Risk Prioritisation (RP): A Decision Making Tool For Risk Management

By

Rabihah Md.Sum

A thesis submitted to Macquarie University
for the degree of Doctor of Philosophy
Department of Applied Finance and Actuarial Studies

Faculty of Business and Economics
23rd December 2015

Typeset in $\LaTeX\,2_{\varepsilon}$.

I certify that the work in this thesis entitled Risk Prioritisation (RP) : A Decision Making Tool For Risk Management has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree to any other university or institution other than Macquarie University.

I also certify that the thesis is an original piece of research and it has been written by me. Any help and assistance that I have received in my research work and the preparation of the thesis itself have been appropriately acknowledged.

In addition, I certify that all information sources and literature used are indicated in the thesis.

The research presented in this thesis was approved by Macquarie University Ethics Review Committee, reference number 5201400295 on 24th April 2014.

Rabihah Md.Sum

Acknowledgements

I am sincerely grateful to my supervisor, Professor Piet De Jong, for introducing me to AHP, and for valuable and inspiring discussions and excellent support. Thank you so much for introducing me to the wonderful world of the Analytic Hierarchy Process (AHP) and decision making, and to the work of the greatest scholars in the field.

This thesis is dedicated to my lovely parents, Zaleha Maasom and Md.Sum Dulah. My mother is a continual source of inspiration, support and encouragement. Thank you to my father for his support and prayers.

Thanks to my sister, Sarmila Md.Sum, for her love, encouragement and support throughout my study. She has been my best friend and confidant during the difficult years.

This thesis would not have been completed without constant motivation, prayers and encouragement from my family: my aunt Zaiton Maasom, my brother-in-law Abdul Razak, my brothers Mohd. Asyraf and Mohd. Akbar, my lovely nephew Muhammad Razen, and my nieces Shafiqah, Aishah and Rahah.

Thanks to my good friend Fiza, whom I go to whenever I need cheering up.

List of Publications

- *Risk Management Decision Making.* Proceedings of 12th International Symposium on Analytic Hierarchy Process (ISAHP 2015), 23-26 June 2013, Kuala Lumpur Malaysia.
- *Risk Prioritization: The Analytic Hierarchy Process Approach.* Presented at Australia - New Zealand Society of Risk Analysis (ANZ-SRA) 8th Annual Conference. Massey University, Palmerston North, New Zealand. 26-27 August 2014.
- *Risk Management Decision Making: The Analytic Hierarchy Process Approach.* Journal for International Business and Entrepreneurship Development, Vol.8, No.2, 2015, pp.108 - 127.

Abstract

This thesis develops a decision making tool for risk management. The tool Risk Prioritisation (RP) exploits the Analytic Hierarchy Process (AHP). AHP has been widely applied to variety of complex problems. This thesis brings AHP to a new area of application: risk management. The contributions of this thesis are twofold. The first part is the design and development of RP. To use the AHP for risk management, several modifications have to be made. RP is a modified version of the AHP. Developing RP contributes to the development and application of the AHP to risk management. The second part of the contribution is the application of RP to risk management, which is a two-step procedure. First, RP is applied to risk management problems. Second, using the problems as a medium, risk managers evaluate RP practical usability. Risk managers' feedbacks are used to identify how RP is useful for risk management, how to use RP for risk management and what risk managers require in order to use RP effectively. Analysis of the feedback is used to improve RP's practical usability for risk management decision making.

RP structures and simplifies complex risk management problems. Complex problems do not necessarily need a complex solution; rather, they need to be disentangled and simplified to find solutions. RP disentangles a complex risk management problem by structuring it in a hierarchy and simplifying it by breaking it down into sub-problems. To structure and simplify a problem, risk managers need to understand it, gather facts and factors relevant to the problem, and justify the rationales for including the factors in the hierarchy. Hierarchies systematically structure the influences, connections and interactions of a problem. To break down a problem, risk managers must exercise reductive thinking and logical analysis

To investigate whether RP has something to offer to risk management, it is applied to the following risk management problems: (i) prioritising risks faced by an insurance company and (ii) determining an insurance company's line of business that has the highest risks. These problems are then presented to risk managers. The purpose is to bring RP to the practical risk management setting and obtain risk managers' feedback on RP practical usability. The feedback is used to modify, refine and improve RP, to understand RP from risk managers' perspectives, and to increase knowledge regarding the applications of RP to risk management

Decision making is an important component of risk management. A reliable and systematic decision-making process is as important as a reliable and systematic risk management process. RP is a systematic, practical, reliable and easy-to-use decision-making tool for risk management. It improves risk managers' understanding of a problem through decomposing and structuring the problem in a hierarchy. RP enables risk managers to simplify the problem, yet maintain the complexity of the problem. RP logical and easy to use decision making process enables risk managers to understand how each step guides them towards achieving the decision goal. Furthermore, a practical and easy to use decision making process facilitates communication between risk managers, top management and relevant stakeholders.

Contents

Acknowledgements **v**

List of Publications **vii**

Abstract **ix**

List of Figures **xvii**

List of Tables **xix**

1 Overview Of the Research **1**

1.1 Introduction to Chapter 1 1

1.2 Research Background 2

1.3 Research Motivation 5

1.3.1 Lack of Studies on Decision Making in Risk Management 6

1.3.2 Wide Application of Multi-Criteria Decision Making to Finance 10

1.3.3 Wide Application of AHP 11

1.3.4 Section Summary 12

1.4 Research Aim and Objectives 13

1.5 Research Questions 13

1.6 Research Process 14

1.7 Thesis Structure 15

2 Main Results and Conclusion **19**
2.1 Introduction to Chapter 2 19
2.1.1 RP as a Tool to Make Explicit Risk Trade-off 20
2.1.2 RP as a Tool to Prioritise Risks 22
2.1.3 RP is a Practical and Effective Tool to Structure Complex Risk Management Problems 27
2.1.4 RP is a Simple and Easy to Use Tool for Firm-Wide Risk Management Decision Making 29
2.1.5 RP is a Tool for Group Decision Making 31
2.1.6 RP Uses Both Intuition and Analytic to Make Decisions 34
2.2 Conclusion 36

3 Risk Management, Risk Management Decision Making and Decision Theory **39**
3.1 Introduction to Chapter 3 39
3.2 Risk Management 40
3.2.1 Different Risk Management Processes 46
3.3 Risk Management Decision Making 47
3.4 Risk Management Versus Risk Management Decision Making 52
3.5 Risk Management Decision Making Challenges 53
3.5.1 Bias in Heuristic Judgements 54
3.5.2 Bias in Decisions Framing 60
3.5.3 Bias in Human Thinking Systems 66
3.6 Current Risk Management Tools 71
3.6.1 Comparing the Usability of the Tools for Risk Management Decision Making 81
3.7 Risk Management and Decision Theory 83
3.8 Choosing the Analytic Hierarchy Process as Decision Making Tool for Risk Management 85
3.9 Summary 88

4 The Analytic Hierarchy Process (AHP) 91
4.1 Introduction to Chapter 4 . . . 91
4.2 AHP . . . 92
4.2.1 AHP Decision Making Steps . . . 94
4.3 AHP Application to Complex Problems . . . 98
4.3.1 Prioritisation . . . 99
4.3.2 Predicting . . . 102
4.3.3 Choice . . . 104
4.3.4 Benefit Cost Risk . . . 106
4.3.5 Benefit Opportunities Cost Risk . . . 109
4.3.6 Benefit Cost Analysis . . . 111
4.3.7 Conflict Resolution . . . 116
4.4 AHP Strengths and Limitations . . . 124
4.4.1 Strengths . . . 124
4.4.2 Limitations . . . 127
4.5 Using AHP for Risk Management Decision Making . . . 129
4.5.1 Elements in Risk Management Decision Making . . . 129
4.5.2 Modifying AHP for Risk Management Decision Making . . . 130
4.6 Summary . . . 131

5 Risk Prioritisation (RP) 133
5.1 Introduction to Chapter 5 . . . 133
5.2 RP . . . 134
5.3 Differences and Similarities between AHP and RP . . . 136
5.3.1 Differences . . . 136
5.3.2 Similarities . . . 140
5.4 RP Decision Making Process . . . 140
5.5 RP Potential Applications . . . 153
5.5.1 Choosing an Alternative from a Set of Alternatives . . . 153
5.5.2 Prioritising Alternatives . . . 154

5.6 Summary 155

6 RP Application to Risk Management **157**

6.1 Introduction to Chapter 6 157

6.2 Prioritise Risks of an Insurance Company 158

6.3 Determining Insurance Company Line of Business with the Highest Risk 170

6.4 Summary 177

7 Evaluating the Practical Usability of RP **183**

7.1 Introduction to Chapter 7 183

7.2 Overview of Evaluation 184

7.3 The Design of RP Evaluation 188

7.3.1 Purpose of Evaluating RP 189

7.3.2 Criteria Used to Evaluate RP 189

7.3.3 Potential Use of RP Evaluation Feedbacks 190

7.4 Conducting the RP Evaluation 190

7.4.1 Description of the Risk Managers 190

7.4.2 Evaluation Session with the Risk Managers 191

7.4.3 Tool Supporting RP Evaluation 192

7.4.4 RP Evaluation Questionnaire to Collect Feedbacks 194

7.4.5 RP Evaluation Session Procedure 195

7.5 Feedbacks Collected from the Risk Managers 196

7.5.1 Risk Management Implementation Challenges 197

7.5.2 Current Risk Assessment Tools 198

7.5.3 The Practical Usability of RP 199

7.6 Summary 205

8 Analysis of the Evaluation Feedback **207**

8.1 Introduction to Chapter 8 207

8.2 RP Strengths 208

8.2.1 Easy to Use and Understand 208

8.2.2 Improves Understanding of a Problem . . . 208
8.2.3 Improve Risk Assessment . . . 209
8.2.4 RP for Problem with Scarce Data . . . 209
8.3 RP Limitations . . . 210
8.3.1 The Pairwise Comparison . . . 211
8.4 Improving RP Practical Usability . . . 212
8.4.1 Connecting Risk Assessment and Response Decisions . . . 213
8.4.2 Pairwise Comparison Questions . . . 214
8.4.3 Explaining Priority Weight to Decision Makers . . . 215
8.4.4 Improving Decision Consistency . . . 216
8.4.5 Organising a Large Number of Risks in a Hierarchy . . . 217
8.4.6 Group Decision . . . 218
8.4.7 Document a Decision . . . 220
8.4.8 Parties Involve in RP . . . 220
8.4.9 RP for Enterprise Risk Management . . . 223
8.5 Post Evaluation RP . . . 224
8.5.1 Differences Between Pre and Post Evaluation RP . . . 227
8.6 Summary . . . 228

9 RP Strengths and Limitations **233**
9.1 Introduction to Chapter 9 . . . 233
9.2 Risk Management Decision Making . . . 234
9.2.1 RP Strengths . . . 234
9.2.2 RP Limitations . . . 244
9.3 Risk Management Decision Making Challenges . . . 245
9.3.1 RP Strengths . . . 245
9.3.2 RP Limitation . . . 250
9.4 Summary . . . 251

10 Contribution, Limitation and Future Direction **253**
10.1 Introduction to Chapter 10 . . . 253

10.2 Research Questions, Aims and Objectives Revisited 254
10.3 Contribution to Knowledge 255
10.4 Contribution to Practice 257
10.5 Research Limitations 258
10.6 Future Research 259
10.7 Final Remark 260

A Appendix **261**
A.1 Email Invitation to Potential Participants 261
A.2 Participant Information and Consent Form 263
A.3 RP Evaluation Questions 265
A.4 Ethics Approval Letter 267

List of Acronyms **271**

References **273**

List of Figures

3.1 Risk Matrix Example 72
3.2 Components of Decision Theory 86

4.1 Basic Hierarchy 94

5.1 Decision Making Steps: AHP versus RP 137
5.2 RP Steps 141
5.3 Hierarchy to Prioritise Risks Faced by a Firm 145

6.1 Source of Risks, Sub-Risks and Risk Categories 162
6.2 Risks Hierarchy of An Insurance Company 164
6.3 RP Risk Prioritisation Results 168
6.4 Hierarchy of Risks of Line of Business 172
6.5 RP Results for Line of Business Risk 181

8.1 AHP versus RP Pairwise Comparison Question 213
8.2 Decision Making Power Hierarchy 221
8.3 RP Decision Report Template 222
8.4 RP Steps, Actions and Actors 229
8.5 ISO31000:2009 Risk Management Standard 230
8.6 Connecting the the ISO31000:2009 Risk Management Standard and RP 231
8.7 Post Evaluation RP Decision Making Steps 232
8.8 Post and Pre Evaluation RP Decision Making Steps 232

List of Tables

1.1 Risk Management Research 7

2.1 Decision Matrix and Priority Weight of Market Risks 23

3.1 Narrow Framing: Separate Choices 61
3.2 Broad Framing: Combination of Choices 62
3.3 Dictionary Attributes 64
3.4 Comparison between System 1 and System 2 68
3.5 Risk Score Calculation 73

4.1 Types and Structures of Hierarchy 96
4.2 Priority Weight of Alternatives 109
4.3 Weight of Alternatives for BOCR Merit 111
4.4 Overall Ranking of the Alternatives 111
4.5 Conflicting Parties and Objectives 117

5.1 RP Pairwise Comparison Scale 146
5.2 Decision Matrix for Sub-Risks of $Risk_1$ 147
5.3 Decision Matrix for Risks 148
5.4 Random Consistency Index 151
5.5 Calculating λ 151
5.6 Priority weight of sub-risks and risks 152

6.1 Decision Matrix and Local Priority Weight of Sub-risks within Category 166
6.2 Decision Matrix and Local Priority Weight of Risks 167
6.3 Global Priority Weight of Sub-Risks 169
6.4 Risk and Required Capital 171
6.5 Decision Matrix and Local Priority Weight of Risks 174
6.6 Decision Matrix and Local Priority Weight of Sub-risks 174
6.7 Global Priority Weight of Sub-risks and Risks 176
6.8 LOB Decision Matrix & Local Priority Weight 177

8.1 Decision Matrix for Risk A, B and C 216
8.2 Priority Weight of Each Decision Maker and Group Priority Weight . . 219

1

Overview Of the Research

1.1 Introduction to Chapter 1

This chapter explains the aim of the thesis, the background of the research project and the motivation to undertake the project. The discussion includes the research aims, objectives, questions and process. It also outlines the structure of the thesis.

The goals of this chapter are as follows:

- discuss the research issue and justification for undertaking the research (Sections 1.2 and 1.3)
- specify the aim and objectives of the research (Section 1.4)
- specify the research questions (Section 1.5)
- describe the steps undertaken to answer the research questions. (Section 1.6)

- provide an outline of the thesis. (Section 1.7)

1.2 Research Background

This thesis develops a practical and easy-to-use decision-making tool for risk management. Risk management problems are generally too complex for risk managers to rely on intuition or common sense alone. Grunig and Kuhn (2005) stated that complex problems must have at least one of the following criteria: (i) they must have many aspects, and some of the aspects should only be described in qualitative terms; (ii) their parameters are interdependent, creating an unclear problem structure; (iii) more than one department in the company is included in the problem; (iv) a large number of possible solutions exist; and (v) the environment in which the decision is made is uncertain. If none of these criteria exist, the problem is a simple decision problem. Risk management problems fit the characteristics of complex problems. They are unstructured and have multiple conflicting factors influencing the solutions. The outcome of the decision affects several stakeholders. Risks are interrelated and constantly evolve, requiring constant reviewing of the decisions.

This thesis defines the complexity of risk management problems as:

- high stakes: the outcome of the decision has significant effects on the firm, such as increased costs, damage to reputation and loss of market share
- unstructured: problems are unstructured, difficult to understand and a large number of possible solutions exist
- uncertainty: consequences of decisions are unknown
- multiple factors: solutions are influenced by multiple conflicting factors
- diversity of stakeholders: stakeholders have different values, preferences and perspectives.

Risk managers need to confront the complexity and uncertainty as best as possible using a decision-making tool. However, risk management books and articles contained pages of detailed mathematical models. Complicated techniques are difficult to understand, take more time to dissect and can be easily exploited and manipulated. Only certain parts of the technique are understood, resulting in difficulties in understanding how the decision is made and increasing doubt regarding the reliability of the decision. However, people believe that complex problems require complex solutions (Gigerenzer, 2014). If a complex solution does not work, people look for even more complex solutions. According to Gigerenzer (2014), complex problems do not always require complex solutions. Simple techniques are safe, easy to understand and can produce reliable results. Rudolph (2014) stated, in an uncertain environment, it is easy for management to hide behind complex models. Because the regulators in charged to regulate the environment directly accepted the models instead of hiring experts to peer review them. According to Rudolph (2014) decision making is improved when models are transparent and peer reviewed by experts, and modellers need to concentrate on telling a story to clarify the problems, instead of building additional layers of complexity.

Borge (2001) stated that risk problems have to be simplified to be solved. The best risk managers are those who can simplify a problem without sacrificing the essentials of the problem. The viewpoint of this thesis is that risk management problems need a simple and practical tool to enable risk managers to confront and resolve uncertainty and disentangle complexity. The decision-making tool developed in this thesis allows risk managers to structure complex risk management problems into a simple and organised framework while maintaining a complex view of the problem. The tool uses a hierarchy to structure, simplify and show linkages between the problem's factors. It manages uncertainty by requiring the problem to be clearly understood and well structured before judgements are made. Structuring a complex problem in a hierarchy requires risk managers to gather the facts and factors relevant to the problem in order to have a clear understanding. They also have to state the rationales for including the factors. The solution to a problem depends on the information input into the tool and the preference of the decision maker. The tool assists risk managers to transform the problem's information into alternatives and their knowledge into a preference, and to use their intuition and common sense to make rational decisions to produce an objective and reliable decision.

An objective decision means, the decision is not influenced by risk managers personal feelings, opinions or agendas. Instead, the decision is based on risk managers experience and knowledge. The tool developed in this thesis requires risk managers to detached themselves from the problems. Risk managers need to structure all relevant information that meets the goal of the decision in a hierarchy. Structuring is a gathering-filtering process, which means, first generating a wide set of facts, and then filtering the facts to the most essential information that meets the decision goal. Therefore, the decision is based on facts relevant to the goal instead of bias or conform to risk managers opinions or agendas. As stated by Borge (2001), although only scientific method can achieve 100 percent objectivity, which is the absence of personal bias in forming theories and interpreting evidence. A scientist with a personal stake in a theory is prone to dismiss evidence in favour of a competing theory. To achieve objectivity, the scientist must be detached. Detachment guards against distortion of the truth and consideration whether a particular discovery is useful and valuable. A reliable decision means a decision that risk managers can trust and act on. A reliable decision is characterised by systematic and transparent process, and consistent decisions. A systematic and transparent decision-making process enable risk managers and stakeholders to understand how a decision is made. Therefore, given the information both risk managers and stakeholders agrees on the methodology on how a decision is made. Human mind is inherently inconsistent (Saaty, 2010b). However, the main concern is the degree of inconsistency. The tool developed in this thesis measures decision consistency using consistency ratio. Consistency ratio is a monitoring device to capture whether risk managers decisions are based on their understanding of the problem and how factors relevant to the problem linked with each other, or the decisions are based on random understanding that hits the target now and then.

