. The structure of the Solvency II Directive is presented in Fig. 19.



Fig. 19. The Solvency II approach (created by the author based on [21], [22], [28], [29])

The 1<sup>st</sup> Pillar introduces the approach of calculation of adequate capital to meet all obligations of insurance companies, basically to keep proper amount of capital to cover all risks faced by insurance companies. The biggest challenge is to adapt the standard formula of capital calculation or implement the internal formula that could be more appropriate for some insurance companies.

The  $2^{nd}$  Pillar introduces the qualitative requirement that includes the system of government that creates the biggest challenge for industry since asks for new approaches of risk assessment.

Risk management function also goes under the 2<sup>nd</sup> Pillar that sets out risk management and measurement objectives to ensure adoption of robust risk management processes that are carried out across the entire organisation and form the basis for informing and directing the insurer's decision making [28], [29].

Risk management is about to define a risk profile that intends to align with the stakeholder's risk appetite and risk tolerance, likewise keeping risks and losses within insurer's risk tolerance. Moreover, risk management function should be fit and proper with the aim of developing strategies, processes, reporting procedures to identify measure, monitor, manage and report the risk.

The 3<sup>rd</sup> Pillar covers disclosure and transparency requirements. The biggest challenge of this Pillar's requirements is enhancement of reporting systems in insurance companies to ensure data quality and proper reporting to the supervisory authorities and the public.

The main reasons for the implementation of the Solvency II framework are the following:

- to deepen the integration of the European Union insurance market;
- to enhance the protection of insurance policyholders and beneficiaries;
- to enhance the international competitiveness of the EU insurers through a better allocation of capital at a firm level, at the industry level, and within the EU economy;
- to strengthen supervisory review of insurance companies;
- to enhance the solvency of insurance companies, increasing transparency and confidence in the whole sector;
- to ensure reasonable costs for insurance companies through more efficient allocation of risk and capital within the economy that should promote financial stability in the medium to long term;
- to set the specific risk-profile of each insurance company, using risk measurement principles;
- to enhance transparency and public disclosure;
- to set supervisory convergence and cooperation through harmonised approaches of risk management and risk measurement across Europe.

The Solvency II Directive is based on certain requirements for insurance companies that are based on the following principles:

- new approach to risk measurement to ensure the solvency of insurance companies;
- new approaches to decrease probability of insurance failures through the introduction of the System of Governance;
- new approach to data transparency.

The introduction of the Solvency II Directive was required due the weaknesses of the Solvency I framework described in Section 1.2.1.

The special role under the Solvency II framework is played by the own risk and selfassessment document (ORSA).

In accordance with Articles 45 and 246 of the Solvency II Directive, national competent authorities should ensure that the responsible entity in the group forward looking assessment of own risks adequately assesses the impact of all group specific risks and interdependencies within the group as well as, and the impact of these risks and interdependencies on the overall solvency needs, taking into consideration the specificities of the group and the fact that some risks may be scaled up at the level of the group [48].

Basically, the ORSA has to ensure a comprehensive assessment of the undertaking's overall solvency needs in view of its business strategy, its risk profile and the approved risk tolerance limits it sets for itself and its responsibility to meet financial obligation towards policyholders [49].

ORSA can be defined as the entirety of the processes and procedures employed to identify, assess, monitor, manage, and report the short- and long-term risks an insurance undertaking faces or may face and to determine the own funds necessary to ensure that the undertaking's overall solvency needs are met at all times [21].

Thus, the ORSA requirements are based on the following principles:

- enhancement of risk management function using insurance companies' risk profile;
- enhancement of risk management function using insurance companies' risk tolerance.
   Main challenges for the insurance industry due to requirements of the Solvency II
   Directive are following:
- assessment of own capital;
- ORSA implementation;
- approval of an internal model;
- implementation of synergies within insurance companies;
- establishment of proper enterprise risk management system;
- establishment of qualitative requirements of the System of Governance;
- ensuring the right balance between return on capital and protecting the capital base;
- ensuring data quality and proper IT solutions for capital, risk sensitivity modelling, reporting etc.;
- implementation of proper thinking to establish new principles of risk evaluation;
- ensuring proper knowledge and competence of responsible employees following the principle "right person in the right place";

• development of additional economical balance.

The Solvency II regime sets out broader risk management requirements for European insurers and dictates how much capital firms must hold in relation to their liabilities. The Omnibus II Directive, which completes and finalises the new framework, was approved by the European legislative authorities earlier this year and is expected to be transposed into national laws by 31 March 2015, to come into force on 1 January 2016 [50].

The introduction of the Solvency II Directive was adopted by the Council of the European Union and the European Parliament in November 2009 [21].

The implementation of the Solvency II framework was postponed several times because of the necessity to improve its requirements for proper implementation. The requirements of the Solvency II Directive were enhanced with five quantitative impact studies. Quantitative impact study could be defined as a particular field-testing exercise, where it is possible to assess the practicability, implications and possible impact of specified approaches to insurers' capital setting under the Solvency II regime.

All five quantitative impact studies required the European Union insurance companies to apply a particular set of technical specifications to the calculation of their solvency capital requirement, minimum capital requirement and technical provisions, based on their financial results at the end of the previous year. All five quantitative impact studies have helped to improve the design of the detailed quantitative requirements under the Solvency II framework.

However, revisions to the Solvency II Directive were performed in the Omnibus II Directive. Thus, the Omnibus II Directive includes the following improvements to the Solvency II Directive:

- the adjustment of long-term guarantees;
- transitional measures in certain areas to allow for a more smooth transition to the new regime from the Solvency I regime;
- clarification on technical approaches to the calculation of technical provisions and capital requirements.

To summarize, the Solvency II Directive should improve the financial stability and solvency of the European Union's insurance market through the improvement of risk evaluation applying more sophisticated, sensitive and complicated approaches to measure and manage the risks faced by the industry.

Thus, the Solvency II framework influences each insurance company's activity, asking for additional financial and professional human resources for the implementation of its requirements.

2.1.3. The Theoretical Aspects and Substantiation of Risk Culture

Risk culture is more about the understanding of risk nature with the main aim to define risk tolerance, risk appetite and risk limits of an insurance company.

The integration of the risk culture into an insurance company's processes is illustrated in Fig. 20.



Fig. 20. Risk management function (the author's interpretation based on [47]–[49]; [51]–55]

In fact, the author recognises the risk culture of every insurance company's as the heart of own risk and solvency assessment (ORSA). The ORSA builds on pre-existing concepts from an enterprise risk management framework, such as risk appetite and the need to link to a business strategy, and translates them into specific process that presents management with a picture of their own company's risk positions that can be used to steer the business. The author has made the research based various definitions<sup>3</sup> of risk culture analysis and has discovered 3 (three) main dimensions of risk culture in insurance: understanding of risk nature, establishment of risk strategy and agreement of risk profile. The research results are presented in Fig. 21.

<sup>&</sup>lt;sup>3</sup> Definitions of risk culture was selected based on focus group discussion in 2015

#### Financial and non-financial industry

- •Risk culture is a term describing the *values, beliefs, knowledge, attitudes and understanding about risk*<sup>1</sup> shared by a group of people with a common purpose, in particular the employees of an organisation. This applies to all organisations from private companies, public bodies, governments to not-for-profit organisations [51].
- •Risk culture can be defined as the system of values and behaviours present throughout an organisation that *shape risk decisions*<sup>2</sup>. Risk culture *influences the decisions of management and employees*<sup>3</sup>, even if they are not consciously weighing risks and benefits [57].
- •The organisation's propensity to take  $risks^2$  as perceived by the managers in the organisation [59].
- •Risk culture is a deeper level of basic assumptions and beliefs that are shared by members of an organisation<sup>1</sup>, that operate unconsciously, and that define in a basic "taken-for-granted" fashion an organisation's view of itself and its environment<sup>3</sup>[53]
- •"Risk culture" refines the concept of organisational culture to focus particularly on the collective ability to risk<sup>3</sup>, manage but the wider organisational culture itself is an active backdrop determining, and itself influenced by, risk culture [55].

#### **Financial industry**

- •Risk culture can be defined as norms of behaviour for individuals and groups within an organisation *that determine the collective ability to identify*<sup>2</sup> and *understand, openly discuss*<sup>1</sup> and *act on the organisation's current and future risks*<sup>3</sup> [52].
- Risk culture can be defined as *the norms* and traditions of behaviour of individuals and of groups<sup>1</sup> within an organisation that determine the way in which they identify, understand, discuss and act on the risks the organisation confronts and takes<sup>3</sup> [54].
- •Risk culture, as well as corporate culture, evolves over time in relation to the events that affect the institution's history (such as mergers and acquisitions) and to the external context within which the institution operates<sup>3</sup>. Culture can be a very complex issue as it involves behaviours and attitudes<sup>2</sup> [56].
- •Risk culture can be defined as the *shared* perceptions among employees of the relative priority given to risk management<sup>3</sup>, including perceptions of the practices and behaviours that are expected, valued and supported<sup>2</sup> [57].
- •Risk culture is based on particular beliefs and assumptions<sup>1</sup>. These can be clustered according to specific cultural tenets, namely risk, integrity, governance leadership, decision-making, and empowerment, teamwork, responsibility and adaptability<sup>3</sup>... These tools are in *everyday* workplace expressed practices<sup>2</sup> via attitudes and behaviours and, when they are expressed by leaders, they serve as powerful (human) culture embedding mechanisms [58].

Research results	Identified dimensions of risk culture		
mentioning	Risk nature <sup>1</sup>	Risk strategy <sup>2</sup>	Risk profile <sup>3</sup>
Number of mentioning	5	6	8

\* with italic are marked phases related to identified dimension of risk culture

Fig. 21. Research on definition of "Risk culture" (created by the author based on [51-59])

The author having examined various definitions of risk culture in terms of presented research in Fig.21 and conclude that identified dimensions of risk culture in insurance could be approved. Also, the author can state that all definitions of risk culture are very similar and risk culture is mainly defined as norms and traditions of employees' behaviour within an organisation. According the Institute of Risk Management, the risk culture framework should include [51]:

- organisational culture;
- behaviours;
- personal ethics;
- personal predisposition to risk.

Risk culture framework introduced by the Institute of Risk Management fully corresponds to mechanism that allows to understand the relationship of organizational behaviour and culture similar to Hofstede *et al.* research [55.1].

Furthermore, the Institute of Risk Management points out that risk culture remains a developing area and we do not consider what we have produced to be the last word on the subject. Instead, we envisage our guidance to evolve with new models and tools emerging in the future [51]. The Institute of Risk Management [55] has developed the model of risk culture aspect that identifies eight aspect of risk culture grouped into four themes aligned to an organisation's business model that fully corresponds to the author's identified three risk culture dimensions:

- tone at the top aspect includes risk leadership and how the organisation responds to bad news that corresponds to the author's identified dimension of risk strategy;
- governance aspect comprises the clarity of accountability for managing risk the transparency and timeliness of risk information that matches to the author's identified dimension of risk profile;
- competency aspect encompasses the status, resources and empowerment of the risk function and risk skills that corresponds to the author's identified dimension of risk nature;
- decision making aspect comprises well informed risk decisions, appropriate risk taking rewarded and performance management linked to risk taking that corresponds to the author's identified dimension of risk strategy.

The model introduced by the Institute of Risk Management is based on simple questionnaire or structured interview techniques. The author points out that the model developed by the Institute of Risk Management should ensure a continuous improvement of risk culture through the enhancement of transparency of actions, governance, and competency. However, weakness of the developed model is the requirement of risk leadership and strong organisational culture that could be challenging to ensure for many companies.

Goffee and Jones [60] introduced the "Double S" model that categorised culture in four types:

- corporate culture with high focus on people and high focus on tasks;
- fragmented culture with low focus on people and low focus on tasks;
- networked culture with high focus on people and low focus on tasks;
- mercenary culture with low focus on people and high focus on tasks.

However, in the model the organisational culture is based on two dimensions: sociability and solidarity [60]. The Institute of Risk Management [55] states that "Double S" model is good at predicting the success with which structured approaches to managing risk are implemented in organisations. The author of the Doctoral Thesis agrees with the Institute of Risk management that it is possible to include core principles of the model developed by Goffee and Jones in testing of selected risk strategy (one of the identified risk strategy's dimensions) since the base of risk culture's successful implementation in an insurance company's processes is structured approaches to ensure a sense of cohesion and the same standards of working principles. E.Sheedy and B. Griffin have developed the conceptual model based on the idea that the governance and other structures should be potential drivers of risk culture and at the same time should be distinct from risk culture [61]. The author highlights that introduced conceptual model corresponds to risk profile, identified by the author risk culture's dimension.

The author of the present Doctoral Thesis fully agrees with the proposed concept since strong governance's main aim is to support establishment of proper risk management through strengthening the risk culture. Since the Baltic insurance market, which is similar to the Latvian insurance market, is rather young and still developing, the author is concentrated on risk culture development. The significance of risk culture in an insurance company's processes is presented in Section 3.1.2.

The fact is that different approaches have been developed to risk culture assessment and improvement through its strategy setting in an insurance company. G.Trickey introduces the cascade model for risk culture based on exploration of group dynamics, where propensity for risk begins at the board level and is cascaded down through the organisation [62]. The author

concludes that the cascade model is based on the identified during the research risk culture's dimensions.

The author of the Doctoral Thesis has developed a short-term solution to the risk culture development in an insurance company based on the quantitative impact studies of the Solvency II framework, particularly the 5<sup>th</sup> study. Risk culture development in insurance can serve as the first stage for the risk evaluation development in insurance companies within the next 2–3 years, using different methods. The author concentrates on risk evaluation using risk ranking, Analytic Hierarchy process and Analytic Network Process based on the Saaty rating scale (see Section 4.1).

## 2.2. Risks and Their Measurement in Insurance

# 2.2.1. Risk Classification and Research of Its Nature

The key point here is that the ORSA is not a one-off exercise or a single report. Rather, it is a fundamental part of the risk management system for an insurance undertaking. In other words, it could be defined as a documented process [63]. The ORSA should encompass all material risks that may have an impact on the undertaking's ability to meet its obligations under insurance contracts [22]. Therefore, the author of the Doctoral Thesis can state that the ORSA is a key part of the Solvency II regime and should perform insurance company's target risk profile with risk appetites and tolerances.

However, it is important to recognise that the ORSA does not of itself serve to create an additional regulatory capital requirement [63]. The ORSA should cover at least all SCR (Solvency Capital Requirements) risks. The SCR is the amount of capital to be held by an insurer to meet the requirements of 1<sup>st</sup> Pillar under the Solvency II regime [19]. Risk is the possibility of the occurrence of an insurance event with an impact on the achievement of objectives. According to the Solvency II framework, the main insurance company's risks are based on the solvency capital requirements (see Fig. 22).



Fig. 22. The standard formula of solvency capital requirements [22]

The standard formula of solvency capital requirements includes the following main risk groups (presented in detail in Fig. 22):

- Market risk that is caused by changes in values caused by market prices or volatilities of market prices differing from their expected values [19].
- Operational risk that is the risk of a change in value caused by the fact that actual losses, incurred for inadequate or failed internal processes, people and systems, or from external events (including legal risk), differ from the expected losses [19].
- Credit risk that is the risk of a change in value due to actual credit losses deviating from expected credit losses due to the failure to meet contractual debt obligations [19].
- Life or non-life underwriting risk that is caused by underwritten insurance contract.

Based on the SCR calculation with the standard formula, an insurance company can set its actual risk profile. The point is that the ORSA should cover all material risks; therefore, the risk catalogue establishment is one of the possibilities of risk function improvement. Nature and complexity of risks are closely related and, for the purpose of assessment of proportionality, could best be characterised together. Indeed, complexity could be seen as an integral part of the nature of risks, which is a broader concept [22]. The author of the present Doctoral Thesis concentrates on the operational risk that is included under the SCR core structure since the capital to cover it is still under discussion and there is no clear understanding of how to assess the risk.

## 2.2.2. Theoretical Aspects of the Assessment of Operational Risk

Operational risk (Op) is the risk of a loss resulting from inadequate or failed internal processes, people and systems, or from external events. This definition also includes legal risk but excludes strategic and reputational risks [64]. In the Solvency II framework and the Basel II regime, the basic principles and requirements for operational risk assessment in insurance and banking industries are described. The author is investigating operational risk's assessment in terms of the rational choice theory including experts and mathetical methods.

The usage, integration and implementation of the suggested principles as well as the requirements of operational risk assessment are under active discussion in the recent years. Many researchers have investigated the above-mentioned issues: [65], [66], [67], [68], [69], [70], [71], [72], [73].

For example, M. El-Gamal *et al.* [67] propose using for operational risk measurement a multivariate likelihood-based statistical model that presents the benefits and risks of using extreme value theory in modelling univariate tails of event type loss distributions.

However, G.W. Peters *et al.* [70, 71] investigate the possibility of modelling capital to cover the losses of operational risk under the Basel II/Basel III framework using a loss distributional approach. The author of the Doctoral Thesis recognises the practical application of the research since it provides the understanding of the development of severity models for the assessment of operational risk and gives the overview of possible advantages and disadvantages during the modelling process.

In order to model operational risk losses depending on covariates, recent (over the past five years) studies, use an extension of the Peaks-over-Threshold method and the block maxima approach to a non-stationary setup that allows the dependence (on covariates) to be parametric, non-parametric, or semi-parametric and can also include interactions [69]. The main difference between parametric model and non-parametric model is that the parametic models are based on bigger statistical data and assumptions than non-parametric methods. The author finds the proposed approach appropriate for the modelling of operational risk.

Moreover, most heated discussions are going on in relation to the possibility that the capital, to cover the possible losses of the operational risk, can be directly proportional to the volume of gross profit in the banking industry.

Thus, traditionally it is assumed that the amount of the capital, to cover the possible losses of the operational risk, is equal to the sum of capital charges for each type of the incurred unexpected event in insurance. However, the described approach requires an ideal dependence among the occurred events, which is unreasonable and unrealistic in business conditions of the insurance industry.