Decision-making practices can be categorised into two type (Grunig and Kuhn, 2005):

- Explanatory model: This model is used in decision making to determine the effects of options. An example is the model of purchasing behaviour, which is used by marketing managers to determine how buyers perceive the different offers in the market, how they assess the offers and how they decide in favour of a particular offer.

- Decision-making procedure: This is defined as a system of rules for obtaining and analysing information to resolve a decision problem. The procedure consists of problem discovery and analysis, the development and evaluation of options, and the specification of the overall consequences of the options and decisions. Decision-making procedures help decision makers to process relevant information when dealing with decision problems.

This thesis belongs to the second category of decision-making practice. In a complex and uncertain world, risk managers need a systematic decision-making process. The tool developed in this thesis provides a systematic framework to handle complexities and uncertainties in order to make risk management decisions.

1.3 Research Motivation

The Holy Grail of risk management is to find the best possible decision in an uncertain environment (Borge, 2001). People are quickly satisfied when they find a good solution. Quick thinking is easy and requires little effort. Studies have shown that fast decision making is subject to judgement bias (Kahneman, 2011), and even experts are prone to this biases. According to Kahneman (2011) in uncertain situations, people tend to bet on an answer, and their bets are guided by recent experience. The recent event is given more weight in interpreting the uncertain situation. For example, a person who has recently been to a river would interpret the word 'bank' as not being associated with money.

Another judgement flaw is not using a systematic decision-making process to assist in decision making (Finkelstein et al., 2009). A systematic decision-making process enables people with different views to debate and challenge the facts and factors used to make decisions. However, many firms ignore the importance of systematic analysis in decision making. Instead of improving the decision-making process, firms are more interested in improving business processes.

To make a good decision in an uncertain environment, risk managers need to carefully think and deliberate upon their judgement. They also need a systematic decision-making process to guide them to structure their thoughts and perform logical thinking before making a decision. The next section discusses the motivations behind undertaking this research.

1.3.1 Lack of Studies on Decision Making in Risk Management

The following discussed areas of risk management research. Analysis on the literatures found research on risk management can be grouped into four themes: implementation, impact, practice and theory. The followings explain each theme. The author, research focus and research group for each theme is presented in Table 1.1.

- Implementation. The focus of research includes factors motivating firms to implement a risk management program, characteristics of firms implementing risk management, extent of risk management implementation and effect of hiring Chief Risk Officer (CRO) to risk management implementation

- Impact. The focus of research includes the impact of implementing risk management to firms' performance, value or stock market.

- Practice. The focus of research includes detail explanation on how companies implement risk management.

- Theory. The focus of research includes examining risk management component and its practical application.

Table 1.1: Risk Management Research

Author	Focus	Group
Colquitt et al. (1999)	Assess the characteristics and and extent of integrated risk management.	Implementation
Hoyt and Liebenberg (2003)	Investigate the differences between firms that have risk management process, measured by the appointment of Chief Risk Officer (CRO) and firms that do not have CRO.	Implementation
Beasley et al. (2005a)	Investigate factors associated with extent of risk management implementation.	Implementation
Desender (2007)	Explore the link between risk management implementation and board composition.	Implementation
Pagach and Warr (2008a)	Explore the link between risk management implementation and characteristics of firms that implement risk management. Appointment of CRO is used as a proxy for risk management implementation.	Implementation
Pagach and Warr (2011)	Investigate the characteristics of firms that implement risk management proxies by appointment of CRO.	Implementation
Hoyt and Liebenberg (2011)	Measure the extent of risk management implementation and assess its implication to firms' value.	Implementation
Paape and Speklé (2012)	Examine the extent of risk management implementation and factors associated with different level of risk management implementation.	Implementation
Kleffner et al. (2003)	Examine the impact of Toronto Stock Exchange guidelines on risk management strategy and evolution of risk management discipline.	Impact
Beasley et al. (2008)	Examine equity market reaction to announcement of appointment of CRO as an indication of risk management implementation.	Impact

Continued on next page

Table 1.1 – *Continued from previous page*

Author	Focus	Group
Pagach and Warr (2008b)	Examine the impact of risk management implementation on financial, asset and market characteristics.	Impact
Gordon et al. (2009)	Examine the impact of risk management on firms performance.	Impact
Acharyya (2009)	Examine the influence of risk management on insurers' stock market performance.	Impact
Harrington et al. (2002)	The implementation of enterprise risk management at United Grain Growers.	Practice
Beasley et al. (2005b)	Examine internal auditor involvement in risk management.	Practice
Aabo et al. (2005)	The implementation of enterprise risk management at Hydro One.	Practice
Stroh (2005)	The implementation of enterprise risk management at United Health Group.	Practice
Panning (2006)	Measure a firm's aggregate risk exposure to determine capital requirement.	Practice
Acharyya and Johnson (2006)	The development of risk management of four major insurance companies.	Practice
Yow and Sherris (2007)	Measure insurers' required economic capital under enterprise risk management.	Practice
Nocco and Stulz (2006)	A discussion of the theory and practice of enterprise risk management and implementation at Nationwide Insurance.	Theory, Practice
Gates et al. (2009)	Examine which components of risk management framework lead to better decisions and increased profitability.	Theory

Iyer et al. (2010) stated despite the growing interest of practitioners in risk management of an enterprise and numerous surveys by providers of risk management solution such as risk governance and compliance agencies, very little academic research has been conducted to provide a better understanding of risk management. Iyer et al. (2010)

searched academic journals and database of academic research on risk management of an enterprise. The study documented ten research studies and five case studies that can be classified as either academic research or case studies. Academic research means the paper is published in a peer-reviewed academic journal and/or written for academic audience. Case study means the study is published in outlets marketed for academics. The study grouped risk management research into (i) what enterprise risk management is or is not (ii) practical measurement of the degree to which risk management is implemented within different industries (iii) factors determining risk management implementation or lack of implementation (iv) effect of risk management implementation on business value and (iv) the interaction of risk management with overall business objectives.

Decision making under uncertainties is the essence of risk management. However, risk management literature lacks research on how to systemically integrate risk management and decision making. Borge (2001, pg. 223) stated that risk management is designed expressly for decision makers-that is, people who must decide what to do in uncertain situations where time is short and information is incomplete, and who will experience real consequences as a result of their decisions. Rebonato (2007) stated that risk management is not about measuring risks or assessing probabilities, it is about making decisions in situations of uncertainties.

Decision theory is a well-established discipline that tackles the issues of decision making under uncertainties. Two well-known theories in this area are the Expected Utility Theory (Bernoulli, 1954) and Prospect Theory (Kahneman and Tversky, 1979). Both theories study decision-making behaviour under conditions of uncertainties. Understanding decision-making behaviour helps in understanding how risk managers make decisions, as well as factors influencing their judgements.

However, this thesis is not about risk managers' decision-making behaviour. The ambition of this thesis is to develop a practical decision-making tool to improve decision making in risk management. A branch of decision theory on improving decision making is prescriptive decision theory (Bell et al., 1988). This thesis aims to connect risk management and decision-making theory and develop a practical decision-making tool for risk management.

1.3.2 Wide Application of Multi-Criteria Decision Making to Finance

The wide application of multi-criteria decision making (MCDM) techniques, particularly the Analytic Hierarchy Process (AHP) to financial decision making, has motivated this thesis to explore whether AHP can be used as a decision-making tool for risk management. According to Zopounidis and Doumpos (2002), the globalisation of financial markets, the increased competition among firms, financial institutions and organizations, the rapid economic, social and technological changes and the increased variety and volume of financial products have led to an increasing uncertainty and instability in the financial and business environments. As a result, the importance of making efficient financial decisions has increased, and the complexity of the financial decision making process has also increased. Therefore, researchers and practitioners are forced to use an analytic decision-making tool because to address the complexity of financial problems and the importance of their decisions. According to Zopounidis (1999), the methodological framework of multi-criteria decision aid or technique is well suited to the complex nature of financial decison making problems.

Zopounidis and Doumpos (2002) investigated real-world application of MCDM on financial decision making. The study found MCDM has been applied to bankruptcy and credit risk, portfolio selection and management, corporate performance evaluation, investment project decision, venture capital, country risk assessment, financial planning and, mergers and acquisition. MCDM techniques used includes AHP, Elimination Et Choix Traduisant la Realite (ELECTRE), Multi Attribute Utility Theory (MAUT), Multi-Group Hierarchical Discrimination (MHDIS), Preference Ranking Organization Method of Enrichment Evaluations (PROMETHEE), Utilities Additives (UTA) and Utilities Additives Discriminantes (UTADIS). Acording to Zopounidis (1999), MCDM provides the following advantages to financial decision making: (i) structuring complex problems (ii) including both quantitative an qualitative criteria in the evaluation process (iii) transparency in the evaluation, allowing good arguments in the decision and (iv) sophisticated, flexible and realistic scientific methods in decision making process.

Stuer and Na (2003) investigated 256 studies published between 1955 and 2001 on the application of MCDM to finance. Of these, 18 papers used AHP in capital budgeting, selecting financial instruments, mergers and acquisitions, predicting bankruptcy, and forecasting foreign exchange rates. Other papers have used MCDM techniques such as goal programming, multiple objective programming, MAUT and ELECTRE. Eshlagy and Homayanfar (2011) found 628 papers on MCDM published between 1999 and 2009. Of these, 11 papers applied AHP to investment project assessments, financial alliances, stock selection, foreign direct investment, and partnership selection and merger strategies. The large number of studies on the application of MCDM to financial decision problems shows that MCDM can handle complex financial decision making.

Similar to finance, risk management problems are complex and involve many conflicting factors. Therefore, as one MCDM technique, AHP has the potential to be applied to decision making in risk management.

1.3.3 Wide Application of AHP

Ishizaka and Labib (2011) reported the development of AHP since its inception in 1972. They found that AHP is used in banks, manufacturing systems, operators' evaluation, drug selection, site selection, software evaluation, website performance evaluation, strategy evaluation, selection of recycling technology, firms' competence evaluation, weapon selection, underground mining method selection and its sustainability evaluation, software design, organisational performance evaluation, staff recruitment, construction method selection, warehouse selection, technology evaluation, route planning, project selection, customer requirement rating, energy selection and university evaluation.

Sipahi and Timor (2010) presented bibliography studies on AHP and Analytic Network Process (ANP). Sipahi and Timor (2010) found 235 papers were published from

2005 to 2009. AHP is dominant in manufacturing, environmental management and agriculture, power and energy, transportation, construction and healthcare. Less dominant areas of AHP and ANP application are education, logistics, e-business, information technology, research and development, telecommunication, finance and banking, urban management, defence industry and military, government, marketing, tourism and leisure, archaeology, auditing, mining industry, sports and politics. Common decision-making issues using AHP are supplier selection, supply chain evaluation, location selection, system selection or evaluation, and strategy evaluation. The study identified AHP and Fuzzy AHP are the most used techniques.Vaiday and Kumar (2006) analysed 150 papers that used AHP as a decision-making tool, finding that AHP is applied in education, engineering, government, management, manufacturing, personal, political, social and sports.

Verbano and Venturini (2011) analysed risk management development and application and identified nine main paths of development for risk management: strategic, financial, enterprise, insurance, project, engineering, supply chain, disaster and clinical. The found that AHP is mainly used in project risk management and supply chain risk management, while other MCDM techniques, such as MAUT and Multi Attribute Value Theory (MAVT) are used in supply chain risk management.

The literature shows that AHP is mainly applied to project risk management and supply chain risk management. A lack of AHP application to risk management has motivated this thesis to explore the possibility of applying AHP to risk management.

1.3.4 Section Summary

Risk management is an established and accepted process, as evidenced by the significant amount of research in this area and the published regulations and standards. However, despite this, decision making in risk management tends to be informal and depends on intuition. The importance of decision making in risk management and the lack of studies in the area has motivated the thesis to explore and develop a decision-making tool for risk management. The tool captures the complexity and minimises the ambiguity of risk management problems, assists risk managers in making rational decisions, and able to minimise flaws in the decision-making process.

1.4 Research Aim and Objectives

The primary aim of this thesis is to develop a decision-making tool for risk management that exploits AHP, which is a multi-criteria decision-making method for complex problems. However, to use AHP for risk management, several modifications have to be made. The modified AHP is called Risk Prioritisation (RP), which is a decision-making tool developed for complex risk management problems. This thesis explores whether RP has something to offer that is relevant to the practice of decision making in risk management. Thus, to support the aim of this thesis, the objectives are to:

- explore situations in which RP is useful for risk management, and discuss how it is useful.
- explore situations in which RP is not useful for risk management, and discuss how it is not useful.
- investigate how RP can be used for risk management.
- investigate how risk managers can use RP effectively.

1.5 Research Questions

This thesis aims to answer the question: Does RP have something to offer to risk management? This question is separated into the following sub-questions:

- How or when is RP useful for risk management?
- How or when is RP not useful for risk management?
- How can RP be used for risk management?
- What do risk managers require to use RP effectively?

1.6 Research Process

The steps taken by this thesis to answer the research questions are outlined below:

1. Explore how AHP addresses complex problems: The first step is to investigate the application of AHP to complex problems. The purpose is to analyse how AHP structures the problems, why decision makers use AHP, what output is produced by AHP and how the output assists in decision making.

2. Explore how to structure AHP for risk management: The second step is to analyse how AHP can structure risk management problems. This thesis develops different types of risk management problems and uses AHP to structure them. The outcome from the analysis is that AHP cannot be used directly for risk management problems. Therefore, several modifications have to be made to the original AHP to accommodate risk management problems.

3. Develop a new AHP for risk management: The modifications identified in the previous step are built into the original AHP. To differentiate the original and the modified AHP, this thesis defines the modified AHP as RP, which is a decision-making tool designed for risk management.

4. Tackle actual risk management problems: This thesis develops actual risk management problems and uses RP to structure them.

5. Applied AHP as described by RP into real risk management situations: This stage explores RP's practical usability. The risk management problems structured using RP are presented to risk managers. The thesis recruited members of the Malaysian Association of Risk and Insurance Management (MARIM) as the research participants. The research participants or risk managers evaluated RP and gave feedbacks on its practical usability.

6. Analyse the feedbacks obtained from risk managers to make conclusions: This stage answers the research questions. It analyses and responds to the risk managers' feedbacks and relates the analysis and the responses to the research questions. The findings are used to answer how RP is useful and not useful for

risk management, how RP is used for risk management and what risk managers require to use RP effectively.

7. Evaluate RP and its application to risk management problems based on the experiment conducted with the risk managers and the feedbacks obtained from them: The final stage is to answer the primary aim of the thesis; that is, does RP have something to offer that is relevant to decision making in risk management? The thesis uses the analysis of the risk managers' feedback to discuss RP's strengths and limitations as a decision-making tool for risk management, and to identify contributions to the knowledge and practice of decision making in risk management.

1.7 Thesis Structure

The thesis consists of 10 chapters, which are outlined below.

Chapter 1: Overview of the Research

Chapter 1 discusses the background of the thesis and the motivation for undertaking the research. The discussion includes describing the research questions, aims and objectives, and explaining the research process to answer the research questions. The chapter also provides the outline of the thesis.

Chapter 2: Main Results and Conclusion

Chapter 2 discusses the main results, including how and in what way the decision-making tool developed in this thesis is relevant to risk management. The chapter closes with the conclusion of the main results.

Chapter 3: Risk Management and Risk Management Decision Making

Chapter 3 discusses risk management decision making and the differences between risk management and risk management decision making. The chapter starts by discussing risk management, with a focus on explaining the process for managing risks. It continues with a discussion of the problems and decisions that risks managers have to make to manage risks, followed by the differences between risk management and risk management decision making. Risk managers face uncertainty and ambiguity when making decisions. Risk management problems are too complex for risk managers to rely on intuition or common sense alone. This chapter also discusses the challenges faced by risk managers when making decisions under uncertain circumstances or in a risky environment, as well as the current decision-making tools they use to assist in their decision making. The discussion then highlights the limitations of the tools. The final part of the chapter proposes combining risk management and decision theory. Risk management is about managing uncertainties, while decision theory is about decision making under uncertainties. The discussion starts by identifying a suitable decision theory for decision making in risk management, and it proceeds with how the AHP was chosen as a decision-making tool for risk management in this thesis.

Chapter 4: The Analytic Hierarchy Process

Chapter 4 introduces and explains the AHP, AHP decision-making steps, and its strengths and limitations. It demonstrates the application of AHP to complex problems to show how it structure and simplify complex problems. The final part of the chapter discusses why the AHP cannot be used directly for risk management problems.

Chapter 5: Risk Prioritisation

Chapter 5 explains the RP framework. RP is a decision-making tool designed for risk management. It supports risk management decision-making by structuring and simplifying complex risk management problems. RP is a simple and practical decision-making tool, as represented by its reliability, speed, transparency and validity.

Chapter 6: RP Application to Risk Management

Chapter 6 demonstrates RP's application to risk management. RP is used to structure two risk management problems. The first problem is to prioritise the risks faced by an insurance company. RP is used to structure, categorise, assess and rank the risks. The second problem is to determine which insurance company line of business has more risks. The insurance company has four lines of businesses: Accident and Health, General Liability, Motor Liability, and Motor Non-Liability.

Chapter 7: Evaluating RP

Chapter 7 discusses two issues: the method used to evaluate RP, and feedback on RP's practical usability. This chapter explores whether the RP framework outlined and theoretically explained in Chapter 5, and the application of RP to risk management problems demonstrated in Chapter 6, has something to offer to the practice of decision making in risk management. The purpose of the evaluation is to explore how risk managers use RP and to obtain feedbacks on RP's practical usability as a decision-making tool for risk management. The feedbacks are used to answer the research question: Is RP relevant to risk management?

Chapter 8: Analysis of the feedback

Chapter 8 presents the analysis on the participants' feedbacks to answer the research questions. The analysis are grouped into four areas: (i) RP strengths; (ii) RP limitations; (iii) improving RP practical usability; and (iv) post-evaluation RP.

Chapter 9: RP Strengths and Limitations

This chapter discusses the strengths and limitations of RP from the perspectives of risk management decision making and risk management decision-making challenges.

Chapter 10: Contribution, Research Limitation and Future Direction

Chapter 10 revisits the research aims and objectives, as well as the research questions, and it provides a critically reflective summary of the contribution of the thesis to the theory and practice of decision making in risk management. The chapter also explores the limitations of the research and identifies future research directions.

2

Main Results and Conclusion

2.1 Introduction to Chapter 2

This chapter outlines and discusses the main findings of the thesis. The general area of the thesis is risk management decision making. The thesis proposes, develops and discusses a decision-making tool for risk management decision making called Risk Prioritisation (RP), which is based on the AHP developed by Saaty (1977). AHP is a tool for making decisions; however, it has not yet been considered or tailored to risk management context. The main question that this thesis aims to answer is whether and how best to modify AHP to make it suitable for risk management. The following sections discuss how RP is relevant as a decision-making tool for risk management. The discussion is based on analysis of risk managers feedbacks on practical usability of RP. Chapter 8 provided detail discussion on the analysis of risk managers feedbacks and answered the research questions. Chapter 7 discussed method to evaluate RP practical usability and report risk managers feedbacks. This chapter discussed the main results and conclusion of the analysis.

2.1.1 RP as a Tool to Make Explicit Risk Trade-off

All risks are important, but some risks are more important than others. Risk managers face a difficult task when deciding which risk is more important (i.e., to prioritise risks). When prioritising, risks have to be compared and traded off. Making a trade-off is one of the most important and difficult challenges in decision making (Hammond et al., 1998). RP is a practical and easy-to-use tool for making risk trade-offs. To make a risk trade-off, risk managers compare two risks and determine the importance of the risks in terms of dominance and intensity. Dominance requires risk managers to decide which risk is more important, and intensity signals the magnitude of importance. RP measures intensity using a scale of one to nine. A score of one means that the risks are equally important, and nine signals that a risk is extremely important compared to the others. In judging the importance of risks, it is easy to say, for example, that Risk A is more important than Risk B, but it is difficult to judge how much more important it is. RP forces risk managers to be explicit about the intensity of their preference, and it provides an automatic check on the consistency of pairwise intensities. Borge (2001) stated that one of the principles of assertion in risk management is to be explicit, as it requires risk managers to apply the power of logic to make better decisions. However, according to Borge (2001), the task of explicitly assigning numbers to preferences is difficult and time consuming. Therefore, it is often neglected in actual risk management applications. Using RP means such neglect is less likely.

According to Hammond et al. (1998), before decision makers can make trade-offs, they need to have a clear picture of all the alternatives and the consequences of the alternatives to the problem objective. RP uses hierarchies to display the decision goal, alternatives and criteria to evaluate the alternatives. Therefore, the risk managers can see the trade-offs they have to make to achieve the decision goal. Chapter 5 discusses the RP decision making framework. The discussion includes how RP uses a hierarchy to display alternatives and criteria to evaluate the alternatives. Chapter 6 demonstrates RP application to risk management problems. The application shows how RP displayed risks and sub-risks, and how risk managers make trade-offs to prioritise the risks and sub-risks.

Mental energy is required to make careful and deliberate decisions. According to Tierney (2011), as the number of decisions increases the mental difficulty increases exponentially. As a result, people start to act impulsively instead of carefully thinking through all possibilities. Alternatively, decisions are avoided, which creates more problems in the long term. Studies have shown that trade-off conflicts increase as the attributes of the alternatives become more dissimilar (Chatterjee and Heath, 1996, Wang et al., 2010). Firms face many risks that have different characteristics and potential outcomes, and they can involve immense trade-offs. Hence, risk trade-offs are often difficult to make unless the process is carefully structured to promote rigour and consistency. RP provides a rigorous and consistent structure to make trade-offs, manage and, as far as possible, reduce the cognitive burden and confusion when confronted with comparing a large number of risks. The technique assists risk managers to focus their mental energy on relatively simple steps, which are the most important part of decision making.

The following explains RP risk trade-off technique. RP requires that the risks to be compared have the same order of attributes or characteristics. Therefore, risk managers' perceptions of the elements are the same. For example, changes in regulation, changes in market preference, business planning failure and competitors' activities are grouped as strategic risk. Conversely, changes in interest rate, equity price and real estate price, foreign exchange rate, and financial derivatives prices are grouped as market risk. The RP trade-off technique requires risk managers to compare the risks within groups to determine which risk is more important. This method enables risk managers to easily and meaningfully compare the risks, focus their thoughts on the specific task and reduce the cognitive burden of comparing a large number of risks with different attributes or characteristics.

According to the risk managers participating in an RP evaluation session described in Chapter 7, clustering the risks into similar attributes or characteristics provides systematic organisation of the large number of risks. The risk managers are members of the Malaysian Association of Risk and Insurance Management (MARIM). They are responsible to manage risks in their organisation. An evaluation session was conducted with the risk managers to obtain their feedbacks on the practical usability of RP for risk management. Chapter 7 discusses in detail the RP evaluation session and reports the risk managers feedbacks on RP. From the evaluation session, it was discovered one of the main concerns in risk management is how to organise and rank a large number of risks. One of the risk managers stated his organisation identifies 150 risks and face difficulties to rank the risks. RP has shown to be useful as a tool to organise a large number of risks systematically. Organising the risks into similar attribute assists the risk managers to focus their thoughts and judgement on a similar type of risks. Therefore, making risk trade-offs easier. Detail discussion on how RP organises a large number of risk and the trade-off technique is given in Chapter 6. According to the risk managers, they make risk trade-offs all the time to determine which risk is more or less important. However, making trade-offs using pairwise comparison and measuring the magnitude of importance is new to them. The RP trade-off technique assists them to make logical, considered and thoughtful risks trade-off. They have to confront the ambiguity of every aspect of the risk prioritisation issue at the disaggregate level to ensure they are making judgements on the importance of risks that reflect their knowledge and experience. For example, they need to understand the risks they are comparing, the purpose of ranking the risks and the reason a risk is grouped into a particular category. The risk managers feedbacks on RP risk trade-off technique shows RP enables risk managers to organise risks systematically and replaces risk managers fuzzy intuition on the importance of the risks with explicit pairwise judgement.

2.1.2 RP as a Tool to Prioritise Risks

RP is a technique for prioritising risks. To prioritise risks, risk managers judge the dominance and intensity using pairwise comparison. These judgements, which can be different for different managers, are set out in a matrix where each entry reflects

Table 2.1: Decision Matrix and Priority Weight of Market Risks

Market Risks	Interest rate	Equity price	Real estate	Foreign exchange	Financial derivatives	Priority weight
Interest rate	1	3	5	7	9	0.53
Equity price	1/3	1	5	5	1	0.21
Real estate	1/5	1/5	1	1/5	1/7	0.03
Foreign exchange	1/7	1/5	5	1	1/3	0.07
Fin.derivatives	1/9	1	7	3	1	0.16
CR=0.18						1.00

the intensity of each risk compared to the other risks. The matrix reflects the dual aspects of determining the importance of risks: dominance and intensity. Table 2.1 displays an example of a decision matrix for prioritising market risk, which is the risk of losses in trading activities arising from movements in market prices. Risks on the left of the table are compared against the same risks displayed in the top row. The interpretation of the first row of the matrix in Table 2.1 is as follows. Interest rate risk is moderately more important compared to equity price risk, strongly more important compared to real estate risk, very strongly more important compared to foreign exchange risk and extremely more important compared to financial derivative risk. The other rows of the matrix are similarly interpreted. The numbers 3, 5, 7 and 9 correspond to the verbal judgements of moderately more important, strongly more important, very strongly more important and extremely more important. Reciprocal values are automatically entered in the transposed position of the matrix. For example, the relative importance of equity price risk to interest rate risk is the inverse, 1/3. The diagonal is 1, representing neutrality between the same risks. The matrix approach enables priority weight calculation using a simple method that is similar to that used in AHP. RP uses a simple linear algebra technique and matrix multiplication to calculate priority weights. Chapter 5 explains and illustrates the calculation in detail.

Duckert (2011) stated that subjective judgements are often inconsistent, and a risk manager may have different ratings on the same risk. RP provides a measure of decision consistency using a consistency ratio (CR). The CR is calculated from the decision matrix. It functions as a monitoring mechanism to ensure that risk managers are making careful, consistent and logical trade-offs instead of randomly assigning preferences and intensities. Chapter 5 explains and illustrates the CR calculation in detail and discusses ways to check decision consistency.

Common practice in risk management is to use subjective judgement to determine the likelihood and magnitude of a risk. The likelihood-magnitude approach gives an ambiguous risk ranking. The likelihood and magnitude are determined using a scale of 1-9. For likelihood, 1 means that there is no chance of the risk occurring, and 9 means that the risk will definitely occur. For magnitude, 1 means very low magnitude and 5 means very high magnitude. Chapter 3 provides a detailed discussion of prioritising risks using the likelihood-magnitude approach. The weight of the risks is calculated by multiplying the likelihood and the magnitude. The output of the calculation is a risk score that represents the rank of the risks. For example, a risk with likelihood 1 and magnitude 9 has a score of 9. However, a risk with likelihood 9 and magnitude 1 will also have a score of 9. The risks have the same scores, even though their level of importance is different. A risk that is least likely to occur but that has the highest magnitude (e.g., a major disruption of an information technology system) should have a larger score than a frequently occurring risk with the lowest magnitude (e.g., shoplifting). RP eliminates the ambiguity in determining the importance of risks. Similar to the likelihood-magnitude approach, RP uses subjective judgements to rank risks. However, it quantifies risk managers' subjective judgements to produce objective decisions. The priority weight is the order of importance of the risks. As shown in 2.1, interest rate is the most important risk for the market risk category, followed by equity price risk, financial derivative risk, real estate price risk and foreign exchange risk. The priority weight of interest rate risk is 0.53 and equity risk is 0.21. Therefore, interest rate risk is 2.5 times more important compared to equity risk. Priority weight indicates how much more important a risk is relative to other risks.

Studies have shown that people are poor at making probability judgements (Gigerenzer, 2014, Kahneman, 2011, Tversky and Kahneman, 1974, Yamagishi, 1997). RP enables risk managers to evaluate risks without the cognitive burden of estimating probability or likelihood. Subjective judgements made in the decision matrix combine risk managers' logical thinking with feelings developed from informed experience. According to Saaty (1987b), the contributions or influences of elements to a problem's solution are not always probabilistic. Instead, they are better described in terms of priorities.Hubbard (2007) stated that an important decision often requires better knowledge of the alleged intangible. However, in believing something to be immeasurable, attempts are often not even considered to measure it. As a result, decisions are less informed, the chance of error increases, resources are misallocated, good ideas are rejected and bad ideas are accepted, money is wasted, and in some cases life and health are put in jeopardy. As stated by Vadiveloo (2012), qualitative risks are just as important as risks that can be quantified. The qualitative risks should be prioritised and mitigated, and should not be ignored. The risks that organisations should focused should not be based on whether they can be quantified or not, but how important are the risks to the survival of the organisations.

As discussed in Chapter 7, according to the risk managers participating in the RP evaluation session, RP can be used as a decision making tool for risk management problems with limited or no data, and for problems with non-measurable factors such as customers satisfaction or the effect of changes in regulation to the overall risks of a firm. Specifically the risk managers stated RP is useful for risk management problems with no data and requiring subjective judgement such as operational risks. According to the risk managers, they face difficulties to estimate the likelihood of the risks to occur because the risks have no data as it have never occurred in the past. Consequently, they face difficulties to estimate the magnitude of risks that have yet to materialise. RP does not require the risk managers to estimate the probability of the risks to occur. RP uses the risk managers' value judgement to determine the importance of the risks. Further, RP enables the risk managers to determine the importance of the risks without requiring the risks to be proxy by a unified scale such as dollars or measurable value such as percentage of market loss. RP can be used to evaluate tangible and intangible factors. Therefore, the risk managers have no restriction to include any relevant factors to a problem to achieve the decision goal. RP enables the risk manager to measure the immeasurable factors relevant to a problem and the calibration is achieved using mathematically justified technique.

The risk managers participating in the RP evaluation session also stated they need a technique to quantify subjective judgements. The risk managers are currently using the risk matrix technique to rank risks. Their organisations use The AS/NZS ISO31000: 2009 Risk Management Standard for the risk management process. The standard uses the risk matrix technique, which is a likelihood-magnitude approach to analyse and rank risks. However, according to the risk managers, it is unclear how a risk assessor makes judgement on the absolute importance of the risks. They also face difficulties explaining to the top management and stakeholders how the risks are judged as less or more important. One of the risk managers question the origin of the technique, stating *"it is as if the risk matrix appears out of nowhere. I could not find how it starts and who started to use it"*. RP produces quantitative ranking from risk managers subjective judgements. According to the risk managers, RP risk prioritisation technique enables them to explain clearly the meaning of the risk ranking and how the rankings are derived to the top management and stakeholders. A quantitative risk ranking is easier to communicate and explain to top management and stakeholders compared to subjective risk ranking such as low, medium and high. Further, RP uses a valid mathematical analysis to derive the weight of the risks, which enhances the risk managers confidence on the analysis of the subjective judgement to produce the risk ranking. The mathematical analysis appeals to both risk managers from quantitative background and non-quantitative background. For the risk managers with the quantitative background, RP provides a mathematical analysis that is familiar to them, the linear algebra and matrix multiplication. For risk managers with non-quantitative background, RP provides a sophisticated way to analyse subjective judgements compared to multiplying the likelihood and magnitude of the risks.

To ensure the consistency of the subjective judgements, RP calculates the CR of the pairwise comparison judgements. The CR is an interesting and useful aspect of RP to the risk managers. During the evaluation session, the risk managers wanted to know more on how CR measure judgement consistency as they have never encounters a technique that could measure the consistency of subjective judgements. The CR is useful as a monitoring mechanism. According to the risk managers, the CR helps them to identify inconsistent judgement quickly, which is difficult to do with the risk matrix technique. The CR also enables them to reason why they need a risk assessor to review the risk ranking. As stated by one of the risk manager, *I usually depend on the person in charge (risk owner) to give accurate risk judgement and hope he is making an accurate judgement. With CR, I can check his judgement and justify why I need them to review the judgement'"*.

2.1.3 RP is a Practical and Effective Tool to Structure Complex Risk Management Problems

The main purpose of RP is to disentangle the complexities of risk management problems into manageable parts. RP structures complex risk management problems using a hierarchy tree. The structure and function of the hierarchy provides an effective and practical way to think about, organise and break down risk management problems. The hierarchy enables factors that are relevant to the problem to be organised in gradual, incremental and practical steps, from the more general in the upper level to the particulars in the lower levels. The function of the hierarchy is to enable information to be distributed down the system. Factors in each level are influenced or controlled by factors in the level immediately above. The crucial contribution of hierarchy to risk management is that it forces risk managers to confront and ultimately capture ambiguity and ignorance. It forces them to focus their judgements and intuitions on all parts of the risk management problem to develop an understanding of the relative effects of one factor on another, factors and alternatives, and alternatives and the decision goal.

According to Rebonato (2007), the art of modelling boils down to finding the simplest description of a complex phenomenon; however, it still captures the features that decision makers are interested in. Grunig and Kuhn (2005) stated that complex problems are ill structured and design problems. A design problem is solved by breaking down the problem into parallel and consecutive sub-problems. In contrast, simple problems are well structured and choice problems. For choice problems, the options are known and decision makers need to decide on the best option. Risk management problems are ill structured, with multiple conflicting factors influencing solutions to the problems. The problems need to be simplified and structured to be solved. RP structures risk management problems by deconstructing the problem into manageable sub-problems. Therefore, risk managers can focus their thoughts on making decisions about the sub-problems. RP then synthesises these decisions to obtain decisions for the whole problem. It gives clear and easy-to-follow directions and guidance on structuring a problem until arriving at the overall decision. The hierarchy provides a framework to structure the problems in a simple way while still capturing the complexity of the problem.

Structuring is essential in RP. As discussed in Chapter 7, according to the risk managers participating in the RP evaluation session, a hierarchy provides a holistic view of the problem. Structuring a problem in a hierarchy enables them to see all factors relevant to the problem and identify missing information quickly. The process to structure a problem in hierarchy assists them to structure their thoughts and understanding of the problem, and forces them to sort out the important factors of the problem. Analysis on the risk managers feedbacks, which is discussed in detail in Chapter 8, finds structuring is useful for risk management decision making as the followings:

- It provides a systematic way of disentangling complex problems.

- It reduces uncertainty. Uncertainty relates to the relevance and reliability of the information about the problem, and risk managers knowledge and understanding of the problem. To structure a problem in a hierarchy requires an in-depth understanding of the problem. Risk managers need to understand the interaction between factors of the problem, how the factors influence solutions to the problem and provide rationale for inclusion of the factors. Structuring is a process to analyse and understand a problem, which is essential to reduce judgement uncertainty.

- It provides a holistic view of problems by showing the relationships between decision goals, factors and alternatives. Thus, risk managers, decision makers and stakeholders can immediately see the trade-offs they have to make to achieve their decision goal.

- It enables risk managers to assess whether they are comparing issues of the same order of magnitude or similar attributes. Comparing issues or elements of similar attributes or magnitude reduces the cognitive burden to make large number of trade-offs and improves decision consistency.

- It provides a visualisation of risks and an effective tool for risk-related communication. Instead of the static representation of risk management problems, the hierarchy acts as a catalyst for risk communication and decision making.

- The hierarchy displays the problem in concrete visual terms, which enables risk managers, decision makers, stakeholders and people who are not directly involved in the decision-making process to address, discuss and debate the uncertainty and validity of each aspect of the problem.

2.1.4 RP is a Simple and Easy to Use Tool for Firm-Wide Risk Management Decision Making

RP is a decision-making tool that is relatively simple, logical and easy to understand, communicate and use. Being a simple decision-making tool, RP is useful for analysing and understanding complex risk management problems across organisations, even where different parts of the organisation have diverse understandings of 'risk', and where risk is quantified or thought about using substantively different methodologies. RP imposes unity in pooling risk problems. Normally, each problem has its own specialised model, technique and terminology. For example, risk managers use quantitative analysis to model financial risk and subjective judgement to model operational risks. RP reconciles the segmented view of a problem and provides a standardised framework for reconciling risk management problems. The way the problem is thought of and structured is standardised for financial, operational and market risks, and from operation- to management- and strategic-level decisions. RP provides a standard approach to facilitating data collection, analysis and synthesis, and it produces results to be used in decision making.

The RP framework provides direct and clear guidance to model complex risk management problems, starting from collecting relevant information of the problem, structuring the information in the hierarchy, and calculating priority weight and CR. All the steps are critical to make RP practical and effective. The step provides a clear and transparent decision making process. Although RP imposed certain rules to be followed in the decision making process, it allows flexibility and encourage creativity in structuring the problems.

According to the risk managers participating in the RP evaluation session as described previously, RP is simple, easy to understand and use. Its decision making process is logical and clear with straightforward instructions. A simple, easy to understand and use, logical, clear and straightforward decision-making tool enable RP to be used for risk management problems across the organisation. Analysis on the risk managers feedbacks as discussed in Chapter 8 finds RP is useful as a firm-wide risk management decision making tool as the followings:

- It provides a clear and understandable decision-making process to the diverse participants of problems, so that everybody has the same understanding of the problems, conflicting issues and their roles in the decision-making process. The tool enables busy people with diverse backgrounds and experience to communicate effectively with each other and share their values and ideas relating to the problem. Wide-ranging participation improves the quality, diversity and understanding of information and opinions that are critical to the decisions.

- In risk management problems, there is a separation between risk assessors and decision makers. Risk assessments made by risk assessors is an input for decision makers to make decisions, which affect stakeholders. Therefore, it is important that the decision-making process is clear and understandable by the decision makers and stakeholders. As inputs to their decisions, decision makers need to know the steps involved, the justifications used in the evaluation of the alternatives and the role of participants in the problem. Stakeholders need to know how the decision was arrived at. In uncertain environments and high-stake problems, stakeholders are not satisfied with knowing the results of decisions. A lack of transparency generates doubt, leading to a loss of trust and faith in an organisation, and it decreases the likelihood that the decision will be accepted and implemented. A simple decision-making process can be communicated easily, thus enabling stakeholders to understand how the decision was reached.