The fact is that the author of the Doctoral Thesis suggests using copulas to model the capital volume to cover the operational risk. In fact, copulas allow modelling the multivariate probability distribution using one-dimensional parametric dependences. The fact is that copulas are used to describe the dependence between random variables. In fact, the copula's function enables the task of specifying the marginal distribution to be decoupled from the dependence structure of variables.

The definition "copula" has been first mentioned by Abe Sklar in 1959 [74] as a function that couples a joint distribution function with its univariate margins. Paul Embrechts started his research on copulas, their usage and copula adaptation to banking and insurance in 1995.

Very good insight into the copula theory and its development stages is presented in [75], [76], [77], [78].

Consequently, copula's function allows us to exploit univariate techniques at the first step, and, secondly, it is directly linked to non-parametric dependence measures. This avoids the flaws of linear correlation that have, by now, become well known. [75]

A copula can be defined as a function C of n variables on the unit *n*-cube  $[0, 1]^n$  with the following properties:

- the range of *C* is the unit interval [0, 1];
- $C(\mathbf{u})$  is zero for all  $\mathbf{u}$  in  $[0, 1]^n$  for which at least one coordinate equals zero;
- $C(\mathbf{u}) = \mathbf{u}_k$  if all coordinates of  $\mathbf{u}$  are 1 except the *k*-th one;
- C is n-increasing in the sense that for every a ≤ b in [0,1]<sup>n</sup> the volume assigned by C to the n-box [a, b]= [a<sub>1</sub>, b<sub>1</sub>] × ... × [a<sub>n</sub>, b<sub>n</sub>] is nonnegative.

As can be seen, a copula is, in fact, a multivariate distribution function with univariate margins restricted to the n-cube [77, 3 p.].

However, it is also important to investigate the Abe Sklar theorem. Let us assume that *H* denotes a *n*-dimensional distribution function with margins  $F_1, ..., F_n$ . Then there is a *n*-copula *C* such that for all real  $(x_1, ..., x_n)$ ,

$$H(x_1, \dots, x_n) = C(F_1(x_1), \dots, F_n(x_n)).$$
(1)

If all the margins are continuous, then the copula is unique, and is determined uniquely on the ranges of the marginal distribution functions otherwise. Moreover, the converse of the statement above is also true. If we denote by  $F_1^{-1}, \dots, F_n^{-1}$  the generalized inverses of the marginal distribution functions, then for every  $(u_1, \dots, u_n)$  in the unit *n*-cube [77, 3 p.],

$$C(u_1, \dots, u_n) = H(F_1^{-1}(u_1), \dots, F_n^{-1}(u_n)).$$
<sup>(2)</sup>

In numerical simulation, copulas are a practical tool to generate multivariate distributions with given dependence properties regardless of the marginal distributions. They are particularly useful when dealing with phenomena that cannot be approached by normal distributions. The idea behind generating multivariate distributions from a copula is based on the simple transformation from a uniform distribution on [0, 1] to any other distribution using the cumulative density function [79].

Many authors applied the different copula approaches to model the capital to cover the risks and other financial processes ([75], [80], [81], [82], [83], [84], [85], [86], [87]).

In finance and risk measurement, the most popular approach is the Gaussian copula that is used traditionally to model the risk due to its numerical convenience. Also, Gaussian copula could be called a normal copula and was first introduced in financial modelling by David X. Li. The distribution function of the Gaussian copula is  $\forall (u_1, ..., u_n) \in [0, 1]$  and  $\rho \in [0, 1]$  [79, 8 - 9 p.].

$$C_p(u_1, \dots, u_n) = \varphi_{\rho}^n(\varphi^{-1}(u_1), \dots, \varphi^{-1}(u_n)),$$
(3)

where

 $\varphi^{-1}$  is the inverse of the univariate normal distribution function,

 $\varphi_{\rho}^{n}$  the cumulative distribution function for the n-dimensional normal distribution with  $\rho$  as covariance matrix.

However, the Gaussian copulas are not appropriate for the modelling of operational risk due the possibility of the underestimation of a probability of joint extreme events because of impossibility to model tail dependence.

Archimedean copula belongs to a *n*-dimensional copula C family. An Archimedean copula is defined in the following way:  $\forall (u_1, ..., u_n) \in [0, 1]^n$ 

$$C(u_1, ..., u_n) = \varphi^{-1} [\sum_{i=1}^n \varphi(u_i)],$$
(4)

where  $\varphi$  is generator, i.e., a function that satisfies:

 $\phi(1) = 0$ ,

 $\varphi$  is strictly decreasing on [0, 1],

φ is convex on [0, 1] [79, 10 p.].

The fact is that also in Latvia some researches have investigated and applied copulas in financial field: Matveev *et al.*, Kozovskis *et al.*, Pettere *et al.* and etc. For example, K.Kozlovskis et al. proposed modelling the assessment of financial instruments and portfolio management using Archimedean copulas [85]. The author of the Doctoral Thesis points out that it is possible to use Archimedean copulas in the assessment of financial instrument since they allow modelling dependence in arbitrarily high dimensions with only one parameter ensuring the strength of dependence.

However, the Clayton copula also belongs to the Archimedean copulas. The Clayton copula is an asymmetric copula exhibiting greater dependence in the negative tail than in the positive. The fact is that the Clayton copula is very often used in modelling of the correlated risks due to its main feature of the lower tail dependence. The description of the Clayton formula is presented in Formula (5) [79].

$$C(u,v) = \max[\left(u^{-\alpha} + v^{-\alpha} - 1\right)^{\frac{-1}{\alpha}}, 0],$$
(5)

where

$$\varphi(t) = \frac{1}{\alpha}(t^{-\alpha} - 1)$$
$$\alpha \in [-1, \infty[\setminus\{0\} [75, 10 \text{ p.}]].$$

Under the Archimedean copulas there is also the Gumbel copula. The fact is that the Gumbel copula is an upper tail dependent asymmetric copula; thus, it presents greater dependence in the positive tail than in the negative. The description of this copula is presented in Formula (6).

$$C(u,v) = \exp\left(-\left[(-\ln u)^{\alpha} + (-\ln v)^{\alpha}\right]^{\frac{1}{\alpha}}\right).$$
(6)

However, the Gumbel copula's generator is (see Formula 7):

$$\varphi(t) = (-\ln t)^{\alpha} \text{ where } a \in [1, \infty).$$
(7)

The Gumbel copula is an extreme value copula because it satisfies the max-stable property [79, 10 p.]. The Gumpel copulas graphical interpretation is presented in Appendix 1 and graphical interpretation of the Gaussian copula is presented in Appendix 2.

Pradier [79] in his research of operational risk measurement (in particular, environmental risk) in banking compares the possibility of usage of the Gumbel copula and Gaussian copulas for modelling possible losses of the operational risk. He concluded that he was not able to compare the model with the Gaussian copula and the model with a Gumbel copula due to cumulative effect of highly variable quantile estimations in the tail and overestimated tail quantiles. However, Pradier emphasised that both models based on different copulas presented overestimated results. The author of the Doctoral Thesis agrees with Pradier that the Gumbel copula should be more appropriate for operational risk because of its positive upper tail dependence coefficient.

Kuzmina *et al.* [86] studied the possibility of development of a model for managing small stock portfolios for Latvian insurance companies based on three different copula types: Gaussian copula, skew normal copula and skew *t*-copula. During the research, they came to the conclusion that the modelling of small stock portfolios for Latvian insurance companies is more reliable if it is based on the skew *t*-copula.

To model the capital to cover the operational risk, the author of the Doctoral Thesis uses skew *t*-copula. Skew t-copula is constructed from a multivariate skewed distribution that has the covariance matrix when the number of degrees of freedom is more than 4 (four) [83].

The construction of the skew *t*-copula is based on the multivariate skew t-distribution introduced by Azzalini ja Capitanio [88]. To define a skew *t*-distribution the multivariate *t*-

distribution is needed. The density function of the *p*-variate *t*-distribution with v degrees of freedom is of the form.

$$t_{p,\nu}(\mathbf{x}, \boldsymbol{\mu}, \boldsymbol{\Sigma}) = \frac{\Gamma\left(\frac{\nu+p}{2}\right)}{\left(\pi\nu\right)^{\frac{p}{2}} \Gamma\left(\frac{\nu}{2}\right) |\boldsymbol{\Sigma}|^{\frac{1}{2}}} \left[1 + \frac{\left(\mathbf{x}-\boldsymbol{\mu}\right)^T \boldsymbol{\Sigma}^{-1} \left(\mathbf{x}-\boldsymbol{\mu}\right)}{\nu}\right]^{-\frac{\nu+p}{2}}, \quad (8)$$

where

 $\Sigma$  is a positive definite  $p \times p$ -matrix;

 $\mu_{\text{is a}} p - \text{vector;}$ 

 $x^T$  denotes the transposed vector x.

The multivariate skew *t*-distribution is defined as follows.

The author of Doctoral Thesis defines in line with [83] a random *p*-vector  $\mathbf{X} = (X_1, ..., X_p)^T$  has *p*-variate skew *t*-distribution with parameters  $\boldsymbol{\mu}$ ,  $\boldsymbol{\alpha}$  and  $\boldsymbol{\Sigma}$ , if its density function is of the form

$$g_{p,\nu}(\mathbf{x};\boldsymbol{\mu},\boldsymbol{\Sigma},\boldsymbol{\alpha}) = 2 \cdot t_{p,\nu}(\mathbf{x};\boldsymbol{\mu},\boldsymbol{\Sigma}) \cdot T_{1,\nu+p} \left[ \boldsymbol{\alpha}^T \mathbf{W}^{-1}(\mathbf{x}-\boldsymbol{\mu}) \left( \frac{\nu+p}{Q+\nu} \right)^{\frac{1}{2}} \right],$$
(9)

where Q — denotes the quadratic form

$$Q = (\mathbf{x} - \boldsymbol{\mu})^T \boldsymbol{\Sigma}^{-1} (\mathbf{x} - \boldsymbol{\mu}), \qquad (10)$$

where  $T_{1,\nu+p}(\cdot)$  — denotes the distribution function of the central univariate

t - distribution with v + p degrees of freedom.

The parameter  $\alpha$  is called the shape parameter and it regulates both, shape and location, while  $\mu$  is considered as the location or shift parameter and  $\Sigma$  is the scale parameter.

The skew *t*-copula was define through its density function by Kollo et al. [83].

However, a copula is defined as a skew t-copula, if its density function is

$$c_{p,\nu}(\mathbf{u}; \boldsymbol{\mu}, \boldsymbol{\Sigma}, \boldsymbol{\alpha}) = \frac{g_{p,\nu}[\{G_{1,\nu}^{-1}(u_1; 0, \sigma_{11}, \alpha_1), ..., G_{1,\nu}^{-1}(u_p; 0, \sigma_{pp}, \alpha_p)\}; \boldsymbol{\mu}, \boldsymbol{\Sigma}, \boldsymbol{\alpha}]}{\prod_{i=1}^{p} g_{1,\nu}[G_{1,\nu}^{-1}(u_i; \mu_i, \sigma_{ii}, \alpha_i); \mu_i, \sigma_{ii}, \alpha_i]}, \quad (11)$$

where the density function  $g_{p,v}(\cdot; \boldsymbol{\mu}, \boldsymbol{\Sigma}, \boldsymbol{\alpha}) : \mathbb{R}^p \to \mathbb{R}$  is defined by Formula 8 and function  $G_{l,v}^{-1}(u_i; \mu_i, \sigma_{ii}, \alpha_i) : \mathbb{R}^1 \to I$ ,  $i \in \{1, ..., p\}$  denotes the inverse of the univariate sk*ew*  $t_{l,v}$ -distribution function.

The skew *t*-copula is applied in a special case when the shift parameter  $\mu = 0$ . To find a model for the data the estimation of the parameters  $\Sigma$  and  $\alpha$  is needed. For that the method of moments should be applied. Parameters  $\Sigma$  and  $\alpha$  are estimated from the first two moments [83]. Let  $\overline{\mathbf{X}}$  and  $\mathbf{S}_{\mathbf{X}}$  denote the sample mean and the sample covariance matrix, respectively. Then the estimates are

$$\hat{\Sigma} = \frac{\nu - 2}{\nu} (\mathbf{S}_{\mathbf{X}} + \bar{\mathbf{X}}\bar{\mathbf{X}}^T), \qquad (12)$$

$$\hat{\boldsymbol{\alpha}} = \frac{b(\boldsymbol{\nu}) \cdot \boldsymbol{\beta}}{\sqrt{b^2(\boldsymbol{\nu}) - \bar{\mathbf{X}}^T \hat{\boldsymbol{\Sigma}}^{-1} \bar{\mathbf{X}}}},$$
(13)

where

$$\boldsymbol{\beta} = \frac{1}{b(\nu)} \hat{\mathbf{W}} \hat{\boldsymbol{\Sigma}}^{-1} \bar{\mathbf{X}}, \qquad (14)$$

with  $\hat{\mathbf{W}} = (\delta_{ij} \sqrt{\hat{\sigma}_{ij}})$ , i, j = 1, ..., p, where  $\delta_{ij}$  is the Kronecker delta and

$$b(v) = \left[\frac{v}{\pi}\right]^{\frac{1}{2}} \cdot \frac{\Gamma(\frac{v-1}{2})}{\Gamma(\frac{v}{2})},\tag{15}$$

In formula (13) it is assumed that v > 2.

Smith *et al.* [89] performed the study to approve the possibility of improvement of risk management using models based on skew *t*-copula. During the research, they measured the interregional dependence on electricity prices in different regions of Australia. They have

proved that with the skew *t*-copula it is possible to identify strong asymmetry in the tail dependence in order to ensure more reliable computation of tail probabilities. The second study of Smith *et al.* [89] based on multivariate ordinal data has demonstrated that that due to the usage of the skew *t*-copula it is possible to ensure substantial improvement in the modelling of interstice dependence, similar to the symmetric *t*-copula. The author of the Doctoral Thesis can conclude that the skew *t*-copula allows modelling distributions with heavier tail area; therefore, it is suitable for modelling of capital to cover possible losses of an operational risk.

Since the operational risk encompasses a number of sub-risks, the author suggests establishing the risk catalogue to investigate more deeply the nature of risks. Basically, the scope of risks that should be included in the analysis will depend on the purpose and context of the assessment [22]. For modelling of the capital to cover the operational risk, the author proposes using historical data from the loss database. The fact is that the loss database introduces all incurred operational risk events with details about losses during a particular period. The description of loss database is presented in Section 2.3.2.

# 2.3. The Basis of Risk Management and Its Role in the Insurance Company's Processes

# 2.3.1. The Investigation of Risk Management System

The author focuses on supervision and qualitative requirements that are involved in the System of Governance. The System of Governance under a new regime is presented in Fig. 23.



\* the function on which the author concentrates is marked with italics

**Fig. 23.** The System of Governance under the Solvency II regime (created by the author based on [21], [25],[26], [27], [28])

In order to meet the requirements of the Solvency II Directive, a risk management function should be established. The conceptual framework of the Solvency II Directive is presented in Fig. 24.



**Fig. 24.** The interpretation of the Solvency II Directive (complied by the author based on [47])

Based on Fig. 24, the author can conclude that risk management and risk measurement are related and dependent on each other. In fact, a risk management function should fit within the aim of developing strategies, processes, reporting procedures to identify measure, monitor, manage and report the risk. The main goal of the new regime is to establish common risk management system and risk measurement principles for every insurance company in the European Union.ccording to the requirements of the Solvency II directive, under the System of Governance there should be "fit and proper" key functions. However, the requirements of the  $2^{nd}$  Pillar set a lot of challenges to every insurance company.

Risk management is about to define a risk profile that intends to align with the stakeholder's risk appetite and risk tolerance, likewise keeping risks and losses within insurer's risk tolerance. Henschel has defined that by risk management we mean any kind of considerations which enable businesses to detect critical developments and to take

countermeasures early enough [90]. Under the requirements of the Solvency II Directive, the notion of the risk management system should be reviewed and focused on the key areas that are presented in Fig. 25.



Fig. 25. Risk management key points (created by the author based on [21], [25], [26], [27], [28])

The main idea of the Solvency II framework is to place risk dimension in the heart of every insurance company in order to improve the business strategy and capital management reliability. The author of the Doctoral Thesis has studied rules that should be set in order to provide better risk framework:

- risk appetite requires an insurance company to consider what its overarching attitude is to risk taking and how this attitude relates to the expectations of its stakeholders [31].
- risk tolerance requires an insurance company to consider in quantitative terms exactly how much of its capital it is prepared to put at risk [31].
- risk limits require an insurance company to consider at a more granular level how much risk individual managers throughout the organisation should be allowed to take within their assigned responsibilities [31].
- mission clarity with the long-term value creation proposition.
- real-time risk budget that allows for stress testing through the modelling of different scenarios.

The fact is that a risk management function under the Solvency II framework should be fit and proper in order to identify, measure, monitor, manage and report the risk through the strategy and process development. The author concludes that risk management is the risk management function field; therefore, risk measurement accomplishment provides actuarial and risk management function.

Tower Watson Audit Company in 2010 conducted the study "Financial Crisis Puts Spotlight on Enterprise Risk Management" among 233 insurance companies on core riskcontrol techniques during the recent financial crisis [31]. The main results of the performed study are presented in Fig. 26.

The point is that the main idea of the risk governance is to consider the most effective way for implementing the best risk management practice. Moreover, the risk governance elements help to develop risk management culture that emphasises at all levels the significance of managing risk as part of each person's daily activities. Risk tools allow improving the internal risk and capital models, which are the heart of risk management, by customising risk dashboards and developing improved benchmark framework.



Fig. 26. Core risk-control techniques (based on [31] with the author's changes)

In addition, it has been discovered during the study that insurance companies also use the following instruments as part of risk management:

- economic capital techniques in decision making;
- allowances in risk;
- risk governance structure;
- risk resources;
- skills and capabilities;
- stress or scenario testing as planning capabilities;
- risk appetite statement;
- economic capital modelling;
- risk optimisation capabilities;
- different risk technologies or systems and other risk models.

The author of the present Doctoral Thesis has also conducted the research to investigate the core risk management techniques that are in focus of Latvian insurance companies. The research was carried out in spring 2012. The research was based on interviews with focus groups that involved responsible employees from actuarial and risk management units with the experience of more than 2 years at the Latvian insurance companies. The research results are presented in Fig. 27.