- It provides a standardised systematic approach to the decision-making component of the risk management process. Risk management is a process that identifies, assesses and ranks risks. Each phase has its own decision-making technique. For example, risk managers use scenario analysis to explore and identify risk exposure, the risk matrix to rank the risks, and the cost-benefit analysis to determine the risk mitigation action. RP provides a standardised framework for each phase of the risk management process. It can be used to identify and categorise risks, prioritise risks, and choose the best method to mitigate the risks. RP formalises decision making for the risk management process by providing a systematic process with identifiable steps.

2.1.5 RP is a Tool for Group Decision Making

According to Sunstein and Hastie (2015), group decision making fails because of: (i) groups not only fail to correct the errors of their group members, they amplify the errors as well; (ii) group members follows the decisions of the person who speak or act first; (iii) groups tend to become more extreme. For example, they can suffer from excessive optimism or willing to take more risks; and (iv) groups focus on information that everybody already knew and usually fail to obtain critical information known by a few members of the group.

RP is a useful tool for supporting, if not enforcing, group decision making. It supports the value of diversity of knowledge and opinions in a group, and it encourages group members to discuss and debate the problem. RP encourages group members to exercise critical thinking to explore and identify critical information relevant to a problem. As discussed in Chapter 5, the first step in RP decision making process is to answer the following questions: What is known? What is unknown? What else needs to be known? The purpose is to ensure all relevant and critical information about the problem is identified and discussed among group members. The RP systematic decision-making framework provides a structured group meeting instead of haphazardly jumping from one issue to another or repeatedly discussing the same issue. It forces the group to define the decision goal, explore the alternatives, identify the criteria to evaluate the alternatives, and identify the risk assessors and decision makers. RP requires the decision goal, alternatives and criteria to be structured in a hierarchy. The hierarchy makes the problem transparent and easy to understand. Risk managers can detect quickly and easily overlook information, unclear linkage between the alternatives and the decision goal, or imprecise criteria use to evaluate the alternatives. After a problem is well structured and members of the group agree on the structure and the decision goal, the group can start the judgement phase, followed by the decision-making phase. Further, RP enables group members to identify judgement errors of the group members. Its systematic decision making process provides a clear and transparent decision making steps. Therefore, group members can identify and challenge the flawed thinking of a group member or debate the assumptions used in the judgement.

In an ideal situation, group members work together to structure the problem and evaluate the alternatives. In reality, not all decision-making groups are ideal and dynamic. Some group members may be unwilling to state their opinions openly, while others may be more assertive and could influence other group members. Certain superior members are unwilling to equate their judgements with the subordinate members. As stated by Sunstein and Hastie (2015), group members have the tendency to follow the person who speaks their opinion first, particularly if the person is the leader of the group. According to Kahneman (2011), the proper way to elicit information from a group is not by starting a public discussion, but by confidentially collecting each person's judgement. This procedure makes better use of the knowledge available to members of the group than the common practice of open discussion. RP permits each member to give his or her confidential judgement on the alternatives. The confidential collection of individual judgements eliminates peer pressure, the tendency to conform to the majority and authority pressure, and the tendency to comply with the superior. The individual judgements are then aggregated to obtain the overall judgement of the group. This presents the true representation of the group's preferences, as it is not influenced by judgement biases. Chapter 8 discusses in detail how RP can confidentially collect and aggregate the individual judgements to arrive at the overall group judgement. In situations the superior members are unwilling to compromise their judgements, RP rank the members based on their superiority and influence on the implementation of the decision. The final decision is based on the person with the largest weight of superiority and influence. Therefore, eliminate delay in decision implementation. Chapter 8 explains how RP ranked group members based on superiority. Therefore, the group can based their final decision based on the person with the highest rank

The risk managers participating in the RP evaluation session requested RP for group decision making. According to the risk managers, they always conduct group discussion and decision making in risk management. One of the challenges of group decision making is to produce an overall group judgement that can accurately represent the decision of each member of the group. The current risk prioritisation technique, the risk matrix, could not aggregate group decision. According to them, a tool that can aggregate group decision-making will be useful for risk management. Another challenge faced by the risk managers is handling a superior person who does not agree with the group decision. The disagreement frequently occurs on risk prioritisation problem where the superior person disagrees with the ranking of risks produced by the group members. The disagreement causes delay in planning strategic risk mitigation action as the problem is repeatedly discussed without any decision made.

2.1.6 RP Uses Both Intuition and Analytic to Make Decisions

Hillson and Webster (2005) stated that risk management requires human judgement. Human factors represent an important aspect of the risk management process, from risk identification and assessment to response. Therefore, a framework for a structured approach to risk management should take into consideration the human factors in managing risks. Although automated tools are useful in handling large amounts of data and in performing complex calculations rapidly, humans undertake the entire risk management process. They bring to the process their intuitions, insights, previous experiences and skills, thereby creating a rich source of information of the risks faced by the business. Ignoring human factors would impoverish information and limit risk management to only measurable factors.

Conversely, Hubbard (2009) argued the validity of using human judgement in risk management. According to Hubbard (2009), most risk assessment methods rely on subjective input by human experts, and subjective judgements under uncertainty and risks are prone to judgement biases and inconsistency.Hubbard (2009) stated that risk managers should use quantitative risk modelling using probabilities to perform risk analysis. Quantitative modelling provides an unambiguous description of uncertainty, therefore improving risk managers' unaided intuitions.

Both Hillson and Webster (2005), and Hubbard (2009) discussed the effect of judgement biases on decision making under uncertainty and risk, and they acknowledged the importance of controlling the effect of biases on decisions. Their discussions of decision-making behaviour under uncertainties were based on studies by Amos Tversky and Daniel Kahnemann. The behavioural studies identified a variety of judgement biases, such as availability, anchoring and representativeness. While Hillson and Webster (2005) proposed incorporating human judgement in risk management and controlling the judgement biases using emotional literacy, Hubbard (2009) proposed eliminating biases by using quantitative modelling.

RP uses both intuition and analytic to make decisions. It defines intuition as knowledge and experience, and analytic as the mathematics or quantitative analysis to derive the result. Intuition and analytic are sequential steps in RP. The first part of RP requires risk managers to use their intuition to structure a problem into a hierarchy. They then use their intuition to assess the alternatives of the problem by making trade-offs between the alternatives. The second part of RP is the quantitative analysis of the judgements using linear algebra and matrix multiplication. The output of the analysis is the weights of the alternatives. The weights represent the order of relative importance of the alternatives,

The first part of RP brings human judgement to the centre stage of decision-making process. The RP structure and representation is geared for risk managers to use their intuitions, emotions, experiences and skills into the decision. RP amplifies risk managers cognitive ability to make judgement while minimising the cognitive biases. Chapter 3 discusses the cognitive or judgement biases. The chapter discusses three types of decision-making challenges face by risk managers: (i) judgement biases from heuristic decision-making; (ii) judgement biases from framing of the problems; and (iii) judgement biases from interaction of the human thinking systems. Heuristic decision-making uses experience, knowledge and skills to make decision. Studies have shown heuristic judgements are prone to judgement biases. Problem framing refers to how information relevant to a problem is presented to the decision makers. Studies have shown different problem framing impaired rational judgement. Human thinking systems refers to how the interaction between two mode of thinking system, the fast mode (System 1) and the slow mode (System 2) causes judgement biases. Chapter 9 discussed in detail how the RP framework and structure can mitigate the judgement biases.

RP exploits both thinking systems. RP exploits the quick thinking of System 1 to recognise a problem, making associations among factors of the problem and creating a flow or pattern of the problem information. RP uses the slow thinking of System 2 to check the logic of the associations, evaluate the flow of the information and the validity of the factors of the problem. RP forces risk managers to use the slow thinking mode in making risk trade-off. The pairwise comparison requires risk managers to make deliberate and careful judgement, which is the characteristic of System 2 thinking. Discussed in detail in Chapter 9, the RP decision-making framework proactively addresses the judgement biases. The RP framework and structure is design to mitigate the biases and foster logical and rational thinking. For example, RP requires factors and alternatives of a problem to be structured and displayed in a hierarchy. Studies have shown that displaying all the alternatives of a problem reduces the decision-making biases of overestimating the importance of a particular alternative. The second part of RP uses quantitative analysis to produce an objective and meaningful ranking of the alternatives. The decision matrix and linear algebra calculations fully captured the trade-off and relative importance of the alternatives. Direct ranking of the alternatives (e.g 1, 2 and 3, or low, medium and high) does not represent the trade-off and relative importance of an alternative over another. The priority weight reflects the relative importance and provides meaningful interpretation of the relative importance of the alternatives.

2.2 Conclusion

The results show RP is a useful and practical decision making tool for risk management. It improves risk managers' ability to make decisions by providing a simple, practical and easy-to-use and understand decision-making framework. RP simplifies and structures the most difficult part of decision making: making trade-offs. It enables risk managers to explicitly assign their judgement to the alternatives and handle a large number of trade-off decisions.

RP makes risk priorities clearer. It produces an objective ranking of the risks and eliminates ambiguity in interpreting the importance of the risks.

RP provides a standardised decision-making framework for defining, identifying and quantifying all types of risks faced by a firm. It enables all risks to be compared fairly to each other, to be weighted against each other and to be aggregated into a consolidated view of the firm's entire risk exposure.

RP prompts people to function better as a team. The framework enables clear communication between people with different risk attitudes in a decision-making group and across the organisation.

RP is not a formula or model that finds the right answer for risk managers. It is not a branch of artificial intelligence or an expert system that makes decisions for risk managers. Rather, it is a process for helping risk managers to find the best answer. RP helps risk managers to be as smart as possible in every decision they have to make. It enables them to disentangle the complexity and confront the ambiguity of risk management problems. RP ensures that risk managers have all of the critical information of the problems, and that they are systematic about decision making and communicate with everyone involved with the problems. As a result, risk managers are convinced that the decisions they make are reliable, and they can convince others of the reliability of their decisions. Therefore, increases the likelihood the decision is accepted and implemented. RP enables risk managers to demonstrate to the decision makers and stakeholders they have consider all relevant factors to the problem, provide justification why certain factors are accepted and others are rejected, and explain the rationale of the ranking of the alternatives.

3

Risk Management, Risk Management Decision Making and Decision Theory

3.1 Introduction to Chapter 3

The purpose of this chapter is to explain the context of this thesis. The context of this thesis is decision making, risk management and connecting the two. This thesis argues that risk management and risk management decision making are two different processes requiring different tools. Decision making in risk management needs a decision-making tool. This chapter discusses the differences between risk management and risk management decision making, the challenges involved in making decisions in risk management and the limitations of the current risk management decision-making tools.

The decision-making tool developed in this thesis exploits the AHP, which is a tool under the prescriptive decision theory. To justify why and how this thesis chose the AHP, this chapter discusses the reasons why risk management should look into decision theory to find a suitable tool.

The goals of this chapter are to:

- differentiate risk management and risk management decision making. (Sections 3.2 and 3.3)
- justify why risk management needs a decision-making tool. (Sections 3.5,3.6, and 3.6.1)
- justify risk management needs decision theory and AHP is the suitable decision making tool for risk management. (Sections 3.7 and 3.8)

3.2 Risk Management

Risk management is a process to identify, assess and plan actions to manage risks. The aim is to determine the significant risks that prevent firms from achieving business objectives or that disrupt their core business, and to plan the best action to mitigate the risks. Risk management is a five-step process (Chapman, 2006, Moeller, 2007):

1. The specific business, project or process requiring risk management is identified and analysed.
2. Risk identification is a process that is used to identify the risks that are relevant to the business, project or process.
3. Risk assessment involves evaluating the risks using either quantitative or qualitative analysis to determine significant risks.
4. Risk response involves planning risk treatment or control to mitigate the significant risks.
5. Risk monitoring involves monitoring the performance of the risk responses. The monitoring activity includes adding new risks and deleting risks that never materialised, reassessing current risks, and adjusting the likelihood and effect of the

risks.

Each step is detailed below.

1. Analyse the Business

The purpose of business analysis is to identify and understand the specific business, project or process requiring risk management. Firms need to identify the focus of risk management before proceeding with risk identification. The information sought in business analysis is to

- identify the objective of the business, project or business process
- understand the process required to conduct the business, implement the project or understand the flow of the business process
- check if internal controls are already in place
- identify the level of risk accepted for the business, project or process
- check if a list of risks has been developed.
- describe the organisational structure of the firm. The organisational chart should identify lines of reporting and control, which in turn identify responsibility, power and information flow.

Business analysis involves business or project representatives who are relevant to the project. The representatives should be experts in the field and aware of company risk exposure.

2. Risk Identification

Risk identification is the process of identifying the risks that prevent firms from achieving their business objectives. Risk identification identifies, lists and categorises risks, and it records them in a risk register. First, it identifies known risks; that is, risks that a firm has been exposed to. This risk information is kept in a register or log book. Second, it identifies current risks; that is, risks that a firm is currently facing. These risks are known, but need to be correctly identified, assessed and managed. Third, it identifies unknown risks; that is, risks that a firm might be exposed to in the future. The firm currently has no information about these risks.

Chapman (2006) proposed the following risk identification techniques: risk check list, risk prompt list, Political Economic Social and Technological (PEST), Strengths Weaknesses Opportunities and Threats (SWOT), risk database, process map, risk breakdown structure (RBS) and risk questionnaire. Barton et al. (2002) proposed risk identification techniques such as scenario analysis, business unit self-assessment and brainstorming. Wittenberg and Tett (2009) conducted a survey on risk management tools used by organisations. Respondents list tools to identify and interpret the potential effects of risks. The survey documented the following tools: internal experts, internally generated indicators, scenario analysis, SWOT analysis, key risk indicators, individual or group self-assessments, externally generated indicators, external experts, tabletop or simulation exercises, risk mapping and decision tree analysis, and statistical analysis or probabilistic modelling. Shenkir and Walker (2007) discussed tools and techniques facilitating risk management implementation. Techniques used for risk identification include: brainstorming, event inventories and loss event data, interviews and self-assessments, facilitated workshops, SWOT analysis, risk questionnaires and risk surveys, and scenarios analysis. proposed the following techniques for risk identification: interviews, online surveys, paper surveys, document reviews, facilitated workshops and targeted reviews. CAS (2003) proposed the following techniques for risk identification: surveys, internal workshops, brainstorming and internal auditing.

Firms usually use a combination of techniques to identify risks. For example, a firm may use SWOT analysis and brainstorming. A technique or combination of techniques depends on circumstances such as cost, time and geographical and personnel constraints. Risk managers or risk management groups are responsible for choosing a suitable technique for the firm.

3. Risk Assessment

Risk assessment is a process for evaluating and ranking the likelihood of risks occurring and the magnitude if they occur. The purpose is to rank the risks. This enables firms to focus on managing the significant risks. Risk ranking is also used to inform decisions on the appropriate risk response. Firms use the output of risk assessments to plan their risk responses or strategic risk management actions. Therefore, the risk assessment technique needs to produce an accurate risk ranking.

The following questions are some of the strategic business questions that require a risk assessment:

- Which risk is more important?
- How should risks be prioritised from a set of significant risks?
- How should a preferred risk mitigation technique be selected from a set of techniques?
- How should risk management activity be prioritised?
- How should one judge whether it is more economical to retain or transfer a risk to a third party?

Tonello (2007) provided four risk assessment techniques: expert judgement, benchmarking, non-probabilistic and probabilistic. Expert judgement is a subjective assessment by experts on the level of risks using a nominal, ordinal, interval or ratio measure. Benchmarking is assessing the likelihood and magnitude of specific risks. The purpose is to choose the best method to reduce them. Non-probabilistic techniques use sensitivity analysis, scenario analysis or stress testing to quantify the magnitude of the potential risks. The probabilistic technique measures the likelihood and magnitude of risks using probability distributions. Techniques employed in probabilistic risk assessments are at-risk models such as value at risk, earnings at risk, cash flow at risk, assessment of loss events and back testing. The study also ranked the techniques used to measure the likelihood and magnitude of risks. Based on a survey conducted by the Conference Board of 271 companies in North America and Europe, the study reported the following ranking of techniques: key risk indicators, individual self-assessment, scenario analysis, risk mapping using impact and frequency, facilitated group self-assessment, economic value added, value at risk, industry benchmark or loss experience, and statistical analysis or probability modelling. Chapman (2006) documented the following tools for risk assessments: probability distribution and probability impact matrix, probability trees, expected monetary value, utility theory, Markov Chain and investment appraisal. Shortreed (2010) documented the following tools: estimates of the likelihood of events, estimates of consequences of events, estimates of both likelihood and consequences of events based on risk criteria, and root cause analysis of risks. CAS (2003) proposed the following methods for risk assessment: sensitivity analysis, scenario analysis and simulation.

Risk assessment techniques can be categorised into quantitative and qualitative. Quantitative techniques include probabilistic distribution (value at risk (VaR), cash flow at risk) and loss experience. Qualitative techniques include expert judgement and risk mapping using impact and frequency or industry benchmark. Risk managers need to decide the appropriate risk assessment technique and approach. The risk assessment approach should depend on the firm's culture (Hopkin, 2010). For example, for a firm that rarely holds meetings and workshops, a workshop or group risk assessment may not be effective. If the firm's business culture still relies on reports and written papers, the chosen technique should be conducted using reports and papers. In contrast, high-technology firms could use software to facilitate risk assessment.

4. Risk Response

Risk response involves planning appropriate actions to manage important risks. How a firm responds to risks depends on its risk appetite and risk tolerance. The risk response options are to avoid, retain, reduce or transfer the risk. Risk avoidance involves eliminating the risk from the business. The risk is retained if no other risk mitigation alternatives exist, or if it is more economical compared to other options. Risk reduction involves reducing the frequency or severity of the risk. An example of a risk reduction technique is diversification. Risk transfer involves transferring the risk to an economically capable third party with a premium, such as an insurance company.

Chapman (2006) proposed the following activities for transforming a list of important risks into a concrete plan of risk response action.

- Conduct risk research to obtain sufficient information for informed decision making on risk responses.
- Develop alternative risk responses to permit the selection of the most advantageous response.
- Develop risk responses for each important risk.
- Assess the possible costs of the responses against the effect of the risk.
- Determine risk appetite.
- Identify the risk owner; that is, the individual or team that has ownership of the risk.
- Identify the risk manager; that is, the individual or group responsible for ensuring that the chosen response is implemented.
- Identify that risk actionee; that is, the individual or group responsible for implementing the response.
- Decide when the response needs to be implemented.
- Consider the emergence of secondary risks arising from the response.
- Monitor the effectiveness of the response and establish early warning indicator to measure the success or failure of the response.

5. Risk Monitor

Risk monitoring is the final risk management step. It involves the constant monitoring of performance and suitability of the risk response. The risk environment constantly evolves; new risks emerge and some risks never materialise. Risk responses change as new methods for managing risks are developed or old methods are improved. The purpose of risk monitoring is to continuously update and improve risk management.

Effective risk monitoring depends on a regularly updated risk register and risk assessment. The risk register should be updated to include newly identified risks and expired risks. Risk assessments provide updates on changes to risk rankings. The changes could result from changes in the likelihood and magnitude of the risk, the cost of implementing the risk response, or secondary risks arising from the risk response.

3.2.1 Different Risk Management Processes

The risk management literature has documented a variety of risk management processes. The ISO31000:2009 Risk Management-Principle and Guidelines grouped risk identification, risk analysis and risk evaluation under risk assessment (Shortreed, 2010). The step after risk assessment is risk treatment, which involves actions for reducing the likelihood of negative events and increasing the likelihood of positive events. The final step is risk monitoring and review, which involves observing risks and the effectiveness of risk treatments. The Institute of Risk - Risk Management Standard (IRM, 2002), grouped risk identification, description and estimation under risk assessment. Risk identification is a process for identifying exposure to uncertainty. Risk description describes the characteristics of the identified risk. Risk estimation assesses the risk based on the probability of occurrence and possible consequences. The estimation is quantitative, semi-quantitative or qualitative. The output of risk estimation is a risk profile and the ranking of risks based on probability and consequences. COSO (2004) defined risk identification as event identification. Event identification is the process of identifying the internal and external events that prevent organisations from achieving their business objectives. Event identification identifies both risks and opportunities. Risk assessment analyses risks based on their likelihood and effect.

Risk management is the process of managing the uncertainties faced by a firm. It provides guidelines for risk managers to assess, plan and implement responses to risks. The process requires risk managers to think analytically about all possible risks, evaluate the severity of the risks and determine ways to manage the risks. Different risk management processes have different definitions for the steps or processes. However, the main aim is to identify significant risks and implement actions to manage them. Risk management is concerned with decisions on the true evaluation of significant risks and setting up policies to handle the risks before they occur. Regardless of the different risk management processes, risk management is a tool for eliciting and making explicit the risk manager's understanding of the effect of the risk on the firm's business objectives.

3.3 Risk Management Decision Making

Making decision under conditions of uncertainties is an integral part of risk management. Rebonato (2007) stated that risk management is not about measuring risks or assessing probabilities; rather, it is about making decisions in situations of uncertainty. Risk managers have to face the difficult task of making far-reaching decisions in an uncertain environment. Borge (2001) stated that the power of risk management lies in risk managers' ability to make good decisions. Decision making is an important component of risk management. The following discussions present the challenges, questions and decisions that risk managers have to confront, answer and make for risk management.

Risk Management Problem Identification and Recognition

The first step in risk management is to determine the focus of managing the risk. Risk managers need to identify risk management problems and decide which problems to address first. It is their responsibility to identify the right problem and prioritise risk management activities to address the problem.

According to Yoe (2012), firms are often eager to solve the problem as soon as it arises, so they spend less time understanding, refining and communicating the problem. As a result, the firm treats the symptoms of the problem instead of the causes. Further, the firm does not realise that it is unclear about the problem, so it solves the wrong problem correctly. Yoe (2012) proposed the following steps for identifying the right problem:

- Problem recognition: Recognise that a problem exists in the business, project or business process.
- Problem acceptance: Risk managers need to communicate the problem to the relevant stakeholders to decide whether the problem needs to be addressed. Addressing a problem means being ready to allocate resources to the solutions. Risk

managers need to assess whether the firm has the capability to implement the solution. Problem acceptance is a decision-making issue. The problems compete for resources; therefore, risk managers need to set priorities. The problems can be prioritised based on, for example, mission and vision, business objectives, cost of a solution and timeframe for implementing the solution.

- Problem definition: Risk managers need to communicate and link the problem to its possible solutions. They can write a problem statement, which consists of a commonly understood description of the problem and justifications for why the problem requires risk management.

Risks Identification

Risk identification is the process of identifying risks. Effective and robust risk identification ensures that all relevant risks are identified. Risk identification challenges include (Charette, 1997):

- Risk owners are not aware that the risk exists.
- The techniques used to identify the risk are not effective, resulting in an unreliable list of risks.
- The individual conducting risk identification is inexperienced. As a result, there is a failure to elicit information from risk owners.
- The individual providing the risk information is not an expert or knowledgeable of the problem.

Poor-quality risk identification increases the possibility of overlooked risks. Risk managers are responsible for ensuring that a good-quality list of risks is produced from risk identification. They need to decide on the best technique or combination of techniques for obtaining a reliable and comprehensive list of risks.

The list of risks needs to be categorised. Risks are grouped based on certain attributes or criteria. For example, risks can be categorised into short-, medium- or long-term risks, or quantitative and non-quantitative risks. Hampton (2009) stated that one of the issues impeding risk management implementation is difficulties in determining the risk categories. Hampton (2009) proposed that risks categories should be structured based on accountability, responsibility and business processes. Risk categories should be based on the business model rather than the risk management standard or risk consulting companies, and they should depend on the firm's needs or problem situation.

The following list explains why firms categorise risks:

- Risk categories provide a structure for risk identification.
- Risk categories are used to identify the individual responsible for managing the risk.
- The categories assist risk managers or stakeholders to relate to the risk.
- The categories assist risk managers to plan risk response options.

Risk managers are responsible for developing risk categories and deciding the criteria to categorise the risks.

Risks Assessment

Risk assessment involves evaluating the risks to determine the significant risks. The output of risk assessment is the ranking of risks. A reliable risk assessment technique will produce a reliable risk ranking. According to Yoe (2012), risk assessments should have the following qualities:

- The assessment should answers the question asked by risk managers. For example, a risk manager may want to know the possibility of a potential competitor entering a market, or risks that could arise from outsourcing a business process or from merging with another company to broaden the market share.
- The risk assessment process should be unbiased and produce an objective result.
- The process should be transparent.
- The process should be made as simple as possible, but not simpler.

- The process should be practical, logical, comprehensive, concise, clear and consistent.

A firm conducts risk assessments in order to manage its risks effectively. However, little attention is given to the methodology used in framing and performing the ranking. Florig et al. (2002) stated that a good ranking method should have the following features:

- It should make use of the theory and empirical knowledge in behavioural science, decision theory and risk analysis.
- It should encourage the person doing the ranking to consider all relevant information systematically.
- It should assist the risk assessor in constructing a consistent ranking.
- It should ensure that the risk assessor understands the procedures and feels satisfied with the process and the result.
- It should be able to describe the level of agreement or the sources of disagreement among risk assessors.

Aven and Zio (2011), Flage et al. (2014) proposed the following guidelines for choosing or developing a practical risk assessment technique:

- The representation of knowledge as an input to risk assessment in support of decision making must be faithful and transparent.
- The tools or models should not add irrelevant information or ignore relevant information.
- For problems lacking data, information and knowledge need to be elicited and treated adequately. The information and knowledge need to be approved, and risk assessors' judgements or degree of beliefs should be clearly reflected in the risk assessment.
- Communicate the meaning and interpretation of the quantities computed in an understandable format to decision makers. The format must allow for meaningful comparisons and communication in the deliberation process.

- The tool or technique should consider separation between risk assessors and decision makers. In practice, risk assessors perform risk assessments. The output from the risk assessment becomes the input for decision makers. Therefore, risk assessors' knowledge used in the risk assessment influences the decisions made by the decision makers. The depth of risk assessors' knowledge determines the strength of their assessment. Therefore, the strength of the assessment needs to be transparent and acknowledged in the decision process. Poor knowledge should also be transparent and acknowledged.
- The tool or technique should include sensitivity analysis, which measures the sensitivity of the risk indices to changes in inputs used in the assessment.

Risk managers are responsible for developing or choosing a risk assessment technique or combination of techniques. They need to ensure that the technique produces a reliable output to be used by the decision makers.

Risk Response

The central issue in risk response is to address important risks with concrete risk response planning. Business is all about taking risks. The purpose of risk management is not to eliminate risks, but to control them within acceptable limits. The acceptable limit is determined by risk appetite and tolerance. Risk managers need to identify risk response options, choose an option and implement it. Conscious decisions need to be made when selecting the option from a set of options. The following questions need to be answered: How is the option selected? What are the criteria used to evaluate the options? Who makes the evaluation?

Risk Monitoring

Risk environments change over time. New information or new alternatives emerge, forcing firms to consider previous decisions. The purpose of risk monitoring is to review the effectiveness of the risk response and to monitor new risks. Risk managers need to consider the following questions and decide on the best actions (Shortreed, 2010):

- Has the risk changed in character because of trends?
- Are there any new risks evolving or emerging?
- Has the risk management context or environment change?
- Are the risk responses effective?
- What is the appropriate frequency of monitoring?
- Should monitoring be done by internal audit, third party or self-assessment?
- Based on actual outcomes, was the risk assessment accurate?
- How can risk monitoring be improved?

3.4 Risk Management Versus Risk Management Decision Making

Managing risk is a process of identifying, assessing and planning actions to manage risks. Risk management is a tool used to implement the process systematically, and to elicit and make explicit risk managers' understanding of the effect of risk on business objectives. Risk management decision making involves selecting the best alternatives or ranking the alternatives for a specific risk management goal. For example, identifying the risks faced by a firm is risk management, and choosing the best method to identify the risks with the aim of expediting the risk identification process is risk management decision making. Determining significant risks that affect core business is risk management. Ranking the significant risks based on: Is the risk transferable? Does the risk have long-term effects on the firm? Does the firm have the resources to manage the risk?, is risk management decision making.

This thesis makes a distinction between risk management and risk management decision making, as they are two different processes requiring different tools. Guidelines and techniques for implementing risk management are well developed, as discussed in 3.2. For example, tools used to identify risks include brainstorming, surveys and scenario analysis. The tools used to assess risks are risk matrix, decision tree and loss experience.

The discussion on risk management decision making in Section 3.3 shows that decision making is an integral part of risk managers' responsibility. They have to confront the complexities and ambiguities of risk management problems. Further, they have to make decisions now, and the consequences of their decisions are only known in the future. For example, risk managers need to choose the best risk response action now, but the effectiveness of the action to mitigate the risk is only known in the future. Risk management problems involve many conflicting factors. For example, to choose the best risk response action, risk managers must consider factors such as: Does the firm have the resources to implement the action? What other risks could arise from the action? What are the benefits, and do the benefits justify the costs? Many aspects of the decisions involve intangibles, difficult-to-measure factors and a lack of data.

Risk management decision making requires a decision-making tool. It requires a systematic decision-making process for decision making to be formalised. The tool must be able to handle multiple factors across a range of risk management situations and decision uncertainties, and it must incorporate risk management principles in the decision-making goal. This thesis aims to address the concerns. It aims to develop a systematic decision making tool by exploiting the AHP- a flexible multi-attribute or multi-criteria decision making tool. A multi-criteria decision making tool enables risk managers to consider multiple factors of a problem. A flexible tool enables risk managers to model broad range of risk management problems. A systematic process provides the formality and transparency in decision making to produce useful results.

3.5 Risk Management Decision Making Challenges

The previous sections discussed risk management and the decisions that risk managers have to make to implement risk management. This section discusses the decision-making challenges faced by risk managers. The decision-making tool developed in this thesis aims to address these challenges.

Decision making in risk management is about facing uncertainties and making optimal decisions in uncertain situations. The challenges are divided into three groups: bias in heuristic judgement, bias in decision framing and bias in the human thinking system. Awareness of decision-making biases enables risk managers to minimise or eliminate them when making decisions. A study of more than 1000 major business investments showed that reducing the effect of judgement bias in the decision-making process increased returns by up to 7 per cent (Kahneman, 2011).

The purposes of this discussion are twofold. First, it will show that biases are implicit. Decision biases such as previous experience, psychological biases, decision framing and interactions between thinking systems are unconsciously influencing risk managers' thoughts and affecting their judgement. A tool that can minimise biases is useful for risk management decision making. Second, the discussion will provide an understanding of how biases arise and how the tool developed in this thesis can prevent the biases from influencing decisions.

3.5.1 Bias in Heuristic Judgements

Kahneman (2011) defined heuristic as a simple procedure for answering a difficult question. Gigerenzer (2014) defined heuristic as a conscious or unconscious strategy that ignores part of the information of a problem in order to make better judgements and fast decisions. Heuristic should be used in uncertain situations where not all risks are known. Risk managers generally use heuristic to evaluate risks. Risk managers' experience, knowledge and skills are translated into preferences and beliefs regarding the importance of risks or the likely occurrence of uncertain events. However, heuristic judgements in an uncertain environment are exposed to judgement biases, which interfere with rational judgements. The following section discusses heuristic judgement biases and how AHP can address the biases.

What You See Is All There Is (WYSIATI)

WYSIATI bias is the failure to consider that the critical evidence of a problem is missing (Kahneman, 2011). The bias commonly occurs when a problem's information is scarce. Thus, decision makers make decisions based on the limited information instead of asking what they need to know before forming an opinion. The WYSIATI bias causes risk managers to overlook the range of possible outcomes of uncertain events, focus on a narrow scope of possibilities and make decisions based on the possibilities. As a result, risk managers could be caught by surprise when the outcome falls outside the range of the possibilities.

AHP require decision makers to collect relevant information of the problem and structure the information in a hierarchy. Presenting a problem in a hierarchy promotes transparency, facilitates debate and discussion of the problem, assists decision makers to identify missing information and enables decision makers to detect bias in representing the information.

Representativeness

Representativeness is evaluating the likelihood of an uncertain event by its degree of similarity to its parent population, or by its ability to reflect the prominent features of the process generating the event (Kahneman and Tversky, 1972). For example, a tall and thin athlete is judged to be more likely to play basketball than football, young men are more likely to drive aggressively compared to elderly women, and a financial analyst with four years' above-average performance is more likely to be a talented analyst. However, in reality, a four-year record of accomplishment reveals little about the performance of the analyst in the next four years. The consequence of representativeness bias is an excessive willingness to predict the occurrence of an unlikely event (Kahneman, 2011).

In risk management, the representativeness heuristic influences the forecast of financial risks and returns. Bondt (1993) investigated stock prices and exchange rates forecast by non-experts. The study documented two results. First, people predict stock prices by extrapolating from past trends, as they expect past trends in prices to continue. Further, they become optimistic in a bear market and pessimistic in a bull market. Second, people exercise caution and hedge their forecasts in projecting the future price of stock. If a large price increase is predicted, the subjective probability distribution of future prices is left-skewed, recognising a possible decline, and vice versa if a price decrease is expected. The study showed that perceived risks are represented by prior performance. Hillson and Webster (2005) stated that representativeness results in a less rigorous assessment of risks in the current situation, arising from a reliance on perceived similarity with a situation previously experienced. Representativeness bias can be countered by examining the current situation without comparing it to previous situations or stereotypes.

AHP addresses representativeness by using consistency ratio to detect random or extreme judgement. Consistency ratio is a monitoring device to differentiate between careful and deliberate decisions based on decision makers understanding of the problem, and random or extreme decisions based on guesses and feelings.

Availability

The availability heuristic means assessing the frequency or probability of an event by the ease with which the instances or occurrence of the event comes to mind (Tversky and Kahneman, 1973). Easily retrieved or familiar events are judged to have a high frequency compared to events with equal frequency but that are less retrievable. Factors influencing availability bias are personal experience, actual experience and imagination. For example, the effect of witnessing a house burning causes an individual to judge high frequency to risk of fire compared to reading about a fire in a newspaper.

In risk management, the risk associated with terrorism in the aftermath of September 11 was considered more serious and dangerous compared to unfamiliar risks such as risks associated with sun bathing. The risk of a terrorist attack is given a higher probability compared to the risk of skin cancer. Vivid and easily imagined causes of death (e.g., tornadoes) often receive high estimates of probability compared to less vivid causes (e.g., asthma attacks), even though more deaths are caused by asthma attacks than tornadoes, by a factor of 20 (Thaler and Sunstein, 2008).

The availability heuristic can influence risk identification. For example, using checklists for risk identification can result in memories of previous risks being activated, leading to an increased tendency to identify the same risks for the current situation, or a risk that occurred on a previous project could be assessed as having a higher likelihood of occurring on the current project (Hillson and Webster, 2005). The availability heuristic results in an inaccurate assessment of risks and risk response, and the inaccurate assessment results in an individual or organisation allocating resources to less important risks instead of responding to more important risks. According to Hillson and Webster (2005), the availability heuristic can be minimised by consciously reviewing all available data before making a decision.

Similar to the WYSIATI problem, AHP requires decision makers to collect all factors or data to a problem. A decision should not be made until decision makers understand how the factors relate with each other and the relationship is structured in a hierarchy.

Anchoring and Adjustment

The anchoring and adjustment heuristic refers to making a judgement based on the first known information and adjusting the judgement until a plausible estimate is reached (Epley and Gilovich, 2006). According to Tversky and Kahneman (1974), anchoring and adjustment is a technique commonly used to estimate unknown quantities. The decision makers start with a known value and adjust the value until an acceptable value is reached. For example, how much a person is willing to pay for a house is influenced by the first information about the house: the listing price. The house will appear more valuable if the listing price is high compared to if the listing price is lower. The person will adjust the price of the house from the listed price to arrive at the final price. If the listed price is high, the person will put a higher value on the house. If the listed price is low, the person will put a lower value on the house. The adjustment is usually insufficient, as different initial values yield different estimates.

In risk management, the anchoring and adjustment heuristic could influence estimations of the probability of a firm going bankrupt. A risk manager may make a lower estimate if a lower initial probability is given, and a higher estimate if a higher initial probability is given.

AHP is a multi-attribute or multi-criteria decision making method. Therefore, it requires multiple criteria to evaluate problem alternatives or options. For example, to decide whether to buy a house requires more than one information or criteria of the house, such as price, location and number of rooms. To use AHP to make decisions, risk managers need to identify more than one criterion.

Affect

The affect heuristic refers to decision makers allowing their likes and dislikes to determine their beliefs or preferences. Alhakimi and Slovic (1994) stated that, in people's minds, risk and benefit are inversely related. People refer to affective feeling in judging the risks and benefits of hazards. If an activity is liked, the activity is judged as having low risks and high benefits. If an activity is disliked, the risks are high and the benefits are low. For example, if a decision maker likes a certain project or investment, the perception is that the costs are low and the benefits are high. In finance, if a risk manager likes a certain financial model, the model is perceived to have high benefits and impose few risks.

The affect heuristic produces another heuristic: substitution. Substitution refers to replacing a difficult question with an easier question (Kahneman, 2011). For example, a difficult question, such as 'What do I think about the project?' is replaced by an easy question, such as 'How do I feel about the project?'. In another example, 'How should financial advisers who prey on the elderly be punished?' is replaced by 'How much anger do I feel when I think of financial predators?'. The affect heuristic produces a halo effect. Favourable first impressions influence judgements. For example, if a person thinks that a baseball pitcher is good-looking and athletic, the pitcher is likely to be rated better at throwing balls (positive halo). If a person thinks a player is not good looking, the player's athletic ability will probably be underrated (negative halo). If a risk manager thinks that a financial model is complex and sophisticated, the model is perceived to be more trusted to produce an accurate result (positive halo). If a risk manager thinks that a model is simple, the model's ability to produce a reliable result is probably underrated (negative halo).