Fig. 27. Risk management techniques of Latvian insurance companies (created by the author)

Thus, risk management is the process of identification, analysis, assessment, control, elimination and evasion of unacceptable risks. Risk management is the process of organising, planning, leading, and controlling the activities of an insurance company with the purpose to minimise the effect of possible risks on the insurance company's activity, profit and development.

Risk management according to the requirements of the Solvency II Directive is one of the most significant functions of every insurance company. The fact is that risk management function should include statistical process control and periodic testing in order to ensure the reliability of all the processes.

The risk management expands all the processes to involve not only risks that are associated with possible and accidental losses but also operational, credit, underwriting, market risks. The concept of the risk management system for Baltic countries is presented in Fig. 28.



**Fig. 28.** Risk management system description (created by the author based on [21], [22] [25], [26], [27], [28], [31])

Thus, for developing a market similar to the Baltic insurance market the risk catalogue approach could be implemented. The risk catalogue creation goes under the risk identification process in the risk management framework (see Fig. 28) and is presented in Fig. 29.

Effective risk management system is a basis to establish strategic reliability programme for every insurance company. Moreover, the risk management should be a continuous process in general but due to the specific features of insurance industry the author uses the semicontinuous qualitative approaches to manage the risk. After establishing the risk catalogue, it is necessary to create a risk matrix with the aim to identify key risks. The risk management system of every insurance company should be promoted with the aim to control and manage the reliability of business strategy. The example of risk catalogue is presented in Table 4.



**Fig. 29.** Risk catalogue creation (complied by the authors based on [21], [25],[26], [27], [28], [31])

The Fragment of Example of the Risk Catalogue (created by the author based on [21], [22],

Risk	Sub-risk	Sub-risk of sub- risk	Description
Life underwriting risk	Policyholder behaviour risk		Risk of the insurance company's policyholders will act in ways that are unanticipated and have an adverse effect on the company.
		Mortality risk	The treatment of mortality risk is intended to reflect uncertainty risk.
		Longevity risk	The treatment of longevity risk is intended to reflect uncertainty risk.
		Disability risk	The treatment of disability risk is intended to reflect uncertainty risk.
	-	-	-
rket risk	Interest rate risk		The risk of a change in value caused by a deviation of the actual interest rates from the expected interest rates.
Ma	-	-	-
redit Risk	Settlement Risk		The risk of a change of value due to a deviation from the best estimate of the time-lag between the value and settlement dates of securities transactions.
Ū	-	-	-
Operational risk	Reputational Risk		The risk that adverse publicity regarding insurer's business practices and associations, whether accurate or not, will cause a loss of confidence in the integrity of the institution.
	Strategic risk		The risk of a change in value due to the inability to implement appropriate business plans and strategies, make decisions, allocate resources, or adapt to changes in the business environment.
	Systematic risk		Any risk inherent to the entire market or entire market segment that cannot be mitigated through diversification.
	-	-	-

[48], [91])

Article 44 of the Solvency II Directive states that insurance and reinsurance undertakings shall have in place an effective risk-management system comprising strategies,

processes and reporting procedures necessary to identify, measure, monitor, manage and report, on a continuous basis, the risks at an individual and at an aggregated level, to which they are or could be exposed, and their interdependencies [21].

The author of the Doctoral Thesis has conducted the study on the proposed algorithm (see Fig. 29) that is presented in Appendix 3 to prove the significance and positive impact on the establishment and improvement of risk identification under the risk management system.

The three indicators — nature, scale and complexity — are strongly interrelated, and in assessing the risks the focus should be on the combination of all three factors. This overall assessment of proportionality would ideally be more qualitative than quantitative, and cannot be reduced to a simple formulaic aggregation of isolated assessments of each of the indicator [48].

In terms of nature and complexity, the assessment should seek to identify the main qualities and characteristics of the risks, and should lead to an evaluation of the degree of their complexity and predictability. For this purpose, it may be helpful to broadly categorise the risks according to the two dimensions "scale" and "complexity / predictability" [48]. Risk matrix consists of three main parts:

- risks in the yellow part are classified as normal risks with the minimum impact on company's activity; therefore, it is necessary to devote attention to their future development;
- risks in the orange part are classified as critical risks with the necessity of managing and controlling;
- risks in the red part are classified as very critical risks with the necessity of the immediate actions towards managing and controlling the risks.

It is also necessary to set occurrence probability and possible loss ranking in the risk matrix:

- 1<sup>st</sup> rank if the risk probability is rare (less than 1%) and possible losses are insignificant;
- $2^{nd}$  rank if the risk probability is unlikely (1.1%–10%) and possible losses are low;
- $3^{rd}$  rank if the risk probability is unlikely (10.1%-50%) and possible losses are average;
- 4<sup>th</sup> rank if the risk probability is almost possible (50.1%–80%) and possible losses are maximum;
- 5<sup>th</sup> rank if the risk probability is possible (80.1%–100%) and possible losses are catastrophical.

Therefore, risk management should include the following requirements:

- A documented process for developing requirements that meet customers' needs should be realistic, reliable, understandable and achievable within budget and schedule constraints.
- Actions directed at the consolidation of reliability. This includes a special form of the risk self-assessment development with a user-friendly interface that can be performed in MS Excel.
- Risk management should identify and analyse every insurance company's weaknesses with the purpose to eliminate or minimise the effect of failures and to validate the reliability of specified requirements.

Thus, the author of the Doctoral Thesis can conclude that with the effective risk management system it is possible to ensure every insurance company's reliability, thus affecting the goal of insurance to provide the clients with a sense of protection.

# 2.3.2. The Investigation of Operational Risk Management

According to the requirements of the Solvency II Directive, the operational risk management model can be performed in many ways so that the author presents the internal scheme of operational risk management model. In order to manage the operational risk, it is important to understand the capital requirement of the operational risk according to the standard formula of the requirements of the Solvency II Directive that is presented in Formula 16 [22].

$$SCR_{op} = \min\{0.3*BSCR; Op\} + 0.25*Exp_{ul},$$
 (16)

where

*BSCR* — Basic solvency capital requirement; *Op* — *max(oppremium;opprovision)*.

Before measuring the operational risk, it is necessary to manage operational risks; therefore, the author has investigated the standard formula of operational risk measurement according to the 5<sup>th</sup> quantitative impact study under the Solvency II regime. In order to measure the operational risk, the following components should be taken into account: annual expenses that incurred during the previous 12 (twelve) months in respect of the investment risk by policyholders from life insurance, earned premiums, insurance obligations and basic solvency capital requirements.

Therefore, the author can conclude that operational risk management involves many issues that should be assessed, controlled and leaded. The establishment of the risk strategy belongs to part of risk strategy of the described risk management system (see Fig. 28).

In order to better understand the nature and basis of operational risk model, the author of the Doctoral Thesis has performed the analysis of the risk strategy establishment, the results of which are presented in Fig. 30.



**Fig. 30.** Establishment of risk strategy (created by the author based on [22], [25], [44], [90], [91], [92], [93], [94], [95])

In fact, in the operational risk model the connection among risk appetite, limits, tolerance statements, and risk strategy should be analysed. Moreover, the author of the Doctoral Thesis can conclude that it is important to define the risk appetite, risk limits and risk tolerance in a proper and correct way as their wrong estimation can lead to the incorrect risk strategy.

According to the Solvency II framework, risk management strategy must be clearly defined and well documented. This strategy must set risk management objectives and key risk management principles, define the organisation's risk appetite and finally describe the roles and responsibilities of the risk management function across the company and in accordance with its business strategy [44].

The fact is that the author of the Doctoral Thesis fully agrees with the approach how the risk strategy should be established and implemented in an insurance company. The operational risk model describing the basis of risk strategy setting created by the author is presented in Fig. 31.



Fig. 31. The scheme of operational risk management model (the author's own research based on [22], [25], [44], [92], [93], [94], [95], [96], [97])

On the basis of Fig. 31, the author can conclude that the operational risk management model is complicated and involves many key risk management objectives. Therefore, a wrong risk strategy can negatively influence insurance company's business processes and aggravate financial stability and development.

Loss database belongs under risk identification section of risk management system (see Fig. 32). For operational risk, details should be provided on the gross operational loss amount suffered by undertakings, the number of operational loss events, how the undertaking monitors,

classifies and collects data on operational loss events and some detail of operational losses suffered compared to own funds [21].



Fig. 32. Loss database implementation algorithm as part of risk management system (created by the author)

Loss databases<sup>4</sup>, both internal and external, are important aspects of an operational risk programme. The understanding of interconnectivity of different risks is a prerequisite to controlling problems and assessing practices. Firms should strive to understand the causes and related factors relevant to operational risk losses. Comprehensive qualitative information can help managers identify the commonalties among loss events. Seeing these patterns or common threads may allow managers to recognise red flags in their own controls before incidents occur. Quantitative tools further enhance a database by allowing it to be used for benchmarking [93].

Loss database has the following aims:

- to improve operational risk management;
- to minimise the probability of operational risk occurrence;
- to reduce possible losses in case of operational risk occurrence;
- to improve communication at all company's levels, control system, procedures, processes and IT system.

Loss database should include the following information:

- mistake registration date, identification of sub-risks of operational risk ;
- mistake description;
- direct or indirect loss assessment;
- profit or loss evaluation;
- company's units where a mistake has occurred;
- identification of a risk category and a risk status;
- identification of mistake risk factor.

Implementation of the loss database according to the operational risk model should be prepared based on the loss database algorithm of operational risk (see Fig. 32).

The fact is that operational risk management is the process of identification, analysis, assessment, organising, planning, leading, controlling, elimination and evasion of operational risk events in order to minimise the probability of risk occurrence and reduce possible losses or near miss.

The successful integration of operational risk management in the organisational structure is dependent not only on an accurate model and correct data but also on the ability to demonstrate the connection between decision making and data produced taking into account capital, estimated risk appetite, risk tolerance and risk limits, risk framework. Therefore, the

<sup>&</sup>lt;sup>4</sup> Loss database is used for operational risk management in insurance.
	Α	В	С	D	E	F	G	Н		J	K
1	N∙ ▼	Registration date	Sub-risk identification 💌	Description	Direct expenses 💌	Indirect expenses 🔻	Losses, EUP	Unit 👻	Category 👻	Status 👻	Risk factors 👻
2	1	07/10/2011	Human risk	Mistake in booking	yes	yes	-500	Finance	2	In process	Manual work
3	2	13/10/2011	IT system risk	Incorrect calculation of policy mathematical reserve	no	yes	-300	Actuarial	1	In process	IT system
4	3	20/10/2011	Human risk	Incorrect premium fee for group policy since start	yes	yes	-100	Finance	1	Open	Manual work
5	4	01/11/2011	Human risk	Incorrect claim amount paid out	yes	no	-1200	Finance	3	Finished	Manual work
6	5	09/11/2011	Internal audit risk	Mistake in reinsurance calculations	yes	yes	-14500	Actuarial	4	In process	Manual work
7	6	14/11/2011	Human risk	Incorrect administration costs calculation for several policies	no	yes	-203	Policy administration	1	Open	People
8	7	30/11/2011	IT system risk	Incorrect P/L amount	yes	no	-35000	Actuarial	5	Finished	IT system
9	8	06/12/2011	Bussiness risk	Incorrect fund price	yes	yes	-1400	Actuarial	3	Finished	Outside factors
10	9	15/12/2011	Human risk	Incorrect acquisition cost amount for several policies	yes	no	-400	Policy administration	2	In process	Manual work
11	10	19/12/2011	Human risk	Incorrect booking	yes	yes	-110	Finance	1	Open	Manual work

insurance company should show how effectively the risk culture is integrated in all processes. The author has also prepared the example of loss database fragment that is presented in Fig. 33.

Fig. 33. Example of a loss database fragment (developed by the author)

The point is that one of the most critical key factors for operational risk management integration in the insurance company's processes is human social capital.

The term "social capital" refers to the benefits that can be obtained from social relationships, similar to financial capital, physical capital (e.g., a dwelling) and individual capital (e.g., education) [98]. The point is that social human capital requires attention to be paid to the relationships, which shape the implementation of every employee potential. Therefore, human social capital is a key to the company's activity success and development. Therefore, the author has conducted the research<sup>5</sup> of human social capital impact on operational risk management using the methods of expert estimation and priority charts.

During the research, the author has identified the criteria of social human capital that have the biggest impact on operational risk management according to the requirements of the Solvency II regime. To identify the criteria of social human capital that have the biggest impact on operational risk management according to the requirements of the Solvency II regime, the author has used the method of expert estimation. The author has carried out the interviews in focus groups of 5 experts. The experts were the key specialists from Latvian insurance

<sup>&</sup>lt;sup>5</sup> The research was conducted in 2012 based on focus group approach among key specialists in Latvian insurance companies.

companies whose responsibilities were connected with risk management, audit, business control and risk measurement functions.

All experts evaluated the following criteria of human social capital according to the five-degree scale:

- board and executive role modelling (K1);
- new and improved skills and knowledge (K2);
- increased transparency in decision making (K3);
- collaboration around decision making (K4);
- establishing risk management at the heart of the company's culture (K5);
- ensuring clarity of ambition (K6);
- building greater leadership alignment (K7);
- establishing and proactively managing key stakeholders (K8);
- having the right team (K9);
- engaging human resources (K10).

The experts' evaluation of human social capital criteria summarised by the author is presented in Fig. 34. The experts were asked to rank the criterion based on the importance.



Fig. 34. The experts' evaluation of human social capital criteria (created by the author)

The results of the importance evaluation of the factors of human social capital of the Solvency II Directive based on the model of factor evaluation and identification that compares the pairs of criteria and identifies the criteria that are the most important according to experts' evaluation (see Table 5).

#### Table 5

Evaluation criterion										Total	Importance	
	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	evaluation	ratio
K1	-	2	1	1	1	1	1	1	1	1	8	0.18
K2	2	-	2	2	2	2	2	2	2	2	9	0.20
К3	1	2	-	4	3	3	3	3	9	3	5	0.11
K4	1	2	4	-	4	4	4	4	9	4	6	0.13
K5	1	2	3	4	-	5	7	5	5	9	3	0.07
K6	1	2	3	4	5	-	7	6	9	10	1	0.02
K7	1	2	3	4	7	7	-	7	9	7	4	0.09
K8	1	2	3	4	5	6	7	-	9	10	0	0.00
К9	1	2	9	9	9	9	9	9	-	9	7	0.16
K10	1	2	3	4	5	10	7	10	9	-	2	0.04
Total											45	

Human Social Capital Requirements of Solvency II (created by the author)

Result for each criterion is the average of all experts' evaluations. After that the author has compared the experts' evaluation with the model of factor evaluation and identification that shows the importance ratio of every human social capital criterion in order to identify the most critical ones (see Table 5).

According to the results of model of factor evaluation and identification, the author of the Doctoral Thesis has identified and described the five main criteria of human social capital with the most significant impact on operational risk management:

- According to the experts' evaluation, the criterion of new and improved skills and knowledge has 0.20 importance ratio because of the Solvency II framework's challenges and sometimes incomprehensible requirements regarding operational risk management that requires a lot of knowledge, new developed skills to support all changes in processes, models, policies, organisational structure and procedures.
- The criterion of board and executive role modelling is evaluated with 0.18 importance ratio that demonstrates a significant role of the board under the Solvency II framework that requires considering the results of internal model during strategic decision making.
- The criterion of having the right team has 0.16 importance ratio as due to the Solvency II regime implementation all insurance companies need to have internal capacity to

manage the operational risk. The companies need to find the best solution between permanent and temporary resources; therefore, they need to find the appropriate role for every employee to enable more precise and effective implementation of new processes.

- The criterion of collaboration around decision making has 0.13 importance ratio. In fact, the Solvency II framework implementation involves almost all insurance company's processes and units; therefore, they are related and dependent on each other. Due to this reason, it is critical to have all decision making harmonised.
- According to experts' evaluation, the criterion of increased transparency in decision making has 0.11 importance ratio. The point is that one of the main requirements of the Solvency II framework is transparency of insurance company's decision making that affects financial stability, solvency and activity.

Human social capital significantly influences operational risk management; therefore, good qualification of insurance company's employees, ability to work in a team and independency are the most important requirements of the Solvency II regime.

# 3. THEORETICAL ASPECTS OF NEW APPROACHES TO RISK MANAGEMENT AND ITS PRACTICAL IMPLEMENTATION 3.1. Risk Culture: New Approaches of Measurement and Improvement

#### 3.1.1. Quantitative Approaches to Assessment of Risk Culture

The author has developed a short-term solution to the risk culture development in an insurance company based on the quantitative impact studies of the Solvency II framework, particularly the 5<sup>th</sup> quantitative study.

Ranking methods are used in order to assess and measure the expert evaluations. The author has adapted the ranking methods to perform risk evaluation in the Baltic insurance companies. Using risk ranking methods, there is a necessity to investigate average statistical importance evaluation of each risk (see Formula 17) [99].

$$M_{j} = \frac{\sum_{i=1}^{m} C_{ij}}{m},$$
(17)

where

 $M_j$  — an average statistical value of *j* risk importance assessment;

m — the number of experts that have evaluated j risks;

 $C_{ij}$  — experts *i* assessment of *j* risks.

The point is that it is also important to calculate a proportion coefficient of each risk identified in an insurance company (see Formula 18) [99].

$$K_{yj} = \frac{\sum_{i=1}^{m} C_{ij}}{k_{aej} \sum_{j=1}^{n} \sum_{i=1}^{m} C_{ij}},$$
(18)

where

 $K_{yj}$  — *j* risk proportion coefficient, the overview of part of all risk points;

n — risk amount;

 $k_{aej}$  — expert activity coefficient for *j* risk.

In order to approve the conformity of attracted experts, the level of conformity should be calculated. The level of the expert conformity can be calculated using all expert evaluation variance for each risk (see Formula 19), average quadratic variation of expert evaluation (see Formula 20), and relative variation coefficient of evaluation (see Formula 21) [99].

$$D_{j} = \frac{\sum_{i=1}^{m} (C_{ij} - M_{j})^{2}}{m}.$$
(19)

$$\sigma_j = \sqrt{D_j}.$$
 (20)

$$\upsilon_j = \frac{\sigma_j}{M_j}.$$
 (21)

However, the conformity of expert evaluation for all identified risks can be assessed using Kendall's coefficient of concordance (see Formula 22) [100, 32 p.].

$$W = \frac{S}{S_{\text{max}}} = \frac{\sum_{i=1}^{n} \left\{ \sum_{j=1}^{m} r_{ji} - \frac{1}{2} m(n+1) \right\}^{2}}{\frac{1}{12} m^{2} (n^{3} - n) - m \sum_{j=1}^{m} T_{j}},$$
(22)

where

 $r_{ji}$  — expert (*j*) the importance rank of *i*-object;

 $T_j$  — is calculated as  $\frac{1}{12} \sum_{ij} (t_j^3 - t_j)$  where  $t_j$  is the repeated number of an expert (*j*) in the range;

n — number of experts;

m — number or criteria/objects.

Kendall's coefficient of concordance calculation is significant in experts' evaluation assessment, since it describes the evaluation correctness. The fact is that Kendall's coefficient of concordance range may vary from zero to one. If Kendall's coefficient of concordance is equal to 1, the expert evaluations are fully harmonised and can be used in the analysis. In order to prove the results of the conducted research using ranking methods, the hypothesis of the research should be verified (see Formula 23) [101]. The null hypothesis approves that no variation exists between variables, meaning that a single variable is no different from zero. It is assumed to be true until statistical event nullifies it for an alternative hypothesis.

H<sub>0</sub>: 
$$\chi_{\rho}^{2} = m \cdot (n-1) \cdot W \leq \chi_{T}^{2}$$
,  
H<sub>1</sub>:  $\chi_{p}^{2} = m \cdot (n-1) \cdot W > \chi_{T}^{2}$ ,
(23)

where

 $\chi_p^2$  — calculated chi-squared test based on probability  $\rho$ ;  $\chi_T^2$  — chi-squared test according to the table value dependent on degrees of freedom *T* and probability less than the critical value.

The author also uses another type of ranking method — pairwise comparison where each pair of risks should be compared using 10-point scale. The fact is that the expert evaluates how many points should belong to each risk from a pair. All expert evaluations are summarised in the matrix and compared to find out the most important risks with evaluation of each risk importance (see Formula 24) [101].

$$w_i = \frac{1}{\sum_{j=1}^{m} b_{ij}},$$
 (24)

where

 $b_{ij}$  — multifactorial distribution of expert evaluation.

Another approach to the assessment of risk culture is the use of the Analytic Hierarchy Process and the Analytic Network Process.

The research on risk culture improvement based on the Analytic Hierarchy Process was presented in the 30<sup>th</sup> International Congress of Actuaries and awarded the "Best Research" in the section "Financial and Enterprise Risk".

The valuable impact on the development of multi-criteria methods of factor evaluation for decision making in companies has been examined in the following studies: [102], [103], [104], [105], [106], [107], [108], [109], [110]. For example, Roy proposes using a multi-criteria methodology for decision making, using more sensitive methods based on pairwise comparison of alternatives [109]. Potapov *et al.* propose the usage of methods of determining weight coefficients for evaluation of the reliability of commercial banks [104].

Voronova [111] in her research has prepared the detailed summary of the methods of determining weight ratios with regard to the assessment of economic objects. She has proposed the usage of Fishburn's technique in the sample evaluation of reliability of non-life insurance

companies. Jansone *et al.* [112] have also used Fishburn's technique for the evaluation of risks in trading enterprises. The author of the Doctoral Thesis points out that the application of Fishburn's technique is advisable only in cases when for risk assessment only the degree of the preference of some risks to another risks should be investigated, for example, ranking with a proportional reduction in the significance of risks. For this reason, the author has not applied the Fishburn's technique to evaluate the risk culture.

The author of the Doctoral Thesis suggests using for risk culture management risk ranking and Analytic Hierarchy Process in a short-term period. The basis of the Analytic Hierarchy Process is the Saaty hierarchy method that introduces the theory of measurement through pairwise comparisons on expert evaluation to derive priority scales. The fact is that these scales measure intangibles in relative terms. Therefore, the Saaty hierarchy method measures how much one element dominates another with respect to the given attribute. The fact is that the attracted experts perform evaluation of concrete elements using the Saaty scale by means of pairwise comparisons according to the derived priority scales that measure intangibles in relative terms. The comparison matrix introduced by Saaty [113] is presented in Formula 25.

where

 $a_{i}$ , (i, j = 1, 2, ..., n) are the comparisons evaluated by the experts. Note  $a_{ji} = \frac{1}{a_{ij}}$ ,  $\forall i, j$  $\frac{w_i}{w_j} = a_{ij}$  (i, j = 1, 2, ..., n) are the relative weights obtained by the comparisons.

The Eigenvector method [114], including calculation of  $\lambda_{max}$ , has been described in Formula (26), Formula (27) and Formula (28).

$$\frac{w_1}{w_1} \quad \frac{w_1}{w_2} \quad \cdots \quad \frac{w_1}{w_n} \quad w_1 \qquad w_1 \\
\vdots \qquad \vdots \\
\frac{w_n}{w_1} \quad \frac{w_n}{w_2} \quad \cdots \quad \frac{w_n}{w_n} \quad w_n \qquad w_n$$
(26)

or

$$(A-n)\cdot w = 0, \tag{27}$$

$$A \cdot w = \lambda_{\max} \cdot w, \tag{28}$$

where

A — reciprocal matrix from  $(a_i,)$ ;

w — eigenvector of A matrix with eigenvalue n;

 $\lambda_{\max}$  — largest eigenvalue of *A*.

Saaty evaluation is based on the specific scale using pairwise comparison, presented in Table 6. During the case study, experts should use this scale. Also, there is a possibility to use a 5-point scale.

Table 6

Impor	tance definition	Description				
1	Equal importance	Two risks contribute equally to the objective				
3	Moderate importance	Experience and judgment slightly favour one risk over another				
5	Strong importance	Experience and judgment strongly favour one risk over another				
7	Very strong importance	A risk is favoured very strongly over another; its dominance is demonstrated in practice				
9	Extreme importance	The evidence favouring one risk over another is of the highest possible order of affirmation				
2, 4, 6, 8	Compromise between the values above	Sometimes one needs to interpolate a compromise judgement numerically				

Saaty Evaluation Importance Scale [113]

However, the estimates of the weights for the activities could be calculated by normalising the eigenvector that is appropriate to the largest eigenvalue in the matrix equation above (see Formula 26). However, there is a possibility to use least squares and logarithmic least squares methods. Saaty [114] describes the possibility of using the geometric mean and the row average techniques for approximation of the eigenvector of a reciprocal matrix (see Formula 25). The author suggests the practical application approximation using geometrical mean investigated in [115].However, the author of the Doctoral Thesis in her study uses the geometric mean method for approximation of the eigenvector of a reciprocal matrix. However, the experts' evaluation should be confirmed by calculation of CI (consistency index) (see

Formula 29) or CR (t consistency ratio) (see Formula 30), RI (random index) (see Formula 31) [114-117].

$$CI = (\lambda_{\max} - n) / (n - 1), \tag{29}$$

$$CR = CI / RI, \tag{30}$$

$$RI = 1.98 \cdot (n-2)/n,$$
 (31)

where

 $\lambda_{\max} \ge n$  are main eigenvalues of matrix. If the matrix returns to a positive value then  $\lambda_{\max} \ge n$ .

n — number of comparable elements.

In case the consistency ratio is less than 10%, conformity of expert view is likely to take place and results can be defined as reliable. Saaty [116] proposes fulfilling the following activities if the consistency ratio is higher than 10%:

- to find the most inconsistent judgment in the matrix;
- to determine the range of values to which that judgement can be changed corresponding to which the inconsistency would be improved;
- to ask the decision-maker to consider, if he can, changing his judgment to a plausible value in that range.

However, Saaty [116] has also reviewed the values for consistency ratio in his recent studies:

- if the calculated consistency ratio is 5% or less and the number of factors is equal to 3, the results are consistent;
- if the calculated consistency ratio is 9% or less and the number of factors is equal to 4, the results are consistent;
- if the calculated consistency ratio is 10% or less and the number of factors is equal or is higher than 5, the results are consistent.

Saaty [114] has also developed the method to recalculate concrete experts' evaluations of factors in case of inconsistency. The basis of the proposed method is to form the matrix of priorities  $w_i/w_j$  by preparation of the matrix of absolute differences (see Formula 32) with aim to revise the judgment of the elements or sumirized lines with the largest differences.

$$a_{ij} - \frac{w_i}{w_j} . aga{32}$$

Saaty and his colleagues at the Oak Ridge National Laboratory and at the Wharton School of the University of Pennsylvanian have investigated the possible values of the random ratio. However, there is the possibility to use the random ratio based on Saaty's research performed. During the research, 500 random reciprocal n x n matrices were generated for n = 3 to n = 15 using the 1 to 9 scale [114 - 116]. The results of research conducted by Saaty are presented in Table 7.

Table 7

Matrix values n	RI	
	1980	2001
1	0	0
2	0	0
3	0.58	0.52
4	0.9	0.89
5	1.12	1.11
6	1.24	1.25
7	1.32	1.35
8	1.41	1.4
9	1.45	1.45
10	1.49	1.49

Random Ratio Values Investigated by Saaty (based on [114], [116])

Tihomirova *et al.* [110] changed the scales in their research, so the calculation of consistency index for the random matrix of the following type was performed to ensure the consistency of the matrix. Unfortunately, the authors of the research modelled only 100 random matrices only for 3, 4, 5 factors. Therefore, the author of the Doctoral thesis has not used the modified hierarchy method for the evaluation of risk culture in insurance.

The Analytic Hierarchy Process is defined as a multi-criteria decision-making technique that can help express the general decision operation by decomposing a complicated problem into a multi-level hierarchical structure of objectives, criteria and alternatives [118]. The Analytic Network Process is the combination of SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis and the choice of a business strategy that helps to ensure further successful development and financial stability of an insurance company. The Analytic Network Process allows measuring the dependencies and feedback among decision elements and strategic factors in the hierarchical or non-hierarchical structures; thus, it might be used within the analysis of complicated and sensitive interrelationships between decision levels and attributes.

The Analytic Network Process can also be defined as the combination of the Analytic Hierarchy Process and SWOT that allows including tangible and intangible strategic factors and elements into the decision-making process of an insurance company by applying specified functions or field steering, analysis and management.

According to scientific definitions, the SWOT analysis is a commonly used instrument, which scans internal strengths and internal weaknesses of a product or service industry and highlights the opportunities and threats of the external environment [119], [120]. In addition, the SWOT can be explained as a widely applied tool in the analysis of internal and external environments in order to achieve a systematic approach and support for strategic decision situations [121]. The combination of the Analytic Hierarchy Process and SWOT analysis sets a strong basis for assessing the existing situation and applying the most valuable development strategy in a simpler and more efficient way.

The introduced technique was used in many areas, such as tourism [122], [123], forest and park services [124], [125], [120], [126], project management [127], agriculture [128], manufacturing [129], household appliance industry [130], tannery industry [131] sport marketing outsourcing [132], fishing industry [133], textile industry [134], selection in maritime transportation industry [135], water resource management [136], information system outsourcing [137]. The author of the Doctoral Thesis can conclude that the Analytic Network Process is mostly used in particular areas and projects; thus, there are only a few studies on its application to processes and its improvement.

The application of hybrid method (A'WOT) for the search of development strategy and performance of SWOT analysis in different areas of business was adapted firstly in studies of Kajanus *et al.* [123], Kangas *et al.* [124].

The Analytic Network Process was firstly introduced by Thomas Saaty [117] in his work regarding the decision making based on multi-criteria assessment that applies network structures with dependences and feedback among specific elements of decision-making process by arranging them in a hierarchical structure with the aim to evaluate the relative importance of pairs of elements and synthesise the results. While the Analytic Hierarchy Process represents a framework with a unidirectional hierarchical relationship, the Analytic Network Process allows for complex interrelationships among decision levels and attributes [134].

One approach to evaluate the relative performance of decision alternatives with respect to multiple criteria is provided by the Analytic Hierarchy Process. The method is based on pairwise comparisons between attributes, and several numerical measurement scales for the ratio statements have been proposed. The choice of measurement scale is re-examined, and new arguments supporting the measurement scale of geometric progression are derived [138]. During the research, the author has investigated the difference in risk evaluation methods adapted to an insurance company, using attracted experts' assessments (see Section 4.1).

However, the risk culture could be improved using the Analytic Network approach that ensures proper decision making based on risk management core principles to eliminate the possible risk of the insurance company and to improve its development, profit, and financial results. The Analytic Network Process is the combination of SWOT analysis designed to evaluate an insurance company's activity and the choice of strategy with the purpose to ensure its further successful development and financial stability. The logic of the Analytic Network approach is presented in Fig. 35. The description of the Analytic Network Process, adopted for insurance is presented in Fig. 36.



Fig. 35. The description on Analytic Network Process (created by the author based on [116],



\*Please consider that strengths, weaknesses, threats and opportunities are interconnected between each other

Fig. 36. The determination of the strategy based on the Analytic Network Process for insurance (created by the author)

Based on Fig. 35, the author can conclude that the Analytic Network Process should be used for complex interrelationships among decision levels and attributes. The Analytic Network Process allows measuring the dependencies and feedback between decision elements and strategic factors in the hierarchical or non-hierarchical structures; thus, it might be used within the analysis of complicated and sensitive interrelationships between decision levels and attributes. The most valuable advantage of using the Analytic Network Process in insurance is the possibility to include tangible and intangible strategic factors and elements in the decisionmaking process of an insurance company by applying specified functions or field steering, analysis and management. All described quantitative approaches should help to improve the risk assessment through enhancement of the risk culture.

# 3.1.2. The Significance of Risk Culture in Insurance Company's Processes

According to the requirements of the Solvency II regime, insurance companies' solvency and financial stability should be managed and improved through risk assessment; therefore, the author introduces the approach to risk evaluation implementation in the Baltic countries, particularly in Latvia. The fact is that the author has divided the implementation of Solvency II Directive requirements into 3 stages:

- Establishment of risk culture where the nature of each risk should be investigated with the aim to set appropriate risk appetite, tolerance and limits.
- Risk measurement where the capital for each risk should be calculated according to the standard formula of the Solvency II or an insurance company's internal model.
- Risk management process should be fully implemented with the aim to manage and control all processes of an insurance company with the aim to eliminate the possible risk of the insurance company and to improve its development, profit and financial results.

The interpretation of the impact of risk culture on an insurance company's activity is demonstrated in Fig. 37.



Fig. 37. The impact of the risk culture on an insurance company's activity (created by the author)

The interconnection between the Analytic Network Process and risk culture is presented in Fig. 37, since the Analytic Network Process helps to educate the key employees (including members of the board) in risk nature understanding, establishment of a risk strategy and risk profile.

Risk evaluation involves the implementation of risk culture, risk measurement and risk management cover all Solvency II requirements. In fact, the author considers the risk culture of every insurance company to be the heart of ORSA.

#### 3.2. The Application of Scenario Planning to Risk Management

## 3.2.1. Scenario Planning Role in Risk Management

All business activities are accompanied by risk situations and uncertainties. Living in the modern era, in which globalisation of business has been increasing, science and technology have been intensively developing, especially usage of computers and information technology, so it is crucial to assess possible risk of the business. Scenarios are always used in order to develop the strategy for various future outcomes. All in all, the scenario should involve an area of interest along with the future developments for better understanding of possible future outcomes in the business environment. The author of the Doctoral Thesis has made the historical overview of scenario planning (see Fig. 38).

Scenario planning is a way of understanding the forces at work, such as demographics, globalisation, technological change and environmental sustainability that shape the future. While the origins of scenario planning were in the domain of strategic planning, many organisations now apply scenario planning techniques to the operational planning, budgeting and forecasting processes as a means of evaluating their effectiveness under different sets of assumptions about the future [139].

Initially, scenario planning was used by the military: during World War II, the U.S. Air Force tried to prepare alternatives strategies. Herman Kahn was the founder of scenario planning and created the idea of "thinking the unthinkable" and used scenarios as a tool for the business forecasting. Later Shell [140] began to use scenario as a strategy tool. The scenarios in 1985 were defined as an internally consistent view of what the future might turn out to be not a forecast but one possible outcome [141]. Also the scenario planning could be defined as a planning method used to deal with uncertainties in the future business environment [142].



**Fig. 38.** Historical overview of scenario planning (created by the author based on [139], [140], [141], [142], [143], [144])

However, the difference among scenarios, forecasts and visions is demonstrated in Fig. 39.

Fig. 39 describes differences among scenarios, forecasts and visions. Scenario, forecast and vision can be defined as strategic tools for short- or medium-term planning under uncertain conditions. As far as qualitative techniques are concerned, their way of operating is to combine experience intuition and other skills in order to derive relationships between the variables that can be applied when making the forecasts. The quantitative techniques operate in a different way; they make use of sets of data to establish trends and patterns useful for projecting quantities into the future [145].