AHP uses subjective judgement to make decisions. However, instead of directly asked decision makers 'what do you think about the project?. AHP requires the decision makers to compare two projects and decide which project they like more. The pairwise comparison technique forces the decision makers to simultaneously evaluate both projects. For example, they need to identify strengths and weaknesses, and cost and benefits of the projects before judging which project they like more.

Conformity Effect

The conformity effect is the tendency of an individual to follow a groups judgement (Asch, 1956). Asch (1956) conducted a series of experiments to investigate the factors that influence independent and independent failure judgement. In the study, the experimenter told the participants that they were participating in a vision test. Unknown to some participants, most of the other participants were the experimenter's assistants. The experiment required the participants to match the length of a given line (called a standard line) with one of three other lines. One of the three comparison lines was equal to the standard line, and the other two lines differed from the standard line and from each other. The assistants first chose the correct answer, but eventually began to purposely choose the wrong answer. The unknowing participant was either the last or second last to be called to give an answer. The experiment showed that 75 per cent of the participants followed the group's decision at least once. In contrast, the control group participants wrote their judgement on a form. The control group's choices were mostly free of errors, with 35 out of the 37 participants making correct judgements.

The experiment showed that people conform to group decisions even though they know the decision is incorrect, and people are more likely to conform if they are required to express their decisions verbally in front of others. In the interviews conducted after the experiment, Asch (1956) found that many of the participants were reluctant to question the accuracy of the majority, even though they were confident of their own judgement, because they did not want to face the risk of being left out or ridiculed. Few participants pushed aside their doubts; they chose to believe that the majority was making the correct judgement because they thought that the majority could not be wrong. Asch (1956) conformity experiment was replicated and tested in more than 130 countries (Thaler and Sunstein, 2008), with results showing that 20-40 per cent of the participants conformed to the group's decisions.

The conformity effect bias may affect the outcome of risk assessment. For example, assessing the importance of risks of a business unit requires risk managers to assemble the relevant stakeholders. The group consists of people with different academic backgrounds, experience, knowledge and expertise. The conformity effect bias develops as superior members of the group dominate the judgement. To avoid conflict, less dominant group members may decide not to argue, even though they may have important information about the risks. Avoiding conflicts and conforming to a superior person produces an inaccurate and unreliable risk assessment result.

AHP can be used to address conformity effect. AHP allow decision makers to make individual decision and later aggregate their judgements to produce an overall judgement. The decision makers can work as a group to collect relevant factors of a problem and organise the factors in a hierarchy. However, they do not necessarily need to make a decision as a group. They can conduct individual assessment of the factors and later submit their decisions to the group leader.

3.5.2 Bias in Decisions Framing

The section discusses the effect of problem framing on rational judgement. Tversky and Kahneman (1981) stated that rational choices should not change by changing the framing of the problem. However, studies have shown that different problem framing impairs rational judgement. Kahneman and Tversky (1979) showed that a person becomes risk averse in choices involving gains and becomes a risk seeker in choices involving losses. Max H. Bazerman and White (1992) showed that the preferred option in a separate evaluation is no longer the preferred option in a joint evaluation.

Table 3.1: Narrow Framing: Separate Choices

Choice 1	Choose Between
A	Sure gain of \$240
B	25% chance to gain \$1000 and 75% chance to gain nothing
Choice 2	Choose Between
C	Sure loss of \$750
D	75% chance to lose \$1000 and 25% chance to lose nothing

Kahneman (2011) stated that reasoning is impaired when information is presented in terms of percentage versus frequency. A low-probability event described in relative frequencies is given more weight than an event described in abstract terms of chance or probability.

The next section discusses decision-making framing biases.

Narrow Versus Broad Framing

An unbiased framing is that a preference or judgement should be independent of the problem description. The two ways to construct choices are: (i) narrow frames, in which a sequence of simple choices is considered separately; and (ii) broad frames, in which a combination of choices and decision makers determines the most preferred combination (Kahneman, 2011).

The following example shows the differences between narrow framing and broad framing (Tversky and Kahneman, 1981). Consider the options in Table 3.1.

For the separate choice, 84 per cent of respondents choose A in Choice 1, and 87 per cent choose D in Choice 2. Only 16 per cent choose B in Choice 1, and 13 per cent choose C in Choice 2. The results showed that the majority of respondents in Choice 1 are risk averse. A prospect with a lesser risk is preferred to a risky prospect of equal or greater expected value. The majority of respondents in Choice 2 are risk takers. A risky prospect is preferred to a lesser-risk prospect of equal expected value. Tversky and Kahneman (1981) stated that people become risk averse when choices are framed

TABLE 3.2: Broad Framing: Combination of Choices

AC	Sure loss of $510
AD	25% chance to gain $240 and 75% chance to lose $760
BC	25% chance to gain $250 and 75% chance to lose $750
BD	25% chance to gain $1000 and 75% chance to lose $1000

in gains, and they become risk takers when choices are framed in losses. The framing of choices affects a person's risk attitude.

However, changing the frame changes the result. Table 3.2 shows a combination of choices: A and C, A and D, B and C and, B and D. The participants prefer the combinations of AD and BC. The combination of BC dominates the combination of AD. All respondents chose combination BC. In a separate framing, B and C are the least favourable options. However, combining B and C enables the participants to see that B and C are the reasonable options.

Kahneman (2011) stated that: (i) simple choices can be deconstructed in a variety of ways into a combination of choices; and (ii) human rationality has limitations. First, people may not think of the possibility of deconstructing a problem into pairs of choices. Second, people may not see the pairing of choices, as the inferior choice now becomes the dominant choice. Comparisons made in a combined evaluation require careful and effortful assessment, which is a more preferred decision-making method. Tversky and Kahneman (1981) stated that combining decision options is the preferred decision-making method compared to a single, separate decision. The combining of options is broad framing - a comprehensive decision. Narrow framing is a sequence of simple decisions considered separately.

Another way to frame a decision choice is by presenting all of the alternatives or a single alternative. Presenting all of the alternatives is broad framing, and a single alternative is narrow framing. Fox (1999) demonstrated the effect of broad and narrow alternative presentations on judgement. The study showed that the probability of an event is overestimated when not all alternatives are displayed. Fox (1999) recruited 50 fans of professional basketball to elicit judgement on the winner of the National Basketball Association (NBA) championship. They were required to estimate the chances of their favourite team winning. The focal event-that is, estimating the chances of a favourite team winning-was clearly defined. Therefore, a fans memory would construct a victory for the favourite team winning and would be less aware of the chance of the other teams winning the championship. Next, the same fan was asked to assess the chance of another team winning. The fan performed the same selective activation, with the result that total probability added to more than 100 per cent. In contrast, by clearly defining the focal event and disclosing all of the alternatives, the probability of the judgement added to 100 per cent. Therefore, the study showed that people make impaired probability judgements when one alternative is displayed.

AHP is a broad-framing decision making technique. It requires decision makers to consider all alternatives relevant to a problem before making a decision. AHP requires the alternatives to be displayed in a hierarchy. Therefore, the decision makers can see the linkage between the alternatives and criteria used to judge the alternatives.

Joint Versus Separate Evaluation

For joint evaluation, alternatives are presented to decision makers simultaneously. For separate evaluation, alternatives are presented separately from other alternatives. Studies have shown that the presentation of alternatives affects judgement of choices (Hsee, 1996, 2000, Hsee et al., 1999). An alternative that is favoured in a separate evaluation is no longer favoured in a joint evaluation. Decision makers who assign a higher preference to one option compared to other options in a separate evaluation reverse their preference when the options are evaluated simultaneously (Hsee et al., 1999).

Hsee (1996) demonstrated the effect of joint and separate evaluation on judgement. The study defined joint evaluation as options that are presented side by side and evaluated by the same people. It defined separate evaluation as options that are presented separately and evaluated by two different groups of people. The study asked the participants to imagine that they were music students looking for a music dictionary.

Table 3.3: Dictionary Attributes

	Dictionary A	Dictionary B
Year of publication	1993	1993
Number of entries	10000	20000
Condition	Like new	Torn cover otherwise like new

Participants were given information about two dictionaries: A and B. They had to decide which dictionary they would be most likely to buy. Table 3.3 shows the attributes of the dictionaries.

Dictionary A was superior in the defect attribute, while Dictionary B was superior in the number of entries attribute. The results showed that, in the separate evaluation, the participants assigned a higher price to Dictionary A compared to B. However, in the joint evaluation, the participants assigned a higher price to Dictionary B compared to A. Hsee (1996) explained that the number of entries attribute had no weight in the separate evaluation; it was not evaluable. According to the evaluability hypothesis, number of entries is a low evaluability attribute in separate judgement. The participants could not decide whether 10,000 or 20,000 entries was an important attribute in judging the value of the dictionary. Unable to compare the number of entries side by side, the participants were unaware of the importance of the information. As a result, the information concerning the number of entries was ignored. The dictionaries were instead judged by their physical condition. The participants reversed their preference when both dictionaries were presented simultaneously. Dictionary B was judged to be more valuable than A. Comparing the dictionaries simultaneously enabled the participants to see the importance of the attribute number of entries.

From this experiment, Hsee (1996) developed the evaluability hypothesis, which stated that joint-separate preference reversal occurs because one attribute is difficult to evaluate independently, while another is relatively easy to evaluate independently. An attribute that is difficult to evaluate independently means that the evaluator does not know the value of the attribute without comparison. An attribute that is easy to evaluate independently means that the evaluator knows the value of the attribute. Hsee (1996) experiment showed that number of entries is difficult to evaluate independently compared to the physical condition of the dictionary. When unable to compare the dictionaries simultaneously, the participants did not know the value of the attribute number of entries. However, the defect attribute was easy to evaluate independently. Even without comparison, people consider a new dictionary more valuable than a defective dictionary.

According to Hsee (1996), when two options require a trade-off between a difficult-to-evaluate attribute and an easy-to-evaluate attribute, the difficult-to-evaluate attribute has fewer effects in a separate evaluation compared to a joint evaluation. A joint evaluation detects attributes or criteria that are not noticeable in a single evaluation. Kahneman (2011) stated that rationality is better served by broader and more comprehensive decision frames. A joint evaluation provides a broader and comprehensive frame compared to a single evaluation.

AHP uses pairwise comparison to make decision. In pairwise comparison, two criteria are compared and decision makers decide, based on the decision goal which criteria have more influence on the alternative. To make explicit trade-off, decision makers need to state their preference in terms of dominance and intensity. Dominance determines which criteria have more influence and intensity measures strength of influence based on a scale of 1-9.

How Many Versus How Likely

Different styles of comparing risks affect risk judgement. For example (Kahneman, 2011):

(i) A vaccine protecting children from a fatal disease carries 0.001 per cent risk of permanent disability.

(ii) 1 of 100,000 vaccinated children will be permanently disabled.

The risk appears to be small in the first statement. However, the second statement causes a decision maker to imagine a permanently disabled child. The other 99,999 safely vaccinated children faded from the decision-maker's mind. Kahneman (2011) stated that presenting risk statements in terms of relative frequencies causes the risks to be heavily weighted compared to abstract terms such as probability or chance.

Consider the following statements (Yamagishi, 1997):

(i) A disease kills 1286 people out of every 10,000

(ii) A disease kills 24.14 per cent of the population.

Although twice as many people die in the second statement compared to the first, the first statement is judged more threatening. The vividness of presenting 1286 actual people rather than an abstract percentage causes suboptimal judgement. However, Kahneman (2011) stated the judgement bias can be reduced or eliminated by asking direct comparison of the two scenarios.

AHP uses consistent way to ask question in the pairwise comparison and avoids using confusing probabilities or frequencies in the question. The examples discussed previously can be constructed in the following ways:

(i) The goal of the decision is to decide which vaccine is more dangerous to children as it can cause permanent disability. Compare vaccine A and B. Which vaccine is more dangerous and the intensity of danger? A possible answer is, vaccine A is more dangerous compared to B with intensity 3 (strong).

(ii) The goal of the decision is to decide which disease kills more people. Compare disease A and B. Which disease is more dangerous and the intensity of danger? A possible answer is, disease B is more dangerous compared to A with intensity 9 (extreme).

3.5.3 Bias in Human Thinking Systems

Humans have two modes of thinking: fast and slow. Stanovich and West (2000) referred to the modes as System 1 and System 2. System 1 operates automatically and quickly, with little or no effort. It is uncontrolled, effortless, associative, fast and unconscious. In contrast, System 2 requires attention, effortful mental activities, concentration and complex computations. It is controlled, effortful, deductive, slow, self-aware and rule following. System 1 is automotive and System 2 is reflective. Examples of the automatic activities of System 1 are calculating 2+2, driving a car on an empty road, understanding a simple sentence and reading words on a billboard. Examples of the effortful activities of System 2 are parking in a narrow space, filling out a tax form, comparing two washing machines for overall value, deciding whether to enrol in business or law school, focusing on the voice of a particular person in a crowded and noisy room, and deciding which route to follow. Several activities performed by System 1 are involuntary-for example, automatically understanding simple sentences or automatically knowing that 2+2 is four. Activities performed by System 2 require attention. System 2 is ineffective or less effective if it is not ready or if attention is not directed at the activities. The phrase 'pay attention' is appropriate for the activities of System 2.

Decision-making bias occurs because of interactions between the two thinking systems (Kahneman, 2011). Kahneman (2011) stated that System 1 runs automatically and is biased and gullible, whereas System 2 is in charge of doubting and unbelieving. However, System 2 is normally in a comfortable low-effort mode. Only a fraction of its capacity is engaged. System 1 generates suggestions for System 2, such as impressions, intuitions, intentions and feelings. If endorsed by System 2, impressions and intuitions turn into beliefs, and impulses turn into voluntary actions. System 2 adopts the suggestions of System 1 with little or no modification. System 1 calls on System 2 when it faces difficulties, or when problems or questions arise that it cannot answer, or when it needs the support of detailed and specific processing to solve problems. System 2 is also activated when an event violates the model of the world maintained by System 1. For example, lamps do not jump, cats do not bark and gorillas do not cross basketball courts. In summary, the thinking of System 2 originates from System 1. System 2 takes over only when problems or questions are difficult.

System 1 and System 2 complement each other. System 1 generates suggestions and System 2 endorses and transforms the suggestions into actions. System 1 is generally good at what it does-that is, the accurate modelling of familiar situations, accurate short-term prediction and appropriate reactions to simple problems or questions. Unfortunately, System 1 has biases; it makes systematic errors in specific situations, such as substituting a difficult question with an easy question and lacking an understanding of logic and statistics. System 1 operates automatically. Therefore, errors are difficult

Table 3.4: Comparison between System 1 and System 2

	System 1	System 2
Characteristics	Fast	Slow
	Effortless	Effortful
	Unconscious	Concious
	Associative	Logical
	Pattern seeker	Deliberate
	Emotional	Abstract
	Causation seeker	Calculative
	Explain events by creating story	Frames decisions broadly
	Frames decision narrowly	
Strengths	Quick response	Able to handle logic, mathematics and statistics
	Easy completion of routine	Reflection and consideration
	or repetitive tasks	for bigger picture
	Creative in making	Able to evaluate option,
	associations	pros and cons, and consequences
	Good for expansive thinking	Good for reductive thinking
Weaknesses	Jumps into conclusion	Slow - requires time
	Emotional responses	Requires effort and energy
	Wrong assumption	Decision fatigue
	Poor judgements	
	False causal link	

to prevent. Although System 2 is in charge of controlling and is activated when System 1 runs into difficulties, System 2 is generally unaware of the presence of an error.

Table 3.4 presents the characteristics, strengths, weaknesses and examples of tasks of Systems 1 and 2.

Chabris and Simons (2010) showed the limited capacity of human attention and demonstrated that people could be blind to the obvious. They constructed a short film of two teams passing basketballs. One team wore white shirts and the other team wore black. Participants were instructed to count the number of passes made by the white team and ignore the black team. The task was difficult and absorbing. Halfway through the video, a woman wearing a gorilla suit appeared, crossed the court, thumped her chest and moved on. The gorilla was in view for nine seconds. The video was shown to thousands of viewers, and half of the viewers watching the video did not see the gorilla walking through the middle of the game. However, viewers watching the video without the task saw the gorilla.

The experiment showed that people's attention becomes narrow when concentrating on a task. The counting task and the instruction to ignore the other team caused the narrow view, as the viewers were focusing on counting the passes between the players and ignoring other things happening in the video. Further, people's attention can be moved away from an unwanted focus. The instruction required the viewers to focus intently on a target-that is, counting the number of passes. The viewers wanted to achieve that target, so they had to focus on the game. They did not expect anything unusual to happen. This experiment has relevance to risk management. First, a risk manager who focuses on managing a particular risk could ignore other important risks. Second, risk managers' expectations and assumptions could influence what they do and do not see.

Another thinking process of System 1 is seeking patterns and making causal relationships between events. This process is called associative activation (Morewedge and Kahneman, 2010). For example, simultaneously seeing the words 'banana' and 'vomit' causes the brain to make a causal connection between the banana and vomit. In this scenario, the banana is causing the sickness. The associative activation occurs automatically and effortlessly. System 1 makes the connection as logical as possible from completely unexpected or unrelated events. The causal connection between the banana and vomit causes the brain to think that it understands the past, and it uses the information to prepare for the future. The bias of System 1 thinking affects risk management decision making. A risk manager could perceive certain risks to exist by examining past trends and data. However, past trends and data are not accurate predictions of future performance. A risk manager could therefore make a causal connection between risk events when an associative connection does not exist.

Different people associate ideas differently depending on the information or stimulus given before the judgement. Bargh et al. (1996) asked a group of students aged 18-22 to assemble four-word sentences from a set of five words. For one group, the words given were 'Florida, forgetful, bald, grey and wrinkle'. After completing the experiment, the participants walked to another office down the hall to conduct another experiment. The researchers observed the time taken for each participant to reach the other office. The results showed that participants who were given words associated with elderly people walked slower compared to other participants, even though the word 'old' was not mentioned. The participants were influenced by the thought of elderly people, and this was reflected in their action of walking slowly. The information or stimulus provided to decision makers has a priming effect on risk judgement.

Erb et al. (2002) showed that priming could affect risk attitudes The study investigated whether exposing participants to risk-related content would affect risk preferences. The first part of the study required the participants to judge the frequency of occurrence of two sets of 15 words. The first set comprised risk-seeking words, and the second set comprised risk-averse words. Both the risk-seeking and risk-averse sets consisted of 15 words. For each set, eight out of 15 words were associated with risk-seeking and risk-averse behaviour. The remaining words are random words that were not associated with risk behaviour. For the risk-seeking set, four words had positive connotations for risk-seeking behaviour, such as 'enterprising', and four words had negative connotations for risk-averse behaviour, such as 'fear'. Similarly, for the risk-averse set, four words had negative connotations for risk-seeking behaviour, such as 'thoughtless', and four words had positive connotations for risk-averse behaviour, such as 'responsible'. The second part of the study required the participants to read four risk scenarios and decide between a safe or risky option. The results showed that priming affects risk preference, and that risk-seeking priming induces risk-seeking behaviour. In contrast, risk-averse priming induces risk-averse behaviour. In addition, the study found that judgements made against the prime were made with less confidence. Participants who were primed to be risk seeking, but who produced a risk-averse response had less confidence in their judgement compared to participants with a risk-seeking response. Further, participants were not aware of the priming effect. Only one respondent was aware of the relationship between the first and second part of the study.