# Future outcomes

ScenariosForecastsVisions- Possible, plausible future- Probable future- Desired future- Based on certain relations- Value based- Uncertainty based- Hide risks- Hide risks- Illustrate risks- Hide risks- Usually quantitative- Qualitative or quantitative- Quantitative- Energising- Necessary to know on what we decide- Daily used- Function as triggers- Rarely used- Strong in short-term perspective and low degree of uncertainty- Strong in short-term	-		
Possible, plausible futureProbable futureDesired futureBased on certain relationsValue basedUncertainty basedHide risksIllustrate risks- Hide risksQualitative or quantitative- QuantitativeNecessary to know on what we decide- Necessary to dare to decideNecessary to know on what we decide- Daily usedStrong in medium- to long-term perspective and uncertainties- Strong in short-term perspective and low degree of uncertainty	Scenarios	Forecasts	Visions
	<ul> <li>Possible, plausible future</li> <li>Uncertainty based</li> <li>Illustrate risks</li> <li>Qualitative or quantitative</li> <li>Necessary to know on what we decide</li> <li>Rarely used</li> <li>Strong in medium- to long-term perspective and medium to high uncertainties</li> </ul>	<ul> <li>Probable future</li> <li>Based on certain relations</li> <li>Hide risks</li> <li>Quantitative</li> <li>Necessary to dare to decide</li> <li>Daily used</li> <li>Strong in short-term perspective and low degree of uncertainty</li> </ul>	<ul> <li>Desired future</li> <li>Value based</li> <li>Hide risks</li> <li>Usually quantitative</li> <li>Energising</li> <li>Relatively often used</li> <li>Function as triggers for voluntary change</li> </ul>

Fig. 39. Scenarios, forecasts and visions (created by the author based on [142], [143], [144])

Scenario planning is an internal strategic view of possible future outcomes under continuously increasing uncertainties that dominate the insurance market. Scenario planning is based on the short-term method that offers the development of effective scenarios with considerable knowledge, discipline, and construction to focus on the company's main problems and issues. Several authors [143], [146], [147] investigate concepts, models and techniques of the scenario planning as a possible strategic instrument of effective performance management.

Basically, the scenario planning is about making choices today with an understanding of how they might turn out. Scenario is a tool for ordering one's perceptions about alternative future environments in which one's decisions might be played out [148].

However, the scenario planning is usually used for the companies using 6–8 stages [149], [150]. The core structure of scenario planning for the insurance market is presented in Fig. 40.





The scenario planning is based on the four main components: risk management, decision making, finance and planning that forms the basis of each insurance company's organisational structure and heart of financial stability.

The fact is that the scenario planning can be based on historical and statistical data and hypothetical scenarios. The author has identified the following main features of an insurance market historical scenario:

- based on statistical and actuarial data of past years;
- more conservative and less influence on the part of management;
- not enough suitable and advanced for risk sensitive and sophisticated evaluation; therefore, measurement of insurance company's risk tolerance, risk appetite and risk limit is not appropriated.

Therefore, the insurance market scenario planning based on hypothetical scenarios includes the following main features:

- forecast of macro-economic development and significant market events;
- influenced by specialist expertise and management;
- sometimes can be lack of support on the part of business;
- statistical data can be used to identify the interconnection between different elements and factors that influence company's activity and stability.

However, the scenario planning has quite a big impact on decision making since requires deep understanding of the environmental forces and policyholders' behaviour. Scenario planning is a situational dynamical exercise that should be performed on a regular basis and requires detailed and adequate documentation of all development and establishment processes that is totally suitable for the requirements of the Solvency II regime.

In order to prepare possible scenarios of future outcomes for insurance company's development, it is necessary to analyse all internal and external factors. The insurance company's possible future outcome that was forecasted using the scenario planning should be evaluated by critical stress testing that allows performing the sensitivity analysis of external factor influence on company's possible development.

The author has investigated the factors that influence scenario planning and presents the main findings in Fig. 41.



Fig. 41. The factors influencing scenario planning (created by the author based on [17], [21], [22])

To conclude, it is evident that simulation models give us the opportunity to test different strategies under different assumptions. This can help us to a great extent by simulating the scenarios already developed. However, to implement them successfully, the following guidelines should be satisfied [151]. The author's research of scenario planning role in risk management is presented in Fig. 42.



Fig. 42. The scenario planning role in the risk management framework (created by the author based on [17], [21], [22])

Based on Fig. 42, the author can conclude that the mission of scenario planning is to model uncertainness of the business improving governance of the process, risk profile and risk culture within an organisation.

#### 3.2.2. Scenario Planning Application to Operational Risk Management

The integration of scenario planning into insurance company's processes should be performed through the establishment of the Solvency II Directive requirements.

The scenario planning in the Baltic non-life insurance market will mainly be used for planning where possible outcomes should be evaluated and estimated. However, correct identification of key factors of the scenario planning is the first step for the scenario planning in insurance. It is also significant to investigate the main functions of an insurance company that can be covered using the scenario testing according to the Solvency II methodology.

The key factors of the scenario planning and stress testing in an insurance company for operational risk management, according to the Solvency II regime requirements, are presented in Fig. 43.



Fig. 43. The key factors of the scenario planning in insurance companies for operational risk management (created by the author based on [17], [21], [22], [25], [27], [28], [29])

According to the own risk and solvency assessment document, all key factors from Fig. 43 should be included in the scenario development.

Fig. 44 demonstrates a possible way of scenario planning for operational risk management integration and implementation process in the Baltic non-life insurance market.





Based on Fig. 44, the author can conclude that the scenario planning for the operational risk management should be interconnected with almost all insurance processes and external processes like economic, political, social situation in the Baltics.

In fact, the scenario planning covers almost all key functions of  $2^{nd}$  Pillar since it is responsible for managing business risks of non-life insurance company. The research of the key functions, on which scenario planning is based, is presented in Fig. 45.



Fig. 45. Key functions involved in scenario development (created by the author based on [17], [21], [22])

Based on Fig. 45, the author can conclude that in order to prepare the suitable and trustable scenario of possible future company's development the competence of risk management, control and actuarial functions should be in line with the requirements of the Solvency II framework.

However, it is challenging to integrate the analysis of the macro-economic situation in the Baltics into the scenario planning since the Baltics is fully affected by the global economy development. The author concludes that the scenario planning integration for operational risk management is a structured process that helps develop a business strategy of the insurance company and improve its solvency through correct decision making using possible future outcomes.

# 4. DEVELOPMENT OF RISK MANAGEMENT MODEL AND ITS IMPACT ON THE BALTIC INSURANCE MARKET 4.1. Development of Risk Management Strategy and Its Impact on Insurance Company's Activity

4.1.1. Improvement of the Risk Assessment Using Hierarchy and Ranking Methods

In order to improve the risk assessment, the author has prepared the algorithm for the risk assessment improvement. The proposed algorithm introduces the risk evaluation process starting from its establishment in an insurance company and is presented in Fig. 46.



Fig. 46. Algorithm for improvement of risk management (created by the author)

The proposed algorithm should serve as a basis for the established operational risk management system. The introduced algorithm of the risk management can be included in the first stage of risk culture establishment within an insurance company.

Initial stage of the proposed algorithm for improvement of the risk management in an insurance company is explained below:

- Step 1: Identify sub-risks of risk and create a risk catalogue.
- Step 2: Attract the internal experts of different units at your insurance company.
- Step 3: Ask internal experts to independently evaluate the main risk using the Saaty scale.
- Step 4: Calculate the importance of each risk using the geometric mean.
- Step 5: Check the conformity of calculated results with the calculation of consistency index (CI), or consistency ratio (CR) and random index (RI).
- Step 6: If the consistency ratio is less than 10% and number of factors is equal or higher than 5, if the consistency ratio less than 9% and number of factors is equal or higher than 4, the consistency ratio less than 5% and number of factors is equal or higher than 3, you can say about the conformity of experts' view.
- Step 7: If the consistency ratio exceeds 10% and number of factors is equal or higher than 5, if the consistency ratio exceeds 9% and number of factors is equal or higher than 4, the consistency ratio exceeds 5% and number of factors is equal or higher than 3, you can say about the non-conformity of experts' view. Additional experts' evaluation is required and analysis should be performed one more time.
- Step 8: Assess the main risk factors affecting main functions of the Solvency II regime using the same experts' evaluation.
- Step 9: Make conclusions about main risk factors and the most important risk that influences an insurance company's activity.
- Step 10: Create an activity plan for the risk possible harm elimination.

The author performed the case study based on risk evaluation of a particular insurance company using the proposed algorithm.

The conducted research should help establish short-term practise of possible risk nature investigation, using expert evaluations. During the conducted research<sup>6</sup> the author attracted experts from the particular insurance company. Each expert had the work experience of two

<sup>&</sup>lt;sup>6</sup> The research was conducted in summer 2013. In the case study, the experts' evaluation was performed using a consensus approach in focus group.

and more years and introduced a concrete process in the given insurance company. The experts represented the following fields of the insurance company:

- actuarial function independent function, responsible for risk measurement according to the Solvency II framework, mainly involved in the 1<sup>st</sup> Pillar, but is also involved in the 2<sup>nd</sup> Pillar and 3<sup>rd</sup> Pillar;
- internal audit function independent function, is involved in the requirements of 2<sup>nd</sup>
   Pillar of the Solvency II Directive;
- risk management function independent function, is responsible for risk evaluation and is involved in the 2<sup>nd</sup> Pillar and 3<sup>rd</sup> Pillar of new regime;
- compliance function independent function, responsible for management action control, planning and forecasting and compliance of functions, is involved in the 2<sup>nd</sup> Pillar;
- sales responsible for gross written premium volume; often heads of the sales departments are board members, mainly are involved in the fulfilment of the Solvency II regime requirements on the part of management;
- risk underwriting responsible for pricing actions for all insurance company's products;
- claims handling responsible for appropriate claims handling process in an insurance company, providing first estimates of case reserves and ensuring proper process of resources and salvages.

The author of the Doctoral Thesis has firstly investigated the main risks of an insurance company using the above-mentioned expert evaluations. The expert evaluations using the Saaty scale are presented in Table 8.

According to experts' evaluations, the risks with the biggest possible negative impact are non-life risk, health and market risk.

The results can be explained by the fact that those are the most well-known risks of the employees of non-life insurance companies; besides, there is a lack of understanding in the nature of risks due to initiating the process of risk management integration in the processes of an insurance company. Moreover, the experts' evaluation of the risks is proved by the calculation of the consistency ratio that is less than 10%.

Risk	Risk Risk								
	1	2	3	4	5	degree, %			
1.Operational risk	1.00	0.50	2.00	0.50	0.50	13.17%			
2.Non-life risk	2.00	1.00	2.00	2.00	2.00	31.45%			
3.Credit risk	0.50	0.50	1.00	0.25	0.25	8.25%			
4.Health risk	2.00	0.50	4.00	1.00	2.00	26.48%			
5.Market risk	2.00	0.50	4.00	0.50	1.00	20.65%			
Total	7.50	3.00	13.00	4.25	5.75				
	$\lambda_{ m max}$								
	1.11								
	0.06993								
	(	CR				6.30%			

Expert Evaluation Using the Saaty Scale (prepared by the author)

However, the author has also asked the experts to evaluate the main risks of insurance company using the ranking method (see Table 9).

Table 9

	Risks									
Statistical value	1. Operational risk	2. Non-life risk	3. Credit risk	4. Health risk	5. Market risk					
Average	3.4	1.1	4.4	2.9	3.1					
Median	3	1	4	3	3					
Mode	5	1	4	2	4					
Ranks	4	1	5	2	3					

Expert Evaluation Using Ranking (prepared by the author)

However, the conformity of experts' evaluation should be proved by the calculation of Kendall's coefficient of concordance. Thus, the calculations to prove the conformity of experts' evaluation are presented in Table 10.

57.1%

16

14.86

13.28

author)	
Statistics	Value
Number of the experts	7
Number of freedom degrees	4

Kendall's coefficient of concordance

 $\chi^2_p$ 

 $\chi_T^2$  (alfa = 0.005)

 $\chi_T^2$  (alfa = 0.01)

Experts' Conformity Approval Using Kendall's Coefficient of Concordance (prepared by the

The author can conclude that experts' evaluation can be used in risk ranking and that
according to the conducted research the results are similar to the results of Analytic Hierarchy
Process. The fact is that according to the both approaches used the risk evaluation follows each
risk capital measurement tendency of the Solvency II framework, where the biggest capital
should be put into non-life risk. The author has also adapted the ranking method to the
operational risk nature investigation that could be a starting point of operational risk culture
improvement. The fact is that an operational risk is one of the most complicated and
unpredictable risks, since it fully depends on the human factor, failures in IT, processes,
organisational structure and external factor failures. Therefore, an interconnection between the
decision making and estimation of a risk appetite, risk tolerance, and risk limits should be fully
integrated into an insurance company's processes. Basically, the author, using the technique of
a risk catalogue, has identified sub-risks of operational risk and asked the same experts to
evaluate sub-risks of operational risk using the ranking method and pairwise comparison.
According to the created risk catalogue, the main sub-risks of operational risk are as follows:

- organisational risk (R<sub>11</sub>);
- reputational risk (R<sub>12</sub>);
- business disruption and system failure risk (R<sub>13</sub>);
- human resource risk (R<sub>14</sub>);
- client, product and business practice risk (R<sub>15</sub>);
- compliance risk (R<sub>16</sub>);
- execution, delivery and process management risk (R<sub>17</sub>);

- external fraud risk (R<sub>18</sub>);
- information technology (IT) risk (R<sub>19</sub>);
- model risk ( $R_{110}$ ).

According to the research<sup>7</sup> based on the operational risk assessment using the ranking method, the author can conclude that sub-risks with the greatest negative influence on insurance company's development and stability are business disruption and system failure risk, organisational and reputational risks. The analysis of the expert evaluations of the operational risk using the standard ranking method is presented in Table 11.

Table 11

Statistical		Risks (R <sub>1</sub> )										
value	1	2	3	4	5	6	7	8	9	10		
Average	3.1	3.4	2.9	4.9	6.1	4.6	7.6	8.4	4.7	9.3		
Median	2	4	3	5	7	5	7	8	4	9		
Mode	2	4	3	5	8	7	10	8	3	9		
Ranks	2	3	1	6	7	4	8	9	5	10		

Operational Risk Evaluation Using Ranking (prepared by the author)

In order to prove the conformity of expert evaluation, the author of the Doctoral Thesis has calculated the Kendall's coefficient of concordance presented in Table 12.

Table 12

Approval of Expert Evaluation Conformity (prepared by the author)

Statistics	Value
Number of the experts	7
Number of freedom degrees	9
Kendall's coefficient of concordance	56.2%
$\chi^2_p$	35.38
$\chi_T^2$ (alfa = 0.005)	23.59
$\chi_T^2$ (alfa = 0.01)	21.67

<sup>&</sup>lt;sup>7</sup> The research was conducted in summer 2013. In the case study, the experts' evaluation was performed using a consensus approach in focus groups.

Using expert evaluations, the author has also performed pairwise comparison with the aim to identify the main sub-risks of operational risk that have the greatest negative impact on an insurance company's activity.

According to the results of the pairwise comparison of sub-risks of the operational risk, sub-risks with the greatest negative influence on the insurance company are IT risk, business disruption and system failure risks and compliance risk. The conducted research is presented in Table 13.

#### Table 13

Risks					Ri	sks				
	1	2	3	4	5	6	7	8	9	10
1	1.00	0.84	0.75	0.84	0.89	0.52	1.50	1.69	0.59	1.59
2	1.19	1.00	0.68	2.04	1.41	0.94	1.92	2.18	0.75	1.50
3	1.33	1.46	1.00	1.92	1.33	0.94	1.50	1.80	1.12	1.92
4	1.19	0.49	0.52	1.00	1.50	0.75	1.50	1.29	0.52	1.06
5	1.12	0.71	0.75	0.67	1.00	1.26	1.80	1.80	0.75	1.50
6	1.92	1.06	1.06	1.33	0.79	1.00	1.50	1.80	0.71	1.59
7	0.67	0.52	0.67	0.67	0.56	0.67	1.00	0.89	0.56	0.63
8	0.59	0.46	0.56	0.94	0.56	0.56	1.12	1.00	0.67	0.89
9	1.69	1.54	0.89	1.92	1.33	1.41	1.80	1.50	1.00	2.50
10	0.63	0.67	0.52	0.94	0.67	0.63	1.59	1.12	0.40	1.00
$\sum_{j=1}^m b_{ij}$	11.32	8.75	7.40	12.27	10.05	8.68	15.23	15.07	7.06	14.18
<b>Evaluation</b>	0.0883	0.1143	0.1351	0.0815	0.0996	0.1152	0.0657	0.0663	0.1416	0.0705
Ranking	6	4	2	7	5	3	10	9	1	8

The Pairwise Comparison of Sub-risks of Operational Risk (prepared by the author)

The comparison between ranking and pairwise comparison is presented in Table 14.

#### Table 14

The Results of Pairwise Comparison and Ranking Methods (prepared by the author)

Methods	Risks									
	1	2	3	4	5	6	7	8	9	10
Ranking method	2	3	1	6	7	4	8	9	5	10
Pairwise comparison method	6	4	2	7	5	3	10	9	1	8

The fact is that two different ranking methods have shown slightly different results; therefore, the author can recommend using the standard ranking method instead of pairwise risk comparison.

However, pairwise comparison should be performed using evaluation of experienced experts with deep risk nature comprehension. However, unfortunately the experts' knowledge in the Baltics is still at a low or medium level; therefore, evaluation can be unreliable.

The conducted research has demonstrated that, according to the experts' evaluations using the Analytic Hierarchy Process and ranking methods, it is possible to assess the risk with the greatest negative possible influence on the insurance company development and performance. The expert evaluation fully corresponds to the Solvency II capital requirements that should be imposed on the risk.

# 4.1.2. Improvement of the Risk Strategy Using the Analytic Network Process

The Analytic Network Process should be applied to the insurance industry in order to ensure proper decision-making process based on the core principles of risk management, to eliminate possible risk of the insurance company, and to improve its development, profit and financial results.

The proposed algorithm of the application of the Analytic Network Process to insurance company's processes is presented in Fig. 47.

In order to ensure the possibility of the Analytic Network Process application to the insurance industry, the author of the Doctoral Thesis has conducted the research on the example of one insurance company, which operates in the Baltics. During the research conducted in 2014, key employees with the professional experience of at least two years from different fields of an insurance company have been attracted: risk measurement, actuarial, underwriting and control areas.

In the case study, the experts' evaluation was performed using a consensus approach [114] in focus group; however, it is also possible to use an average mean approach of all experts' evaluation with the different or similar experts' priorities. Basically, the research was carried out based on the algorithm for the Analytic Network Process application in the insurance industry that was created by the author. During the case study, the experts' discussions were carried out to identify sub-factors of SWOT (see Table 15).

# •1.1. Atraction of experts

1

experts

Attracti on of •1.2. Introduction of the Saaty scale and nature of main insurance risk

•	
2.Analy sis of risk	<ul><li>•2.1. Risk catalogue creation</li><li>•2.2. Identification of sub-risks of risk</li></ul>
3.Asses sment of insuran ce risk	<ul> <li>•3.1. Grouping risk under SWOT internal and external factors</li> <li>•3.2. Identification of SWOT sub-factors</li> <li>•3.3.Determining possible alternative strategies (Strengths/Opportunities, Weaknesses/Threats, Strengths/Threats, Weaknesses/Opportunities), based on SWOT sub-factors</li> </ul>
4.SWO T factors evaluati on	<ul> <li>•4.1. Experts' determination of factor importance according to the Saaty scale, assuming no dependence among the SWOT factors</li> <li>•4.2. Calculating the importance of each factor using its geometric mean (w<sub>1</sub>)</li> <li>•4.3. Checking the conformity of experts' assessment by calculating consistency index (<i>CI</i>), or consistency ratio (<i>CR</i>), and random index (<i>RI</i>)</li> <li>•4.4. If consistency ratio is less than 9%, you can say about the conformity of experts' view. If consistency ratio is more than 9%, you can say about the nonconformity of experts' view. Additional experts' evaluation is needed (repeat from Step 4.1)</li> </ul>
5.SWO T sub- factor evaluati on	<ul> <li>•5.1. Experts' determination of sub-factor importance according to the Saaty scale, assuming inner dependence among the SWOT sub-factors</li> <li>•5.2. Calculating the importance of each sub-factor, using its geometric mean (w<sub>subf1</sub>)</li> <li>•5.3. Checking the conformity of experts' assessment by calculating consistency index (<i>CI</i>), or consistency ratio (<i>CR</i>), and random index (<i>RI</i>)</li> <li>•5.4. If consistency ratio is less than 10%, you can say about the conformity of experts' view. If consistency ratio is more than 10%, you can say about the nonconformity of experts' view. Additional experts' evaluation is needed (repeat from Step 5.1)</li> </ul>
6.Resul t process ing	•6.1. Calculating inner dependence among SWOT factors $(w_2)$ •6.2. Evaluating the interdependent priorities of the SWOT factors using formula: $w_f = w_2 \times w_1$ •6.3.Determining total importance degrees of the SWOT sub-factors with formula $w_{subf1} = w_{subf1} * w_f$
7.Choic e of alternat ive risk strategy	<ul> <li>•7.1. Experts' determination of alternative strategy importance with respect to each SWOT sub-factor using the Saaty scale</li> <li>•7.2. Calculating the importance of each alternative strategy, using its geometric mean (w<sub>strl</sub>)</li> <li>•7.3. Checking the conformity of experts' assessment by calculating consistency index (<i>Cl</i>), or consistency ratio (<i>CR</i>), and random index (<i>RI</i>)</li> <li>•7.4. If consistency ratio is less than 10%, you can say about the conformity of experts' view. If consistency ratio is more than 10%, you can say about the nonconformity of experts' view. Additional experts' evaluation is needed (repeat from Step 7.1)</li> <li>•7.5. Determining total priorities of the alternative development strategies, which reflect the interrelationship between the SWOT factors with a formula: w<sub>str</sub> = w<sub>strl</sub>* w<sub>subf</sub></li> </ul>

Fig. 47. Algorithm for application of the Analytic Network Process to determine importance degrees of possible development strategies (created by the author based on [17], [21], [22],

[25], [113], [114], [115])

SWOT Matrix	of an	Insurance (	Company	(prepared)	by the author
-------------	-------	-------------	---------	------------	---------------

Strengths	Weaknesses				
S1. Improvement of the strategic and financial planning	W1. Challenges to create the operation independence in decision-making				
S2. Improvement of the decision making	W2. Challenges in communication with the management board				
S3. Correct and proper definition of risk appetite, risk tolerance and risk limits	W3. Challenges in calculations and the assessment of limitations either it is a standard or an internal model				
S4. Implementation of stress testing	W4. Challenges with employee skills and knowledge, "the right person in the right place"				
S5. Improvement of culture in risk management	W5. Challenges to create a model that can completely follow up risk dynamic nature in a changing market situation				
Opportunities	Threats				
O1. Allows reducing risk to an acceptable level ensuring cost saving actions, improving the underwriting results	T1. Lack of risk diversification that requires too high risk capital can lead to increase of mergers that can negatively influence the market concentration level				
O2. By achieving risk reduction in a controlled way, there is possibility for higher growth in selected LoB and segments	T2. EIOPA can change the Solvency II requirements that can lead to additional costs				
O3. Product redesign to achieve management goals	T3. The cost of holding extra capital required by a new regime could force prices to increase, particularly in the annuity market that will negatively influence the demand for insurance				
O4. Strong governance ensures process quality and efficiency to increase sales results	T4. The new regime requirements can make the EU insurance companies less competitive against the non-EU insurance companies because of high implementation costs and high risk capital requirements				
O5. Transparency to ensure the policyholders regarding their safety will lead to a positive impact on brand and reputation of the insurance company that can allow increasing sales volumes	T5. A limited number of insurance companies can go bankrupt because of too high capital put into the risk that can lead to industry monopolisation				

According to the presented algorithm (see Fig. 47), its 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> stages should be based on experts' discussions; therefore, results should be assessed by experts and priority chart methods. However, the consistency ratio should be calculated in order to prove the results based on experts' discussions.

The author presents the results of the 4<sup>th</sup> stage of proposed algorithm in Table 16, where the evaluation of SWOT matrix factors is performed.

Table 16

		SWOT							
	S	W	0	Т	Total	W1			
S	1.00	2.00	3.00	2.00	1.9	42%			
W	0.50	1.00	2.00	3.00	1.3	29%			
0	0.33	0.50	1.00	0.50	0.5	12%			
Т	0.50	0.33	2.00	1.00	0.8	17%			
$\lambda_{\max}$									
CI									
CR (based on RI formula)									
	CR (	RI (see Ta	able 9))	= 0.89)		6.14%			

Evaluation of SWOT Matrix Factors Using the Saaty Scale (created by the author)

Based on Table 16, the author can make the conclusion that experts' evaluation of SWOT matrix factors using the Saaty scale can be confirmed, since the consistency ratio is less than 9%. According to the research, the most important factors have been discovered under internal factor group: strengths and weaknesses. The results obtained during the conducted research could be explained by the concentration on internal processes and the identification of strengths and weaknesses due to preparation to implement the Solvency II framework requirements.

The evaluation of sub-factors of SWOT matrix factors from the algorithm described above (see Fig. 45) has also been performed by the author:

- evaluation of strength sub-factors presented in Table 17;
- evaluation of weakness sub-factors in Table 18;
- evaluation of opportunity sub-factors is presented in Table 19;
- evaluation of threat sub-factors --- in Table 20.

		SW					
	<b>S1</b>	S2	<b>S3</b>	<b>S4</b>	<b>S</b> 5	Total	Wsubf1
<b>S1</b>	1.00	2.00	0.50	2.00	0.50	1.00	18%
S2	0.50	1.00	0.50	2.00	2.00	1.00	18%
<b>S</b> 3	2.00	2.00	1.00	3.00	2.00	1.89	34%
<b>S4</b>	0.50	0.50	0.33	1.00	0.25	0.46	8%
<b>S</b> 5	2.00	0.50	0.50	4.00	1.00	1.15	21%
	5.3865						
	0.0966						
	8.13%						
	CR	( <i>RI</i> (s	ee Tabl	le 9)) =	1.11)		8.71%

Evaluation of Strength Factor Using the Saaty Scale (created by the author)

Table 18

Evaluation of Weakness Factors Using the Saaty Scale (created by the author)

	W1	W2	W3	W4	W5	Total	Wsubf1
W1	1.00	3.00	4.00	3.00	2.00	2.35	41%
W2	0.33	1.00	2.00	0.50	2.00	0.92	16%
W3	0.25	0.50	1.00	0.25	0.50	0.44	8%
W4	0.33	2.00	4.00	1.00	0.50	1.06	18%
W5	0.50	0.50	2.00	2.00	1.00	1.00	17%
	5.4091						
	0.1023						
CR (based on RI formula)							
	C	R (RI (s	ee Tabl	e 9)) = 1	1.11)		9.21%

		SW					
	01	02	03	04	05	Total	Wsubf1
01	1.00	0.50	2.00	0.50	0.50	0.76	14%
02	2.00	1.00	2.00	2.00	2.00	1.74	32%
03	0.50	0.50	1.00	0.50	0.50	0.57	11%
04	2.00	0.50	2.00	1.00	2.00	1.32	24%
05	2.00	0.50	2.00	0.50	1.00	1.00	19%
	5.1947						
	0.0487						
	4.10%						
	CR	( <i>RI</i> (se	ee Tab	le 9)) =	1.11)		4.39%

Evaluation of Opportunity Factors Using the Saaty Scale (created by the author)

## Table 20

Evaluation of Threat Factors Using the Saaty Scale (created by the author)

		SW					
	<b>T1</b>	T2	<b>T3</b>	<b>T4</b>	Т5	Total	Wsubf1
<b>T1</b>	1.00	0.50	0.50	0.50	2.00	0.76	14%
T2	2.00	1.00	0.50	0.33	2.00	0.92	17%
Т3	2.00	2.00	1.00	0.50	2.00	1.32	24%
<b>T4</b>	2.00	3.00	2.00	1.00	2.00	1.89	35%
Т5	0.50	0.50	0.50	0.50	1.00	0.57	11%
	5.2378						
	0.0595						
	5.00%						
	CR	? ( <i>RI</i> (s	ee Tab	le 9)) =	1.11)		5.36%

All experts' evaluations of SWOT sub-factors have been approved by the consistency ratios that are less than 10% (see Tables 17, 18, 19, 20).
The detailed explanation of calculation approach of  $w_2$  matrix is presented in Table 21. Based on the described 6<sup>th</sup> stage of the proposed algorithm, the author has calculated interdependent priorities of the SWOT factors (see Table 22).

The calculation of the total importance degrees of the SWOT sub-factors is presented in Table 23.

Table 21

Strengths	w	0	Т	Total	Local weight
Weaknesses	1.0	0.5	0.5	0.6	19.6%
Opportunities	2.0	1.0	2.0	1.6	49.3%
Threats	2.0	0.5	1.0	1.0	31.1%

Detailed Calculation of  $w_2$  Matrix (created by the author)

Weaknesses	S	Th	Total	Local weight
Strengths	1.0	2.0	1.4	66.7%
Threats	0.5	1.0	0.7	33.3%

Threats	S	W	Total	Local weight
Strengths	1.0	3.0	1.7	75.0%
Weaknesses	0.3	1.0	0.6	25.0%

Table 22

Calculation of Interdependent Priorities of the SWOT Factors (created by the author)

	W2				W1		Wf	
	1.000	0.667	1.000	0.750		0.416		0.430
$w_f =$	0.196	1.000	0.000	0.250	×	0.294	=	0.209
	0.493	0.000	1.000	0.000		0.120		0.163
	0.311	0.333	0.000	1.000		0.170		0.198

### Table 23

SWOT group	Group priority	SWOT sub-factors	Sub-factor priority within the group via AHP	Overall priority of sub-factor (w <sub>subf</sub> )
		S1	18.2%	4.5%
hs		S2	18.2%	4.5%
engt	43%	<b>S</b> 3	34.3%	8.6%
Stu		S4	8.4%	2.1%
		S5	20.9%	5.2%
		W1	40.8%	10.2%
ses	21%	W2	16.0%	4.0%
lknes		W3	7.5%	1.9%
Wea		W4	18.4%	4.6%
		W5	17.3%	4.3%
		01	14.1%	3.5%
ities		O2	32.3%	8.1%
ortun	16%	03	10.7%	2.7%
Oppe		O4	24.5%	6.1%
		05	18.5%	4.6%
		T1	13.9%	3.5%
s		T2	16.9%	4.2%
hreat	20%	T3	24.2%	6.0%
F		T4	34.6%	8.6%
		T5	10.5%	2.6%

Overall Importance Degrees of the SWOT Sub-factors (created by the author)

With the assistance of the responsible experts attracted, the alternative development strategies of an insurance company were determined and presented in Table 24.

#### Table 24

Alternative Development Strategies						
S - O	S - T	W - T	W - O			
Growth strategy: ensures strong governance to allow for strong growth in more profitable market segments	Growth / Profitability strategy: by correct definition of risk profile ensures moderate growth and strong risk ratio outcome	Profitability strategy: low growth and only in LoB and segment with expected strong combined ratio outcome to improve the identified internal weaknesses	Balanced strategy: product redesign helps achieve a lower risk ratio outcome			

Description of Development Strategies of an Insurance Company (created by the author)

In order to determine total priorities of the alternative development strategies ( $w_{str}$ ), reflecting the interrelationships within the SWOT factors, importance of alternative development strategies ( $w_{strI}$ ) and the experts' evaluation conformation were performed using the Analytic Hierarchy Process and then integrated with SWOT sub-factor importance ( $w_{subf}$ ) in a similar way as described in the algorithm (detailed explanation of calculation is provided in Appendix 4). Thus, the summary of total priorities of alternative development strategies based on the Analytic Network Process and Analytic Hierarchy Process (can be found in Table 25) is presented in Table 26.

Table 25

Evaluation of Alternative Strategies Using the Saaty Scale Based on the Analytic Hierarchy Process (created by the author)

		Alternative	Total	Importance		
	S-O	S-T	W-T	W-O		degree, %
S-O	1.00	0.50	0.50	0.25	0.50	11%
S-T	2.00	1.00	3.00	0.33	1.19	26%
W-T	2.00	0.33	1.00	0.50	0.76	16%
W-O	4.00	3.00	2.00	1.00	2.21	47%
	4.2325					
	0.0775					
	7.83%					
	CR	(RI (see Tab	(10, 9)) = 0.89	))		8.71%

		•		
	ANP		AHP	
Strategy	Priority	Rank	Priority	Rank
Growth strategy	22%	3	11%	4
Growth / Profitability strategy	32%	2	26%	2
Profitability strategy	13%	4	16%	3
Balanced strategy	33%	1	47%	1

Summary of Priorities of Alternative Strategies Based on the Analytic Network Process and Analytic Hierarchy Process (created by the author)

Based on the experts' evaluation, the most preferable strategy is a balanced strategy that can ensure stable and long-term solvent development of the insurance company. The author has concluded that in the particular case the both methods give almost similar results; however, the importance priorities are different among alternative development strategies, which can lead to various conclusions. The fact is that the author has proposed using the Analytic Network Process as a possibility to evaluate and improve the risk culture of an insurance company, therefore fulfilling the ORSA requirements under the Solvency II framework because of several reasons:

- to improve the knowledge and understanding of the risk nature by key employees and members of the board;
- to integrate the risk culture into all insurance company's processes to ensure proper and coordinated decision making;
- to start the discussion within an insurance company regarding the Solvency II Directive requirements, main challenges and their possible impact on an insurance company's activity;
- to ensure the strong and proper the System of Governance in insurance company.

The Analytic Network Process allows measuring the dependency among strategic factors similar to SWOT factors that affect weights of its factors and sub-factors with the aim to choose the strategy priorities. In fact, it can help improve the decision-making process in an insurance company. Moreover, the author suggests using the Analytic Network Process to evaluate alternative development strategies, since it could help ensure a clear understanding of

the received results and deeper assessment of possible strategy impact on insurance company's development based on the appropriate and more sophisticated analysis of risk nature.

# 4.2. Application and Evaluation of New Methods for Operational Risk Assessment

The author proposes a new approach for the operational risk assessment to ensure proper capital in order to cover this particular risk in an insurance company. The algorithm of measurement of the capital to cover the operational risk is presented in Fig. 48.



Fig. 48. The algorithm of measurement of the capital to cover the operational risk (created by

the author)

In order to prove the practical usage of the algorithm proposed above, the case study has been performed. The case study on the assessment of the operational risk (see Section 2.3.2) is based on a particular Baltic non-life insurance company.

Due to the nature of operational risk that is less depended on macroeconomical cycles it can be modelled by skew *t*-copula and estimated tail dependence in each situation for modelling distributions with heavier tail area. The main idea of the case study is to prove the possibility of identification of *VaR* (Value at Risk) for the operational risk portfolio using a simulation technique. Because of the correlation among different sub-risks of operational risk, their *VaR* (portfolio) has to be smaller than simply added corresponding *VaR* of each sub-risk. The fact is that *VaR* is a quintile of a distribution and used as a (non-coherent) risk measure [91]. The historical data is based on recorded data in relation to the three sub-risks of operational risk from the annual loss database. The simulation model performed during case study is based on three risks and on five risk due to the reason to show the model advantages. In reality the proposed model is possible to use for any number of risks. The performed model is based on several main steps that are illustrated in detail in Fig. 49.



Fig. 49. The description of model for determination of VaR for an operational risk portfolio (elaborated by the author)

However, the simulation of 10 000 pairs 20 times in the model has been performed using the skew *t*-copula described in [83] and [152]. The first simulation model created by the author and based on the described algorithms (see Fig. 48 and Fig. 49) is based on the following three sub-risks of operational risk:

- Legal risk (hereinafter referred to as LR) that implies the possibility that lawsuits, adverse judgments from courts, or contracts that turn out to be unenforceable, disrupt or adversely affect the operations or condition of an insurer. The result may lead to unplanned additional payments to policyholders or that contracts are settled on an unfavourable basis, e.g., unrecoverable reinsurance [91].
- Organisational risk (hereinafter referred to as OR) that means possible losses due to unclear organisational structure (unclear processes, unclear responsibilities split between units etc.).
- Informational risk (hereinafter referred to as IR) that means possible losses due to failures in the IT system.

The correlation between standartized risks are presented in Fig. 50 - 52.



**Fig. 50.** The illustration of distribution between legal and organizational risks (created by the author)



Fig. 51. The illustration of distribution between informational and organizational risks (created by the author)



Fig. 52. The illustration of distribution between informational and legal risk (created by the author)

The correlation matrix R of the case study based on the three risks is presented in Fig.

$$R = \begin{pmatrix} 1 & -0.143 & 0.357 \\ -0.143 & 1 & -0.118 \\ 0.357 & -0.118 & 1 \end{pmatrix}$$

Fig. 53. The correlation matrix *R* (created by the author)

The legal risk and informational risk (the first and third) are positively correlated but the others are negative. Descriptive statistics of the marginal distributions of the abovementioned risks is presented in Table 26.