Priming could affect risk management decision making. A risk manager who had a certain prior belief, or who was exposed to a certain risk environment, will be influenced by his or her beliefs or environment. For example, a risk manager in a risk-averse organisation would be less inclined to take more risks. Conversely, risk managers in a risk-seeking organisation would be more inclined to take more risks.

3.6 Current Risk Management Tools

This section discusses current tools and techniques that are used to support decision making in risk management. The purpose of the discussion is to demonstrate the limitations of the tools for risk management decision making.

Risk Matrix

The risk matrix is a graphical representation of risks. The risks are plotted on a graph, with the vertical axis representing impact or magnitude, and the horizontal axis representing likelihood or probability. The matrix is divided into four quadrants: (i) low impact, low, likelihood; (ii) low impact, high likelihood; (iii) high impact, low likelihood; and (iv) high impact, high likelihood. Likelihood and impact are evaluated using a scale of 1 to 9. Other scales are sometimes used to evaluate likelihood, such as: (i) low, medium, high; (ii) improbable, possible, probably, near certainty, certainty; and (iii) slight, not likely, likely, highly likely, expected. Other scales used to evaluate impact are: (i) low, medium, high; (ii) minor, moderate, critical, survival; and (iii) monetary value such as $1 million, $5 million (Shenkir and Walker, 2007).

Moeller (2007) explained how to conduct a risk assessment using a risk matrix. For example, a firm has identified six risks: R1 to R6. The risk management group consists of four people from different business units. Each group member evaluates the likelihood and impact of the risks individually. The following questions are used to assess the risks:

- What is the likelihood of the risk occurring in one year? Use a score of 1 to 9 to assign the best score.

- Score 1 if no chance of the risk occurring in one year.
- Score 9 if the risk will certainly occur in one year.
- Score 2 to 8 if the risk occurrence is between no chance and certain.

• What is the financial impact of the risk to the organisation?

- Score 1 for very low.
- Score 9 for very high.
- Score 2 to 8 for between very low and very high.

The risk assessment is for a specific time horizon. Moeller (2007) proposed a one-year interval or fiscal year, and proposed developing a separate risk matrix to address different time horizons. The group individual assessment was averaged, and the values were plotted on the risk matrix presented in Figure 3.1.

Figure 3.1: Risk Matrix Example

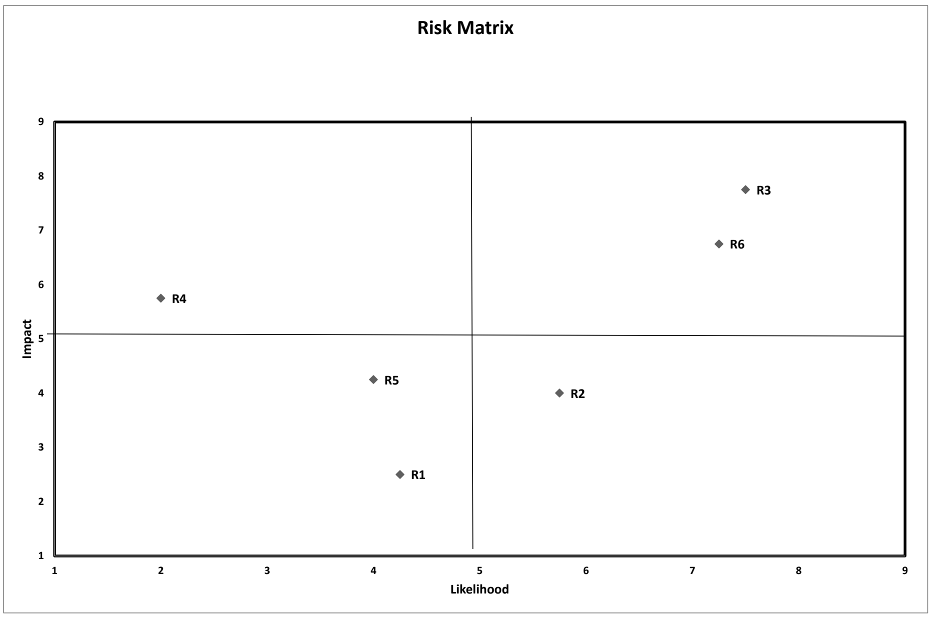


TABLE 3.5: Risk Score Calculation

Identified risk	Impact (P)	Likelihood (L)	Risk Score (P x L)	Rank
Risk 1	4.25	2.5	10.63	6
Risk 2	5.75	4	23.00	3
Risk 3	7.5	7.75	58.13	1
Risk 4	2	5.75	11.50	5
Risk 5	4	4.25	17.00	4
Risk 6	7.25	6.75	48.94	2

To obtain risk scores, the likelihood and impact are multiplied. The risk scores is the ranking of risks. Table 3.5 shows the risk score calculation. Risks 3 and 6 have the highest risk score. The risks are plotted at the upper-right-hand quadrant, which is the high likelihood and high impact quadrant.Risks 3 and 6 are the most important risks compared to other risks. Therefore, the firm needs to focus on planning responses to these risks. Moeller (2007) proposed that risk management teams develop a risk matrix and ranking table for every unit and level in the firm. The rankings should then be aggregated to obtain the overall risk rankings for the firm.

This thesis notes the following limitation of the risk matrix. The risk matrix is a tool for determining important risks. The technique is easy to use and has an intuitive appeal. Risk assessors only consider the function of risk in terms of likelihood and magnitude. The technique is useful for cases in which quantitative data are scarce or do not exist. However, Shenkir and Walker (2007) argued that the likelihood-magnitude approach does not consider the preferences and value judgements of the decision makers, which are important in determining significant risks and planning actions to mitigate the risks. Emblemsvag and Kjolstad (2006) stated that the logic of the likelihood and impact risk assessment is unclear. Further analysis to improve the assessment is not possible. The final act is to place the risks in a likelihood and impact matrix without any inconsistency check or sensitivity analysis.

Cox (2008) noted the ability of the risk matrix to improve decision making, arguing that the risk matrix has the following limitations. First, risk matrices make an accurate comparison on only a small number (less than 10 per cent) of randomly selected hazards. Second, they can mistakenly assign higher qualitative ratings to quantitatively smaller risks. Third, they are ineffective in allocating resources to mitigate risks. Fourth, ratings in risk matrices depend on the subjective judgements of decision makers. Therefore, different decision makers may have opposite ratings on the same risk. Duckert (2011) noted the validity of using subjective judgement in assessing risks, stating that a true risk assessment should consist of three steps: (i) identifying the risk; (ii) calculating the probability of occurrence; and (iii) determining the effect. Duckert (2011) emphasised the importance of using data to calculate the probability of risk occurrence. Data can accurately predict the probability of risks occurring. Risk assessments using subjective judgement rely on guesses and not a true risk assessment. A subjective risk assessment lacks consistency. A different person will give a different assessment of the same risk. Even the same person will give different assessments of the same risks in different situations or at different times. However, Chapman (2006) explained the following reasons for why subjective estimations should be used to evaluate risks: (i) data have never been collected; (ii) data are expensive to obtain; (iii) past data are no longer relevant; (iv) data are sparse, requiring expert opinions to fill in the gaps; and (v) the area of risk is new.

Moeller (2007) argued that low-medium-high risk mapping is suitable for a small number of risks. For a large number of risks, probability estimation is more appropriate for ranking the risks. Hargreaves (2010) stated that the low-medium-high approach works well for a one-person risk analysis. To evaluate risks at each level of an organisation, a number of people will be involved. Different people will have a different perspective of the risks and a different understanding of the low, medium and high scale. The situation requires a tool that can synthesise all judgements, as well as a standardised and formalised risk assessment process.

Scenario Analysis

Scenario analysis is a tool used to uncover risks beyond known risks. Chapman (2006) stated that scenario analysis is useful for identifying strategic risks in less familiar situations by exploring the what-if questions. Microsoft uses scenario analysis to identify significant business risks(Barton et al., 2002). The risk management group at Microsoft has developed various scenarios and identified material risks from the scenarios. The group also identifies worst-case scenarios, events triggered by the scenarios and risks triggered by the scenarios and events. Protiviti (2006) proposed that scenario analysis be used to assess external and internal factors, as well as potential events affecting an organisation. The scenario analysis should answer questions about what event or combination of events could occur in the future. Events and risks identified in the analysis are significant input for formulating a response strategy.

Scenario analysis uses expert judgement to determine a range of scenarios and outcomes (Monahan, 2008). The experts are responsible for determining and defining the scenarios. A scenario is a situation leading to or transpiring risk events. For example, in a scenario-based approach to measure the risk of a portfolio, the portfolio manager considers a number of possible future risk scenarios, such as a 10 per cent rise in key exchange rates, a 20 per cent drop in major stock market indices, or the rise of key interest rates. The risk of the portfolio is the maximum loss of the portfolio under all scenarios. Scenario analysis provides complementary information for loss measurement based on a probability distribution and a useful tool for a portfolio exposed to a relatively small number of risks. However, the challenges are to determine the appropriate number of scenarios, the weight of the scenarios, to make comparisons across the portfolio affected by different risks (Embrechts et al., 2005) and to estimate the likelihood of the scenario occurring (Chapman, 2006).

The steps required to conduct scenario analysis include (Damodaran, 2007):

- determining the case or problem (e.g., building a new plant, assessing competitors before launching a new product, estimating the behaviour of a regulator for a new product)

- determining the factors related to the case or problem
- determining the number of scenarios related to the case or problem
- estimating cash flows under each scenario
- assigning probabilities for each scenario.

Damodaran (2007) stated that scenario analysis has the following limitations. First, scenarios need to be realistic and cover a broad range of possibilities. Thousands of possible scenarios can be created; the challenge is to determine which scenario to consider and the probability of the scenarios occurring. Second, scenario analysis is suitable for risks with discrete outcomes. Setting up scenario analysis is difficult if the spread of outcomes is large or continuous. Scenario analysis has several advantages. First, the output from scenario analysis can be used as input for risk analysis. Second, based on the worst-case scenario, firms can focus on analysing the events with the biggest effect on portfolio value. Third, thinking through scenarios forces decision makers to think about actions to minimise potential downside risks and maximise upside risks.

Decision Tree

A decision tree is a quantitative method use to assist in decision making (Merna and Al-Thani, 2005). A decision tree shows a sequence of interrelated risk events and possible outcomes under each event. Decision makers assign a probability for each event and use the probability to calculate the expected value of the outcome.

Presenting a sequence of interrelated risk events using a decision tree is an effective technique for making risks connection. Decision trees lay out the risks at each stage of the decision-making process, and they assist decision makers in identifying the right responses for each risk. The following steps are used to build a decision tree (Damodaran, 2007):

- Divide the analysis into risk phases: outline potential outcomes and risks faced by each outcome.
- Estimate the probability of the outcome at each phase.

- Define the decision points: A decision point is a phase where the best course of action is determined. The decision depends on observing the outcome of the earlier stages and expected future outcome. For example, the decision points for the problem of whether to introduce a new product could be to conduct a test market, abandon the product or proceed with introducing the product.
- Compute cash flows or cash value at end nodes.
- Fold back the tree: discount the cash flow to obtain the present value of the cash flow.

Damodaran (2007) outlined several benefits of decision trees. First, they enable dynamic responses to risk. Decision tree links actions and choices to the outcomes of uncertain events. They force decision makers to think about risk actions under each circumstance and prepare them to face any circumstances. Second, they provide value of information (e.g., whether to introduce a new product). A firm needs to gather relevant information on chances of success and measure the expected value of the information. Decision trees provide a useful perspective on the value of information in decision making. Third, they present a picture of how cash flows unfold over time. The sequence of events identifies the risk exposure of a problem and enables risk managers to plan actions to mitigate the risks. Damodaran (2007) also identified several decision tree limitations. First, they are only suitable for sequential risks. Second, they are useful for risks with discrete outcomes. Third, they can link risk events that have a limited number of connections.

Simulation

Simulation is a technique used to measure the consequences of continuous risks. A firm facing 100 significant risks needs to evaluate the likelihood and impact of each risk. The risk matrix, scenario analysis and decision tree risk are ineffective in addressing this situation.

Similar to scenario analysis, simulation generates risk scenarios. Variables used to generate the scenarios are weighted by the probability of occurrence (Fraser and

Simkins, 2010). Each risk is presented by a probability distribution instead of a single risk score. For example, a firm can run simulations integrating market risk factors, volatility and correlations. The results of the simulations can be used to view the effect on earnings. Chase Manhattan Corporation used a simulation to measure market risk. The variables used in the simulations were interest rate, foreign exchange rate, equity and commodity prices (Barton et al., 2002).

The following steps are implemented to run a simulation (Damodaran, 2007):

- Determine the significant variables of the problem. There is no limit on the number of variables; however, more time is required to run a simulation that has many variables.

- Determine the probability distribution of the variables. The probability distribution can be determined from the historical data, cross-sectional data or statistical distribution. Statistical distribution is used if the historical or cross-sectional data are insufficient or unreliable. A statistical distribution that best represents the variability of the input and estimate parameters of the distribution should be chosen.

- Check for correlation across variables. If correlation exists between two variables: (i) choose the variable with the greatest effect on the outcome; or (ii) build the correlation into the simulation.

- Run the simulation.

Damodaran (2007) identified the benefits of simulations as follows. First, they improve input estimation. Decision makers need to examine both the historical and cross-sectional data of the variables before making a judgement on the probability distribution and parameters to use. Further, they avoid the sloppiness associated with using single best estimates. Second, simulations yield a distribution of expected value rather than a point estimate. In addition to reporting an expected value, simulations also estimate the standard deviation and breakdown of values in percentiles.

Damodaran (2007) also identified some limitation of simulations. First, the probability distribution needs to be based on analysis and data. A random or guess input produces a great-looking output but a meaningless picture of risks. Second, they require specific knowledge of statistical distributions and characteristics. An analyst who cannot assess the differences between normal and lognormal distributions should avoid using simulation to assess risks. Third, the data seldom fit the requirements of the statistical distribution. Probability distribution has little resemblance to the probability distribution of the underlying variables, thereby producing misleading results. Fourth, even if the data fit the statistical distribution, the distribution is non-stationary. For example, changes in market or economic factors change the form of the probability distribution or the distribution parameters. The mean and variance that are estimated using the data might change in the future. Lastly, there are increased difficulties in modelling the correlation in the simulation if correlations between input variables changes over time.

Cost Benefit Analysis

Cost-benefit analysis is a decision-making tool based on calculating the costs and benefits of options to a problem. The aim is to determine the option with maximum benefits and minimum cost. Nichols (2012) defined cost-benefit analysis in two ways: (i) it is a method for analysing quantitative economic information; and (ii) it is a decision-making framework for making recommendation based on an assessment of the cost and benefits of different options. The rule of cost-benefit analysis is that decision makers should choose an option that maximises the present value of the net benefits. Net benefits is total benefits less total costs.

The steps for conducting a cost-benefit analysis are as follows (Armstrong, 2006):

- Define the problem objective.
- List the costs of each alternative.
- List the benefits of each alternative.
- Estimate the monetary value of the costs and benefits.
- Calculate the net benefits, which is the value of the benefits less the incurred costs. Net benefits can be positive or negative cash flows.

- Assess the net benefits and convert them into present-value terms using the discounted cash-flow approach. Alternatively, the present value of the net benefits can be represented by a benefit-cost ratio. The denominator of the ratio is the total cost.
- Make a decision. If the cost exceeds the benefit, or if the benefit-cost ratio is less than 1, the project should be rejected.

Armstrong (2006) identified the advantages of cost-benefit analysis as follows. First, it can accommodate tangible and intangible costs and benefits. Second, it forces decision makers to concentrate on a particular issue. Third, the task of listing all of the costs and benefits is a valuable discipline of learning and understanding a problem. Armstrong (2006) identified the limitations as follows. First, there are difficulties in placing realistic values on the benefits and costs. Second, there are difficulties in determining an appropriate discounted value.

According to Nichols (2012), even though cost-benefit analysis has a clear procedural structure, it is not an objective or scientific decision-making method. Nichols (2012) discussed the following challenges to using cost-benefit analysis as a decision-making framework. It may leave out or obscure important factors to a problem. Factors that are counted as costs and benefits involve both normative and realistic judgements. A decision maker using cost-benefit analysis needs to be able to make judgements, otherwise the results can be misleading. Further, monetary values must be assigned to the options, and this can create errors in values, such as assigning the wrong values or omitting or excluding things of value. For example, a cost-benefit analysis may be used to decide whether to log an area in the Amazon. The decision would be based on the monetary value of a hectare of the Amazon rainforest. The value assigned is how much money could be gained by logging the area. Monetary gain is not the only factor when valuing an area in the Amazon, as a rainforest has many unquantifiable values. To the occupant, the rainforest provides food, firewood, shelter and other resources. To the ecosystem, the rainforest plays a role in the climatic system. If deforested, the ecosystem could be disrupted and contribute to the climate change problem. To medical scientists, the rainforest contains plants with potential medicinal values. If deforested, the plants could become extinct, and humans would lose the potential medicinal benefits. Thus, it is difficult to assign a monetary value to the loss of the basic use of the forest to the occupants, the disruption to the ecosystem and the loss of potential medicinal benefits. The cost-benefit analysis cannot capture a complete picture of the problem. As a result, the cost-benefit analysis is influenced by monetised costs and benefit factors. Other relevant unquantifiable factors are not included in the analysis.

3.6.1 Comparing the Usability of the Tools for Risk Management Decision Making

This section discusses how risk managers can use the tools described in Section 3.6 to assist risk management decision making. Choosing an effective tool depends on the answers sought by the risk managers, the output produced by the tool and the problem situations.

- Selective versus firm-wide risk analysis: For the scenario analysis, a risk manager considers several scenarios, such as best, most likely and worst case. The risk manager could include all possible scenarios provided that the probability of the scenarios occurring can be estimated. The risk manager could also use the scenario analysis combined with simulation, and use probability distribution to capture all possible outcomes. Firm-wide risk analysis is challenging when using the decision tree, risk matrix or cost-benefit analysis. The tools can address a limited number of risks.

  AHP can be used to structured complex problems with large number of factors. For example, Saaty (1977) used AHP to prioritise transport projects in Sudan. The problem was complex and involved many factors. It requires the decision makers to consider all factors relevant to the projects such as physical, economic and trade requirements for transport, and the major political and social needs of the country, as well as problems to implement the projects. Chapter 4 provides detail explanation of the study.

- Type of risk: The scenario analysis, decision tree, risk matrix and cost-benefit analysis are built for discrete outcomes. The simulation is better suited for continuous risks. The decision tree is for sequential risks where the risks are considered in phases. The risk matrix and cost-benefit analysis are for concurrent risks.