Table 26

Risks	LR	OR	IR
Size	12	12	12
Mean	7 564	45 618	5 425
Median	3 700	1 610	960
Standard deviation	11 151	143 207	9 342
Skewness	3	3	2
Kurtosis	9	12	5

Descriptive Statistics of Data (created by the author)

\*Values in the Table are represented in EUR currency

53.

The fact is that, before fitting marginal distributions, the data were standardised and only then the marginal distributions were approximated by proper exponential and gamma distributions.

Also the author has identified the following findings based on the performed calculations:

- the legal risk should be described by the exponential distribution;
- for the organisational risk the gamma distribution is suitable;
- informational risk should be described by the gamma distribution.

The appropriateness of distributions to each sub-risk was measured by the Kolmogorov test (the 5% critical value equals 0.391). Performed calculation has proved that mentioned univariate marginal distributions are appropriate to the obtained model distributions. The testing results that proved the appropriateness of obtained distributions are shown in Table 27.

Table 27

Risks	Distribution used	Parameters	
LR	Exponential	λ	1.474
		Test value	0.164
OR	Gamma	α	0.101
		β	3.139
		Test value	0.169
IR	Gamma	α	0.227
		β	2.098
		Test value	0.0957

Results of Marginal Distribution Test (created by the author)

The obtained marginal distributions were joined into a three-dimensional distribution by the skew *t*-copula.

The number of degrees of freedom  $_{\nu}$  was taken to be 4 (four) in order to use the multivariate t-distribution with maximally heavy tail area. The  $\hat{\Sigma}$  matrix is presented in Fig. 54. Moreover, the author presents the calculated values of alfa in Fig. 55.

	0.730	0.037	0.340
$\hat{\Sigma} =$	0.037	0.551	0.017
	0.340	0.017	0.614

Fig. 54. The sigma matrix (created by the author)

 $\boldsymbol{\alpha}^{\mathrm{T}} = (1.551 \quad 0.946 \quad 0.681)$ 

Fig. 55. The alfa values (created by the author)

Furthermore, in the experiment of simulation triples from the joint 3 -variate skew *t*-copula were modelled using simulation rule for the skew  $t_{p,v}$ -distribution [83]. Simulation cycle is presented in Appendix 5. However, the experiment stages are explained below:

- 1) Find the Cholesky decomposition A of  $S_{\vec{X}}$ ,  $(AA^T = S_{\vec{X}})$ , where  $S_{\vec{X}}$  is sample covariance matrix.
- 2) Simulate *p* independent values from N(0,1) and form *p*-vector  $\vec{z}$ , where N(0,1) is normal distribution with mean 0 and standard deviation 1.
- 3) Set vector<sup>8</sup>  $\vec{x} = A \cdot \vec{z}$ .
- 4) Simulate value W from N(0,1).
- 5) Get realization of the skew normal vector  $\vec{y}$  putting

$$\vec{y} = \begin{cases} \vec{x} & if \quad \vec{\alpha}^T \vec{x} > w \\ -\vec{x} & if \quad \vec{\alpha}^T \vec{x} \le w \end{cases}$$
(33)

- 6) Simulate *h* from  $\chi_{\nu}^2$ , where  $\chi_{\nu}^2$  is hi-squared distribution with  $\nu$  degrees of freedom.
- 7) Find vector  $\vec{t} = \frac{\vec{y}}{\sqrt{h/v}}$ .
- 8) Set vector  $\vec{u}$  so that every coordinate  $u_i = G_{1,\nu}(t_i; 0, \sigma_{ii}, \alpha_i), i \in [1, ..., p]$ , where  $G_{1,\nu}(\cdot; \mu_i, \sigma_{ii}, \alpha_i)$ :  $R^1 \to I$ ,  $i \in \{1, ..., p\}$  denotes the univariate skew  $t_{1,\nu}$ -distribution function with  $\nu$  degrees of freedom.

<sup>&</sup>lt;sup>8</sup> Vector sign could be marked in formula in two ways: with " $\rightarrow$ " vector sign or marked in bold. In the Doctoral thesis vector is marked in both ways that is more appropriate in particular case.

- 9) Set vector  $\vec{x} = (F_1^{-1}(u_1), ..., F_p^{-1}(u_p))$  where  $F_i(\cdot)$  is the marginal distribution function of the initial random variable  $X_i$ .
- 10) Repeat steps from 2 to 9 *n* times.

Results of simulation are presented in Fig. 56, Fig. 57, Fig. 58. The number of replications was 20.







Fig. 57. The simulation result for informational and organizational risk (created by the author)



Fig. 58. The simulation result for informational and legal risk (created by the author)

Based on the performed calculation of simulations, it is possible to conclude that the portfolio VaR obtained in simulation is smaller, and it means that the capital to cover these risks is less by 10.3%. The author of Doctoral Thesis has collected the main findings and results of simulation in Table 28. In order to understand the information presented in Table 28, the explanation of some values is also provided:

- The first line presents the 99.5% VaR for each sub-risk using inverse marginal distributions and sum of VaR (portfolio) in the current year.
- The next lines present characteristics of 99.5% VaR for each sub-risk and portfolio obtained from modelled simulations.

Table 28

Risks	LR	OR	IR	Sum of VaR	Portfolio VaR
99.5% VaR from distributions	40 078	947 292	55 567	1 042 937	
Mean of 99.5% <i>VaR</i>	40 091	909 123	56 556	1 005 769	935 922
Median	40 034	91 1132	56 821	1 008 493	935 630
Standard deviation	1 005	41 170	2 888	42 721	4 4248
Skewness	0.232	-0.008	-0.399	-0.035	0.178
Coefficient of variation (%)	2.5	4.5	5.1	4.2	4.7

99.5% VaR Obtained Using Simulations and Its Characteristics

\*Values in the Table are represented in EUR currency

In order to evaluate the dependence between risks the author of the Doctoral thesis has used tail dependence coefficient [152, 153].

Let assume that  $(X_1, X_2)$  is two dimensional vector with one dimensional marginal distributions  $F_1(x)$  and  $F_2(x)$ .

Then the upper tail coefficient is

$$\lambda_U = \lim_{u \to 1} \lambda_U(u), \qquad (34)$$

where  $\lambda_U(u) = P(F_1(x) > u / F_2(x) > u)$ .

Similarly is defined lower tail coefficient

$$\lambda_L = \lim_{u \to 1} \lambda_L(u) \,, \tag{35}$$

where  $\lambda_{L}(u) = P(F_{1}(x) < u / F_{2}(x) < u)$ .

 $\lambda_U = \lambda_L = \lambda$  for symmetrical elliptical distribution, but for normal distributions  $\lambda$  equals zero. For two dimensional *t*-distribution with V degrees of freedom

$$\lambda = 2T_{1,\nu} \left( -\sqrt{\frac{(\nu+1)\cdot(\rho-1)}{(\rho+1)}} \right),\tag{36}$$

where

 $T_{1,\nu}(.)$  - the distribution function of standard *t* - distribution with V degrees of freedom;  $\rho$  — coefficient of Spearman correlation.

It is approved in [154] that it is sufficient to study the upper tail dependence due to the lower tail dependence coefficient that is determined by the upper one. Let us denote by

$$\alpha_{1}^{*} = \frac{\alpha_{1} + \alpha_{2} \cdot \rho}{\sqrt{1 + \alpha_{2}^{2} \cdot (1 - \rho^{2})}} \text{ and } \alpha_{2}^{*} = \frac{\alpha_{2} + \alpha_{1} \cdot \rho}{\sqrt{1 + \alpha_{1}^{2} \cdot (1 - \rho^{2})}} \text{ (37)}$$

Assume that  $\alpha_1^* \leq \alpha_2^*$ . Then

$$\begin{aligned} \lambda_{U} &= \lim_{u \to 1} \frac{P(F_{1}(x) > u, F_{2}(x) > u)}{P(F_{2}(x) > u)} = \lim_{x \to \infty} \frac{P(F_{1}(x) > F_{2}(x), X_{2} > x)}{P(X_{2} > x)} \\ &\geq \lim_{x \to \infty} \frac{P(X_{1} > x, X_{2} > x)}{P(X_{2} > x)} \\ &= \lim_{x \to \infty} \frac{2 \cdot P(Y_{1} > x, Y_{2} > x) \cdot T_{1,\nu+2} \left( (\alpha_{1} + \alpha_{2}) \cdot \sqrt{\frac{(\nu + 2) \cdot (\rho + 1)}{2}} \right)}{2 \cdot T_{1,\nu+1} (\alpha_{2}^{*} \cdot \sqrt{\nu + 1}) \cdot (1 - T_{1,\nu}(x))} \end{aligned}$$
(38)  
$$&= \lambda \cdot \frac{T_{1,\nu+2} \left( (\alpha_{1} + \alpha_{2}) \cdot \sqrt{\frac{(\nu + 2) \cdot (\rho + 1)}{2}} \right)}{T_{1,\nu+1} (\alpha_{2}^{*} \cdot \sqrt{\nu + 1})} \end{aligned}$$

In the case of  $\alpha_1 = \alpha_2 = \alpha$  tail dependence coefficient can be calculated using formula:

$$\lambda_{U} = \lambda \cdot \frac{T_{1,\nu+2} \left( 2 \cdot \alpha \cdot \sqrt{\frac{(\nu+2) \cdot (\rho+1)}{2}} \right)}{T_{1,\nu+1} (\alpha^* \cdot \sqrt{\nu+1})},$$
(39)

where  $\alpha^* = \frac{\alpha \cdot (1+\rho)}{\sqrt{1+\alpha^2 \cdot (1-\rho^2)}}$ .

The fact is that the difference of tail dependencies between t-distribution and skew tdistribution is determined by the ratio of univariate distribution functions of the t-distribution. It is shown in [153] that for the equal values of  $\alpha$  the difference in tail dependence is not large. The tail dependence coefficient calculations for given risks is presented in Table 29.

Table 29

Risks	Legal risk — Organizational risk	Organizational risk — Informational risk	Legal risk — Informational risk
λ	0.030612	0.032737	0.099198
$lpha_1^*$	1.033629	0.716906	1.513446
$lpha_2^*$	0.395529	0.414779	0.700886
$T_{1,\nu+2}$	0.996458	0.980886	0.997954
$T_{1,\nu+1}$	0.791520	0.801877	0.911078
$\lambda_{U}$	0.038537	0.040046	0.108657

Results of Tail Dependence Coefficient for the Risks

However, the author of the the Doctoral thesis presents also the second simulation model based on the described algorithms (see Fig. 48 and Fig. 49) and based on the following five sub-risks of operational risk:

- Legal risk (LR);
- Organizational risk (OR);
- Informational risk (IR);

- Human Resources risk (HRR) means losses due to changes or loss of personnel, deterioration of morale, inadequate development of human resources, inappropriate working schedule, inappropriate working and safety environment, inequality or inequity in human resource management or discriminatory conduct.
- Expense risk (ER)The risk of a change in value caused by the fact that the timing and/or the amount of expenses incurred differs from those expected, e.g. assumed for pricing basis [91].

Similar to the simulation model based on three sub-risk, in simulation model based on five sub-risk is used the historical data based on recorded data in relation to the five sub-risks of operational risk from the annual loss database. The correlation between standardized risks are presented in Appendix 6. The correlation matrix R is presented in Fig. 59.

$$R = \begin{pmatrix} 1 & -0.143 & 0.357 & 0.183 & 0.071 \\ -0.143 & 1 & -0.118 & -0.135 & -0.085 \\ 0.357 & -0.118 & 1 & -0.086 & -0.132 \\ 0.183 & -0.135 & -0.086 & 1 & -0.063 \\ 0.071 & -0.085 & -0.132 & -0.063 & 1 \end{pmatrix}$$

Fig. 59. The correlation matrix *R* 

Descriptive statistics of the marginal distributions of the above-mentioned risks is presented in Table 30.

Table 30

Risks	LR	OR	IR	HR	ER
Size	12	12	12	12	12
Mean	7 564	45 618	5 425	1 747	2 308
Median	3 700	1 610	960	18	0
Standard deviation	11 151	143 207	9 342	4 490	6 655
Skewness	3	3	2	3	3

Descriptive Statistics of Data (created by the author)

\*Values in the Table are represented in EUR currency

The fact is that the author has identified the following findings based on the performed calculations:

- the legal risk should be described by the exponential distribution;
- for the organisational risk the gamma distribution is suitable;
- informational risk should be described by the gamma distribution;
- the human resources risk should be described by the gamma distribution;
- for the expense risk the normal distribution is suitable.

The testing results that proved the appropriateness of obtained distributions are shown in Table 31.

The number of degrees of freedom v was taken to be 5 (five) in order to use the multivariate t-distribution with maximally heavy tail area.

Table 31

Risks	Distribution used	Parameters	
LR	Exponential	λ	1.474
		Test value	0.164
OR	Gamma	α	0.101
		β	3.139
		Test value	0.169
IR	Gamma	α	0.227
		β	2.098
		Test value	0.0957
HR	Gamma	α	0.152
		β	2.569
		Test value	0.3380
ER	Normal	μ	3.352
		$\sigma$	1.000
		Test value	0.079

Results of Marginal Distribution Test (created by the author)

The  $\hat{\Sigma}$  matrix is presented in Fig. 60.

	0.876	0.044	0,408	0,268	0,186
^	0.044	0.661	0.020	-0,007	0.016
$\Sigma =$	0.408 0.268	0.020 - 0.007	0.736 0.060	0,060 0.691	0.022 0.044
	0.186	0.016	0.022	0.044	0.674

Fig. 60. The sigma matrix (created by the author)

Moreover, the author presents the calculated values of alfa in Fig. 61.

 $\boldsymbol{\alpha}^{\mathrm{T}} = (1.675 \ 1.657 \ 1.518 \ 1.394 \ 1.408)$ 

Fig. 61.	The alfa	values	(created	by th	e author)
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Results of simulation are presented in Appendix 7. The number of replications was 20. The author of Doctoral Thesis has collected the main findings and results of simulation in Table 32.

Table 32

Risks	LR	OR	IR	HRR	ER	Sum of <i>VaR</i>	Portfolio <i>VaR</i>
99.5 % VaR from distributions	40 078	947 292	55 567	28 530	19 450	1 090 917	
Mean of 99.5 % VaR	39 980	882 287	53 803	27 247	18 936	1 022 333	916 576
Median	39 891	875 210	53 560	27 414	18 992	1 015 070	910 795
Standard deviation	908	50 990	1 700	1 395	224	50 569	44 408
Skewness	0.426	0.923	0.591	-0.023	-0.921	0.938	0.937
Coefficient of variation (%)	2.27	5.78	3.15	5.12	1.18	4.95	4.84

99.5% VaR Obtained Using Simulations and Its Characteristics

\*Values in the Table are represented in EUR currency

The tail dependence coefficient calculations for given risks is presented in Table 33.

Table 33

Risks	LR - OR	LR – IR	LR – HRR	LR – ER
λ	0.018380243	0.076203363	0.048642885	0.035695291
$\alpha_1^*$	0.748892952	1.277118605	1.137221340	1.029393156
$\alpha_2^*$	0.732376766	1.138959998	0.882190218	0.784050760
<i>T</i> <sub>1,<i>v</i>+2</sub>	0.999658475	0.999890136	0.999786603	0.999720237
$T_{1,\nu+1}$	0.938510732	0.938510732	0.938510732	0.938510732
$\lambda_U$	0.019577789	0.081187128	0.051818806	0.038023332
Risks		OR - IR	OR - HRR	OR - ER
λ		0.019948845	0.019366696	0.022215582
$\alpha_1^*$		0.816747661	0.867138801	0.892009744
$\alpha_2^*$		0.686584134	0.615030540	0.656142780
$T_{1,\nu+2}$		0.999582268	0.999457768	0.999538857
$T_{1,\nu+1}$		0.928197391	0.908673744	0.920434408
$\lambda_U$		0.021483051	0.021301589	0.024124845
Risks			IR – HRR	IR - ER
λ			0.022175390	0.019075676
$\alpha_1^*$			0.816969531	0.776091322
$\alpha_2^*$			0.696875477	0.668634687
$T_{1,\nu+2}$			0.999379259	0.999300879
$T_{1,\nu+1}$			0.930652644	0.923712839
$\lambda_U$			0.023812993	0.020636652
Risks				HR – ER
λ				0.023850201
$\alpha_1^*$				0.756681012
$\alpha_2^*$				0.770387633
$T_{1,\nu+2}$				0.999279481
$T_{1,\nu+1}$				0.945953840
$\lambda_{_U}$				0.025194693

Furthermore, based on [153] approval the author of the Doctoral thesis can conclude that when for skew *t*-copula used tail dependence coefficient is slightly larger then it is possible in any case to see that dependence in tails are not very large. It is only a bit larger in case of legal and informational risk.

During the research presented, the author has interconnected the risk management with the risk measurement in an insurance company in order to improve the operational risk assessment.

The author of the Doctoral Thesis suggests using the algorithm of the operational risk evaluation to measure the capital to cover it. The measurement of the operational risk is based on copulas since they allow modelling multivariate probability distribution using one-dimensional parametric dependencies.

Furthermore, the performed case study has proved that because of the correlation among different sub-risks of operational risk, their VaR of portfolio is smaller than a simply added corresponding VaR of each sub-risk (see Tables 28, 32).

Moreover, the suggested approach of the capital measurement to cover the operational risk will enable every insurance company to control and properly assess the capital required for the operational risk in line with the requirements of the Solvency II Directive and to establish a more sophisticated and sensitive risk assessment in future.

## CONCLUSIONS

Risk dynamic nature in the changing market conditions sets a lot of challenges to every company. Thus, it is necessary to implement new approaches to follow the nature of risks with the aim to understand their possible impact on financial stability and further development. In insurance, it is worth mentioning that the requirements of the Solvency II regime require new principles for risk evaluation in order to ensure solvency of every insurance company in the European Union member states, which might create additional problems for an insurer.

Moreover, the new requirements of the Solvency II Directive, which are in force from 1<sup>st</sup> January 2016, set a lot of challenges to every insurance company in the European Union member states in relation to the establishment of more sensitive and sophisticated risk coverage in order to ensure solvency and the safety of policyholders.

Having conducted the research, the author has drawn the following conclusions:

- 1. The development of the Baltic non-life insurance market development has heavily been affected by the economic downturn, and in recent years the non-life insurance has been recovering, particularly quickly in Lithuania. The largest volume of non-life insurance market in terms of GWP is in Lithuania; however, the market volumes in Latvia and Estonia are almost similar.
- 2. The evaluation of the concentration of an insurance market is part of improvement of risk assessment in a particular market since the market concentration is directly related to risk management since leading insurance companies are responsible for solvency of total insurance market. According to the Herfindahl–Hirschman index and Theil's entropy index, the Baltic non-life insurance market concentration corresponds to the medium competitive level. Medium concentration level of the Baltic non-life insurance market enables one to use a common approach to assessing the solvency and financial health of each non-life insurance company in the three Baltic countries.
- 3. The financial evaluation of an insurance company's activity is important since it is part of risk self-assessment with the aim to increase the reliability of an insurance company by means of risk monitoring at each business unit level. Baltic market solvency is quite stable and less than 100% in almost all periods. During the research, it was discovered that the most profitable is the Estonian non-life insurance market with the lowest combined ratio over the last six years. Besides, the Estonian market is characterised by the highest average insurance premium among the Baltic countries. Risk ratio and cost

ratio of the Baltic non-life insurance market are recognised to be at a normal level, but the Latvian and Lithuanian non-life insurance markets' results should be more carefully managed with the control and risk management functions.

- 4. The author has investigated that the performance evaluation model for the Baltic non-life insurance company should involve: monthly activity analysis; preparation of the liability adequacy test to ensure adequacy of reserve level in an insurance company; the implementation of strategic organisational planning tool scenario planning as one of the possible solutions to evaluate and assess possible short-term outcomes of an insurance company activity; testing of the possible future outcomes of an insurance company activity forecasted using scenario planning through critical stress testing, which allows conducting sensitivity analysis of the external factors' influence on the possible development of an insurance company; integration of probabilistic models to ensure appropriate risk measurement in an insurance company.
- 5. The Solvency I Directive has not reflected the true risk profile of an insurance company to ensure the sophisticated analysis of an insurance company's financial and solvent situation in relation to current development, risk assessment, monitoring, financial policy and international financial statements that was crucial in a changing market situation. However, the requirements of Solvency II Directive are not just about capital of an insurance company but about risk assessment through the implementation and enhancement of risk measurement and risk management. Also, the Solvency II regime requires higher required capital compared with the requirements of the Solvency I Directive that should ensure the solvency and financial stability of each insurance company.
- 6. The risk self-assessment is the transitional risk management tool from the Solvency I Directive to the Solvency II framework. The aim of the risk self-assessment framework is to identify, assess, control and mitigate insurance company's risks and to maintain effective reporting of risk and emerging risk issues. Thus, it should improve the risk management system of Baltic insurance companies according to the Solvency II Directive with the aim to increase reliability, improve the solvency and the understanding of risk management strategy.
- 7. The aim of the solvency models is to ensure proper amount of own capital that should be held by the companies to cover all possible obligations to the policyholders and beneficiaries in a certain period of time. Each solvency model is based on common principles and deals with the modelling of particular risk to ensure the solvency and

stability of an insurance company. The solvency models are divided into the two main groups: statistical or accounting models based on strict rules defined in advance and dynamic or cash flow models that are based on principles or specific risk scenarios. Thus, the Solvency I Directive is a statistical model but the Solvency II Directive is a dynamic model to ensure the financial health and solvency of an insurance market in the European Union based on risk management and risk measurement core principles.

- 8. The Solvency II regime requirements might create additional problems for an insurer. However, the biggest challenge for an insurance industry is the System of Governance since it asks for prudent and efficient management. The main idea of the risk governance is to consider the most effective way for implementing the best risk management practice. Moreover, the risk governance elements help develop risk management culture that emphasises at all levels the significance of managing risk as part of each person's daily activities. Risk culture under the Solvency II framework should improve the risk evaluation in an insurance company through enhancement of risk strategy, decision making and processes.
- 9. The Solvency II regime sets out broader risk management requirements for European insurers and dictates how much capital firms must hold in relation to their liabilities. The Solvency II Directive should improve the financial stability and solvency of European Union's insurance market through the enhancement of risk assessment applying more sophisticated, sensitive and complicated approaches to measure and manage the risks faced by the industry. The Solvency II regime sets out broader risk management requirements for European insurers and dictates how much capital firms must hold in relation to their liabilities.
- 10. The Solvency II Directive should improve the financial stability and solvency of European Union's insurance market through the enhancement of risk assessment applying more sophisticated, sensitive and complicated approaches to measure and manage the risks faced by the industry. Under the new regime, all material risks should be covered that could affect an insurance company's ability to meet its obligations under insurance contracts and should be included under the ORSA. Thus, the ORSA could be considered the key part of the Solvency II regime and should perform insurance company's target risk profile with risk appetites and tolerances.
- 11. The main idea of Solvency II framework is to place risk dimension in the heart of every insurance company in order to improve business strategy and capital management reliability. The Solvency II Directive is based on risk management and risk measurement

that are related and dependent on each other. The risk management is the risk function field; therefore, risk measurement accomplishment provides actuarial and risk function. In fact, risk management function should be fit and proper with the aim of developing strategies, processes, reporting procedures to identify measure, monitor, manage and report the risk. Risk management is about to define a risk profile that intends to align with the stakeholder's risk appetite and risk tolerance, likewise keeping risks and losses within insurer's risk tolerance.

- 12. Effective risk management system is a basis to establish strategic reliability programme for every insurance company. However, the risk management should be a continuous process in general but due to the specific features of insurance industry the author uses the semi-continuous qualitative approaches to manage the risk. Effective risk management system consists of two main parts: risk identification and risk strategy setting.
- 13. The operational risk management is the process of identification, analysis, assessment, organising, planning, leading, controlling, elimination and evasion of operational risk events in order to minimise the probability of risk occurrence and reduce possible losses or near miss. The author has proved that with the operational risk model proposed by the author a risk strategy could be set in line with the Solvency II framework. Operational risk management model is complicated and involves many parameters. Also, the point is that a wrong risk strategy can negatively influence insurance company's business processes and aggravate financial stability and development.
- 14. Loss database belongs under risk identification section of the risk management system. The successful integration of operational risk management in the organisational structure is dependent not only on an accurate model and correct data, but also on the ability to demonstrate the connection between decision making and data produced taking into account capital, estimated risk appetite, risk tolerance and risk limits, risk framework.
- 15. The human social capital is a key to the company's activity success and development. Therefore, the author has conducted the research of human social capital impact on operational risk management using the methods of expert estimation and priority charts. According to the evaluation and identification results of model factors, the author has identified that the main criteria of human social capital with the most significant impact on operational risk management are the following: new and improved skills and knowledge, board and executive role, having the right team. The companies need to find the best solution between permanent and temporary resources; thus finding the

appropriate role for every employee to enable more precise and effective implementation of new processes. Human social capital significantly influences operational risk management; therefore, good qualification of insurance company's employees, ability to work in a team and independency are the most important requirements of the Solvency II regime.

- 16. The author has divided the implementation of Solvency II Directive requirements into 3 stages:
  - Establishment of risk culture where the nature of each risk should be investigated with the aim to set appropriate risk appetite, tolerance and limits.
  - Risk measurement where the capital for each risk should be calculated according to the standard formula of the Solvency II or an insurance company's internal model.
  - Risk management process should be fully implemented with the aim to manage and control all processes of an insurance company to eliminate the possible risk of the insurance company and to improve its development, profit and financial results.
- 17. Risk evaluation includes implementation of risk culture, risk measurement and risk management cover all Solvency II requirements. The risk culture is the heart of all insurance company's processes since it is one of the most important parts of ORSA. The author has developed a short-term solution to the risk culture development in an insurance company based on the quantitative impact studies of the Solvency II framework, particularly the 5<sup>th</sup> study. Risk culture development in insurance can serve as the first stage for the risk evaluation development in insurance companies within the next 2-3 year, using different methods. The suggested approach to the risk culture and decision-making improvement within an insurance company in short-term will enable every insurance company to control trends within its development towards the solvency and will introduce a deeper understanding of risk nature which, in its turn, will allow following the requirements of the Solvency II Directive and establishing a more sophisticated and sensitive risk evaluation in the future.
- 18. The author has proved the possibility of risk evaluation improvement using risk ranking and Analytic Hierarchy Process, Analytic Network Process based on the Saaty scale. The research on risk culture improvement based on the Analytic Hierarchy Process was presented in the 30<sup>th</sup> International Congress of Actuaries and awarded the "Best

Research" in the section "Financial and Enterprise Risk". The benefits of the proposed approach are the following:

- to improve the knowledge and understanding of the risk nature by key employees and members of the board;
- to start the discussion with the board members and key employees regarding the Solvency II Directive's challenges and possible impact on an insurance company's activity;
- to implement the strong System of Governance in insurance company's processes.
- 19. Scenario planning plays a special role in the implementation of the Solvency II Directive requirements, since it is part of new regime own risk and solvency assessment. The objective of the scenario planning in the Baltics is to examine possible future development outcomes of the non-life insurance companies and to suggest solutions that will help benefit as much as possible, no matter how the future unfolds. The author has proposed the integration of the scenario planning into all the processes of the Baltic non-life insurance company, in particular, actuarial, risk management and compliance functions should be involved in its development. The scenario planning integration into the processes of the Baltic non-life insurance companies, presented by the author, allows creating a qualitative scenario using the critical stress testing method. The proposed approach of the scenario planning integration into the processes of the Baltic non-life insurance companies can help improve risk management and allow controlling trends within the development towards the solvency.
- 20. The main aim of the algorithm of the operational risk evaluation, prepared by the author, is to measure the capital to cover it. In the presented algorithm, the risk management is interconnected with the risk measurement in an insurance company with the aim to improve the operational risk assessment. The measurement of the operational risk is based on the skew *t*-copula since it allows modelling distributions with heavier tail area and correlation between marginal distributions. However, there are discovered several valuable advantages of skew *t*-copula usage in operational risk measurement:
  - copula has a very simple and clear simulation rules;
  - by choosing degrees of freedom is possible to find appropriate skewness of copula for simulation;
  - another advantage of simulation is the possibility to calculate average measure of necessary characteristic;

- further tail dependence can be evaluated between risks.
- 21. Furthermore, the author has prepared the case study in accordance with the algorithm proposed. The simulation models performed during the case study is based on three risks and on five risk have approved the possibility of application the model for any number of risks. During the case study, it has been proved that because of the correlation among different sub-risks of the operational risk, their VaR (portfolio) is smaller than a simply added corresponding VaR of each sub-risk that allows keeping optimal volume of capital to cover the possible losses due to occurrence of the operational risk. Because VaR is not coherent risk measure the VaR for simulated portfolio will always be less than sum of VaR of different risks. Thus, the proposed method would not allow over-reserving and putting gap capital to other needs of an insurance company. Moreover, the proposed approach of the capital measurement to cover the operational risk will enable every insurance company to control and properly assess the capital required for the operational risk in line with the requirements of the Solvency II Directive and to establish a more sophisticated and sensitive risk assessment in the future.

Taking into account the research results of the Doctoral Thesis, it can be stated that the hypothesis of the doctoral Thesis has been proven.

# PROPOSALS

Based on the conclusions above, the author has formulated the following proposals to be implemented in practice:

- The author recommends the Baltic insurance companies to apply the scenario planning to insurance processes in the business control, risk management and risk measurement fields to improve business planning and decision making and ensure stable development, solvency and strong financial health despite the changing market conditions.
- 2. The author recommends the Baltic insurance companies to apply Analytic Network Process and Analytic Hierarchy Process in the short term (for the first 2 years) for risk culture establishment and enhancement as the first stage of the development of appropriate risk management function in line with the requirements of the Solvency II framework and the improvement of decision making within an insurance company.
- 3. The author proposes the possibility of application of Analytic Network Process in banking and investment industries to improve decision making through a risk analysis and ensure the proper preference of the development strategy based on the understanding of risk nature. However, the author sees the possibility of application of Analytic Hierarchy Process in banking and investment industries to improve the risk culture and ensure proper and sophisticated understanding of risk nature.
- 4. The author recommends the Baltic non-life insurance companies to apply the proposed approach of the operational risk measurement, using the skew *t*-copula, to ensure appropriate amount of capital to cover possible losses due to operational risk occurrence. In addition, the author proposes also including partially actual direct costs under assessed capital to cover an operational risk, since those are part of the possible financial losses caused by the operational risk.
- 5. The author proposes the Baltic non-life insurance companies to use the algorithm of operational risk assessment also to another core risks with the aim to measure how much capital is needed to cover non-life underwriting risk and market risk.
- 6. The author recommends the Baltic Financial Supervisor authorities to apply the proposed approach of the operational risk measurement, using the skew *t*-copula, to test and check Baltic insurance companies' internal models under the Solvency II regime.
- 7. The main findings of the research could be used for educational purposes for university students (mainly master students) as part of the courses covering business control, actuarial field and risk management challenges.

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## **APPENDIX 1.** Gumpel copula's graphical illustration [75]



**APPENDIX 2.** Gaussian copula's graphical illustration [75]

## **APPENDIX 3.** The Case Study for Target Risk Profile Settlement

The case study was performed in spring 2012 in one life insurance company that operates in the Baltics. During the case study, the experts from actuarial, policy administration and risk management fields were attracted. The attracted experts performed the assessment of identified risk (recorded in the risk catalogue) based on a consensus approach in focus group (see Table 3.1).

Table 3.1

Rank	Sub-risk	Probability	Impact			
R1	Pricing risk	3	4			
R2	Policyholder behaviour risk	5	5			
R3	Reserving risk	2	5			
R4	Lapse risk	4	4			
R5	Claim risk	4	3			
R6	Expense risk	3	3			
R7	Biometric risk	2	3			
R8	Product design risk	2	4			
R9	Volatility risk	3	3			
R10	Economic environment risk	4	4			
R11	Interest rate risk	3	4			
R12	Concentration risk	2	3			
R13	Spread risk	3	4			
R14	Equity risk	3	2			
R15	Real estate risk	1	1			
R16	Foreign exchange risk	4	4			
R17	Liquidity risk	4	4			
R18	Settlement risk	3	3			
R19	Default risk	2	3			
R20	Policyholder credit risk	2	2			
R21	Reputational risk	2	5			
R22	Strategic risk	3	5			
R23	Model risk	2	4			
R24	Business risk	1	5			
R25	Legal risk	2	4			
R26	Catastrophic risk	1	5			
R27	Internal audit risk	3	4			
R28	Human risk	5	3			
R29	IT system risk	5	4			
R30	Political risk	1	5			

The Assessment of Sub-risks Based on Risk Catalogue (created by the author)

Based on the technique described (see Fig. 29), by using sub-risk assessment table it is possible to develop a risk matrix presented in Fig. 3.1.

	5			R28	R29	R2						
	4			R5	R4, R10,							
ent					R16, R17							
ssm	3		R14	R6, R9, R18	R1, R11,	R22						
isse					R13, R27							
ty a	2		R20	R7, R12,	R8, R23,	R3, R21						
ilidi				R19	R25							
cobs	1	R15				R24, R26,						
P1						R30						
		1	2	3	4	5						
	Possible impact (loss) assessment											

Fig. 3.1 Risk matrix (created by the author)

The risk matrix analysis is a complex process of the expert's group work, whose illustrated analysis is presented in Fig. 3.2.



Fig. 3.2. Assessment of the risk matrix (created by the author)

The assessment of the risk matrix reflects the company's risks in an obvious way. For the particular company, the most dangerous risks of the company are policyholder behaviour risk with the common assessment of ten points and IT system risk with the common assessment of nine points.

**APPENDIX 4.** Calculation of Total Priorities of Alternative Development Strategies Based on ANP

[																						1		
	Msubf	4 50%	1 50%	8 60%	2.1%	5.2%	10.2%	4.0%	1.9%	4.6%	4.3%	3.5%	8.1%	2.7%	6.1%	4.6%	3.5%	4.2%	6.0%	8.6%	2.6%			
	SWOT sub- factors	<b>S</b> 1	5	23	54 84	S5	W1	W2	W3	W4	W5	01	02	03	04	05	T1	<b>T2</b>	T3	Τ4	T5			
*																					]			
		<b>T5</b> 20% 42% 12%																						
				4	27%	19%		12%	42%															
				3 T	28%	20%		14%	39%															
				Ë	27%	17%		13%	42%															
				1 T	20%	39%		14%	28%															
				5 T	27%	17%		13%	42%							Ś								
				4	28%	20%		14%	39%							/ elgni	m	<i>c</i> '	I		4	1		
				2 03 0	19%	42%		12%	27%							5								
			s		19%	41%		11%	29%						:	ULIOI.	22%	32%			13%	33%		
			SWOT sub-factor	10	20%	39%		14%	28%						-	Z								
		W <sub>str</sub>		SWOT sub	SWOT sub	/5 O	16%	29%		12%	44%									1 I	2		Ś	1
						SW	74 W	19%	38%		11%	32%								ategy	itabil		~	strateg
				/3 W	21%	27%		12%	39%						ANP	ANF	vth str	/ Pro	trateg	ualeg	oility :	ced st		
				72 W	19%	38%	38% 11% 32%			Grov	rowth	S	2 2	rofital	Balan									
				1 W	18%	42%		14%	26%									0	j		с,			
				M	22%	39%		14%	25%						L									
				t S5	19%	42%		12%	27%															
				3 S.	19%	38%		12%	31%															
				32 S	20%	39%		14%	28%															
				S1	30%	19%		12%	38%															
	Stra- tegy				<b>O</b> /S	S/T		T/M	0/M															



## **APPENDIX 6.** The correlation between standardized risks





Values of Organization risk