AHP is a discrete multi-criteria decision making tool. Chapter 4 discussed applications of AHP to complex problems. Factors and alternatives described in the problems are discrete.

- Modelling risk correlation: Simulations can explicitly model the correlation provided that the risk manager can estimate and forecast the correlation. For the scenario analysis, correlation is dealt with subjectively by creating scenarios with the correlation. For example, a risk manager can develop two correlated scenarios: high interest rate with slower economic growth and low interest rate with higher economic growth. Correlated risks are difficult to model in the decision tree and cost-benefit analysis. The risk correlation is not modelled in risk matrix.

  AHP measures the relative strength of factors of a problem. It measures which factors are more important to the alternatives. For example, to forecast the recovery of the timing and strength of the US Economy (Saaty, 2010a), the decision maker compares two factors, conventional adjustment and economic restructuring and decide which factor has more influence on the date of economic recovery. A detailed explanation of the study is presented in Chapter 4.

- Evaluating intangible factors: The cost-benefit analysis and decision tree are not designed for evaluating intangible factors. Variables used in cost-benefit analysis need to have monetary values. For the decision tree, the risk manager needs to determine the payoff values at the end of the tree. The risk matrix and simulation can be used to evaluate intangible factors. For the risk matrix, the risk manager uses subjective judgements to determine the likelihood of the factors. However, monetary values are still required in order to determine the effect. The risk manager can use the simulation provided that the probability distribution of the factors can be estimated. The scenario analysis can be used to evaluate intangible factors; however, it may not be able to accurately determine the likelihood of the factors occurring.

One of AHP strengths is measuring intangibles factors. Chapter 4 discussed seven different problems addressed by AHP. All factors to the problems are intangibles and immeasurable.

- Making group decisions: The scenario analysis, decision tree, simulation and cost-benefit analysis do not specifically describe how to manage and aggregate group decisions. The risk matrix accommodates group decisions by aggregating individual risk scores. Normally, it is assumed that the group decision is made by consensus. Consensus group decisions have several limitations. For example, a more outspoken person could influence another member of the group. Even if the group manages to reach a consensus, a superior person may disagree with the decision. Therefore, the decision may not be implemented. None of the tools address the issue of group decision making.

  On of AHP strengths is making group decision. Chapter 4 provides discussion on how AHP make group decisions.

3.7 Risk Management and Decision Theory

Confronting uncertainty is an integral part of risk managers' responsibility. Firms hire risk managers to manage the complexities of managing risks and to make decisions under uncertainties. Risk managers need a decision-making process or tool that can incorporate complexities and uncertainties, and they need a decision-making theory. A decision theory is a theory of how individuals make decisions under uncertainty (Merkhofer, 1986). Common ground exists between decision theory and risk management. Decision theory addresses the issue of decision making under uncertainty, whereas risk management is about managing risks and uncertainties, and making optimum decisions in an uncertain environment. Decision theory provides a procedure or framework that utilises all available information to give the best possible logical decision (North, 1968). This thesis proposes that the two fields-risk management and decision theory-be joined together.

Decision theory consists of three areas: descriptive, normative and prescriptive. Each area is outlined below:

- Descriptive decisions are concerned with the problems that a decision maker actually solves. It is about how a decision is made in the real world, which is known as behavioural decision analysis (Tzeng and Huang, 2011). Descriptive decision theory belongs to the field of psychology. It uses psychological theory to explain how people make judgements and decisions. A famous theory under the descriptive model is the Prospect Theory (Kahneman and Tversky, 1979).

- Normative is about how a decision maker should ideally address a problem. Normative decision theory addresses the question of how an individual should behave when making risky choices. It is the standard for evaluation and defined as steps to make good judgements or decisions (Baron, 2012). For example, when solving a subtraction problem, normative does not actually make the calculation. Instead, it provides steps for problem-solvers to follow. Normative belongs to the field of philosophy and economy. A famous normative decision theory is the Expected Utility Theory (Bernoulli, 1954).

- Prescriptive decision is about the methods a decision maker should use to improve decisions. If a decision maker follows a prescriptive decision-making process, the likelihood of making a successful decision is improved Tzeng and Huang (2011). Prescriptive models are based on both theoretical foundations of normative decision theory and the observations of descriptive theory. They are designed to improve decisions and judgements. The models are developed and tuned to a specific problem situation and the needs of the decision makers (M.Dillon, 1998). Prescriptive decision theory is an applied field. The field belongs to decision science and operational research. The practical application of prescriptive decision theory is decision analysis.

Choosing a prescriptive decision model requires an understanding of descriptive decision theory. Understanding how risk managers make risky or uncertain decisions facilitates the selection of the best decision-making tool for risk management. Section 3.5 discusses the decision making challenges faced by risk managers. The section discusses decision making biases under uncertainties or in risky situations.

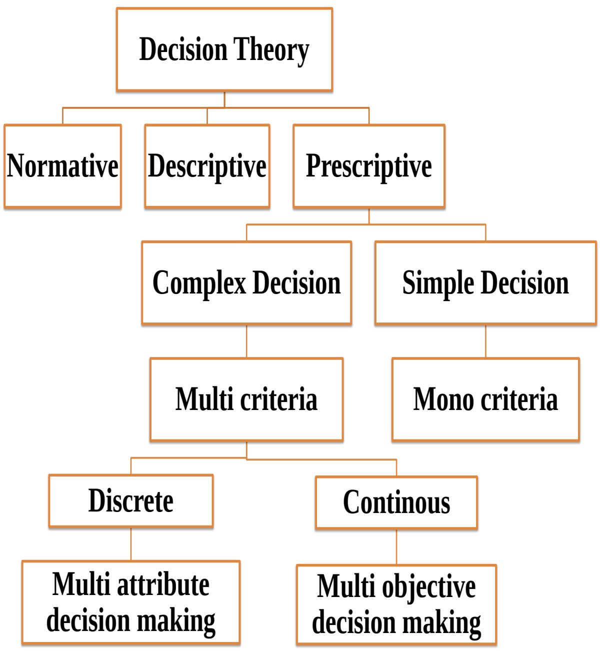
The following explains the relationship between normative, descriptive and prescriptive decision theory to risk management. Normative decision theory is the standard for evaluation. It provides a standard or ideal procedure for managing risk and uncertainties. Risk management processes or standards are an example of normative decision. Risk management provides steps for risk managers to follow to manage risks in an organisation. Descriptive decision theory explains risk managers' decision-making behaviour. It identifies risk managers' judgement biases. Prescriptive decision theory serves as a tool for decision making in risk management. It improves normative decisions and cures descriptive. Therefore, choosing a good prescriptive decision tool is important for risk management decision making, as the tool can improve risk managers' judgement on every phase of the risk management process, and it can cure judgement biases.

3.8 Choosing the Analytic Hierarchy Process as Decision Making Tool for Risk Management

This section explains the steps to choosing a decision-making tool for risk management. The goal of this thesis is to develop a decision-making tool that can handle the uncertainties and complexities of risk management problems. The section starts by explaining the components of decision theory, followed by how the AHP is selected. The AHP is a discrete multi-attribute decision-making (MADM) method. The discussion proceeds with how the AHP has the potential to assist risk management decision making.

Figure 3.2 presents the components of decision theory. To assist and improve decision making, risk management needs prescriptive decision theory. To address complexities, risk managers need the MCDM, which is one of the disciplines of operational research. MCDM is a prescriptive decision and concerned with the design of mathematical and computational tool to support the subjective evaluation of decision alternatives (Lootsma, 1999). MCDM is divided into multi-objective decision making (MODM) and MADM. These terms are commonly used to refer to the same class of models (Triantaphyllou, 2000). MODM is the study of continuous decision problems, while MADM focuses on discrete decision problems Doumpos and Zopounidis (2002). According to Triantaphyllou (2000), continuous decision problems are those with an infinite number of alternatives. Decision makers can only outline the feasible region of the alternatives, and each point in the region corresponds to specific alternatives. Discrete decision problems are those with a finite number of alternatives, which are predetermined and evaluated against a finite number of attributes or criteria. The MADM method is more suitable for risk management. The risks and alternatives of risk management problems are predetermined and discrete.

Figure 3.2: Components of Decision Theory



The decision-making literature has documented a variety of MCDM methods, such as the AHP, ELECTRE and Technique for Order of Preference by Similarity to Ideal Solution(TOPSIS) (Tzeng and Huang, 2011). This thesis aims to develop a decision-making tool to support risk management, manage complexities, address uncertainties and mitigate judgement biases. The tool should also support risk communication and documentation. Further, it should be prescriptive and able to improve normative and consider descriptive. This thesis proposes AHP as a decision-making tool for risk management. It is based on mathematics and psychology, and a prescriptive decision-making tool with a descriptive framework (Saaty, 2008b). AHP can be used to improve decision making in risk management and accommodate risk managers' decision-making behaviour.

Two approaches to modelling decision making are outcome and process oriented (Zeleny and Cochrane, 1982):

- The outcome-oriented approach is the normative decision analysis. If decision makers can correctly predict the outcome of the decision, they can understand the decision-making process.
- The process-oriented approach is descriptive, but it has both prescriptive and normative decision analysis in the approach. If decision makers can understand the decision-making process, they can correctly predict the outcome.

Risk management belongs to the outcome approach. If risk managers can correctly predict significant risks and actions to control the risks, they have successfully implemented risk management. The AHP belongs to the process-oriented approach. If risk managers understand the decision-making process, they can correctly determine which risk are important and plan actions to control the risks. AHP is an aid for risk management decision making. Following the AHP framework, in line with risk management principles enable risk managers to make reliable decisions.

Based on the previous discussions, AHP can be a decision making tool for risk management. The following are features of AHP that makes it suitable to address risk management problems.

- AHP can address biases in heuristic judgements. AHP decision making process such as problem structuring in a hierarchy, pairwise comparisons can address risk managers' decision-making behaviour. Risk managers' decision-making behaviour is under descriptive decision theory.

- AHP can address limitations of current risk management tools. For example, AHP can conduct group decision making and handle a large number of risks. The current tools have limitations to do group decision, and certain tools such as risk matrix and decision tree have limitations on number of risks to be included.
- AHP is based on decision making theory. Risk management is about managing risks and uncertainties, and risk management decision making is about making decisions in risky and uncertain situations. As discussed in Section 3.7, the theory for decision making under risks and uncertainties is decision theory. Decision theory is grouped into three: normative, descriptive and prescriptive. AHP is under prescriptive decision theory. According to the theory, if decision makers use a prescriptive method, they could improve their decisions.

3.9 Summary

This chapter discussed risk management and risk management decision making. Decision making is an essential part of risk management. As discussed in this chapter, every phase of the risk management process requires risk managers to judge and evaluate options and choose the best option. However, there are many challenges to making decisions under conditions of uncertainty and risk, and the current tools used by risk managers have limitations. In a complex world, risk managers need to have a decision-making tool to guide them to do systematic decision making. Organisations expect risk managers to be able to make decisions under conditions of uncertainty and risk. Therefore, risk managers need to have an established decision-making process to address uncertainties and risks. This chapter discussed the connection between risk management and decision theory. The decision-making tool proposed in this thesis belongs to prescriptive decision theory. To address complex risk management problems and to make decisions under uncertainty and risk, the decision-making tool needs to be theoretically sound, performed using analytic techniques and be methodologically defensible. The tool must be able to use subjective information to produce an objective outcome, and consider the psychological and cognitive biases of risk managers. The tool must also be simple and easy to use. As explained in this chapter, this thesis proposes the AHP as the decision-making tool.

The next chapter discusses the AHP, explains the AHP decision-making steps and discusses how the AHP addresses complex problems. The chapter also explains how to use the AHP for risk management problems.

4

The Analytic Hierarchy Process (AHP)

4.1 Introduction to Chapter 4

The decision-making tool developed in this thesis is based on the AHP. To provide an understanding of the tool, this chapter discusses the AHP and demonstrates its applications to complex problems, and discusses the reasons why people use the AHP.

The tool developed in this thesis is designed for complex risk management problems, which have their own characteristics. Therefore, decision making in risk management has its own elements, and the AHP has to be modified to satisfy these elements. This chapter discusses the elements of risk management decision making and modifications made to the AHP to accommodate these elements.

The goals of this chapter are to:

- present a detailed explanation of the AHP to provide an understanding of how this thesis exploits the AHP to develop a decision-making tool for risk management. (Section 4.2)

- explain how the AHP handles complex problems. (Sections 4.3 and 4.4)
- explain how the AHP needs to be modified to be used for risk management decision making. (Section 4.5)

4.2 AHP

Thomas L. Saaty developed the AHP while he was at Wharton Business School, University of Pennsylvania (Saaty, 1977). Saaty (1987a) defined the AHP as a theory of measurement to derive a ratio scale from both discrete and continuous paired comparisons. The comparisons can be actual measurements or fundamental scales reflecting relative strengths of preferences or feelings. The AHP is a framework to execute both deductive and inductive thinking. The framework requires considering several factors simultaneously and making numerical trade-offs between the factors to arrive at a synthesis or conclusion. The AHP concerns the measurement of both physical and psychological events. Physical comprises tangible factors, whereas psychological refers to intangibles, including subjective ideas, feelings and beliefs. The AHP deals with both physical and psychological factors without compromising either one.

The AHP uses a hierarchy to organise a complex and unstructured problem. A problem is deconstructed into parts or variables, and structured into a hierarchy. The hierarchy establishes relations between the parts or variables, and uses pairwise comparisons to elicit decision makers' judgements on the relative importance of the variables. The pairwise comparisons facilitate a trade-off between the variables. The judgements are translated into values and developed into a decision matrix. The values in the decision matrix are then converted into ratio scales. The AHP uses the eigenvector technique to derive the weights of the variables. Decisions are based on the variable with the largest weight.

The reasons for using the AHP include (Saaty, 1999, 2013):

- Manage complexity. The AHP integrates deductive and systematic approaches to address complex problems.
- Judgement consistency. The AHP tracks logical consistency of judgements used in determining priorities.
- Check decisions sensitivity. The AHP performs sensitivity analysis and revision at low cost.
- Synthesis decisions. The AHP leads to an overall estimate of the desirability of alternatives.
- Conflict resolution. The AHP incorporates judgments of several people and resolve conflicts between them.
- Measuring intangibles. The AHP provides a scale for measuring intangibles and a method for establishing priorities.
- Interdependence of the elements of a problem. The AHP addresses the interdependence of elements in a system and does not insist on linear thinking.
- Judgement and consensus. The AHP does not insist on consensus but synthesises a representative outcome from diverse judgement.
- Performance measurement. The AHP is a vehicle for monitoring and guiding organisational performance toward a dynamic set of goals.
- Flexible. The AHP complements other tools such as benefit-cost analysis or scenario analysis for selecting projects or activities.
- Hierarchic structuring. The AHP reflects the natural tendency of the mind to sort elements of a system into different levels and to group similar elements at each level.
- Process Repetition. The AHP enables decision makers to refine definition of a problem and to improve judgement and understanding through repetition.
- Trade-off. The AHP takes into consideration the relative priorities of factors in a system and enables decision makers to select the best alternative based on their goals. It enhances the capacity of decision makers to make explicit trade-offs.

- Unity. The AHP is a flexible model for a wide range of unstructured problems. It can be a single replacement for a variety of schemes for projecting the future and protecting against risk and uncertainty.

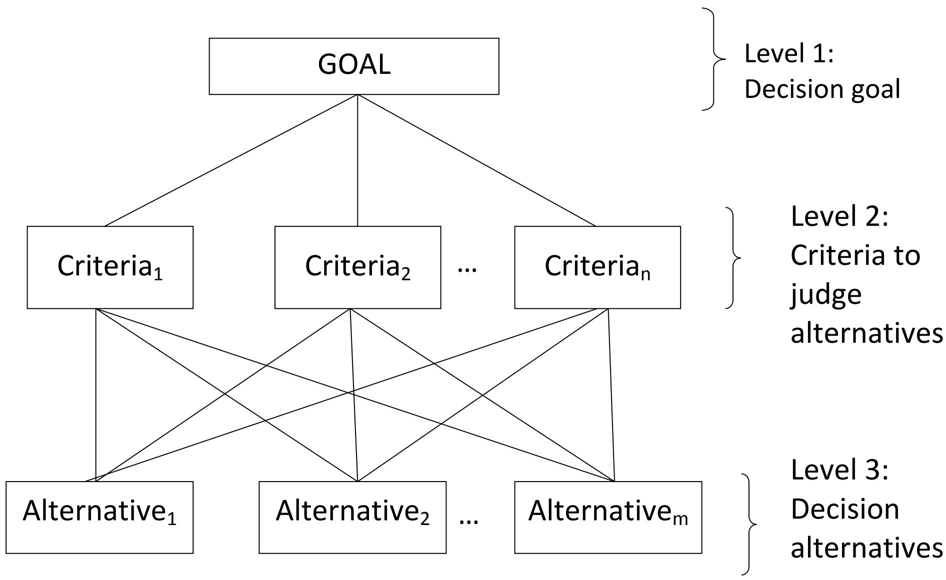
4.2.1 AHP Decision Making Steps

The following are the AHP decision making steps:

1. Understand the problem and define the goal of the problem. Decision makers need to consider the environment surrounding the problem and collect relevant information representing the problem as thoroughly as possible. The following aspects must be defined and identified: the decision goal, solutions, issues or attributes contributing to the solutions, and participants associated with the problem.

2. Organise the problem in a hierarchy. Figure 4.1 shows a basic three level hierarchy.

FIGURE 4.1: Basic Hierarchy



The following steps outline how to build a hierarchy (Saaty, 2010b):

- Define the purpose, goal or focus of the decision at the top level. The purpose or focus will be the desired state or goal of the problem. For instance, the goal could be the vision or mission statement of an organisation, or the target value of a performance measure.
- Break down the purpose, goal or focus into supportive elements. Break down the elements at the first level into sub-elements. For example, break down a system into sub-systems, units into sub-units and components into subcomponents. The elements should be comparable and homogeneous, or close in their possession of common attributes.
- Insert actors into a suitable level. Depending on the requirement, insert players or decision makers in the hierarchy.
- Establish the bottom level of choice. The bottom level of the hierarchy is the elements to be chosen or ranked. The elements should solve the problem if implemented. The elements can be alternatives, actions, consequences, scenarios or policies.
- Examine the hierarchy level forwards and backwards. Check and revise the elements and levels. The elements at the higher levels can be deconstructed into many elements at the lower levels. Elements at the lower levels should support elements at the upper levels.

The hierarchy has different types and structures. Table 4.1 presents the types and structures of hierarchies (Saaty, 2010b).

3. Evaluate preference for criteria and alternatives using pairwise comparisons. The AHP uses pairwise comparisons to determine the relative preference of alternatives for criteria. First, a decision maker decides which alternative is more dominant in the context of a criterion. Dominance means having properties that satisfy the criterion more. Second, the decision maker decides the intensity of dominance using a scale of 1 to 9.

TABLE 4.1: Types and Structures of Hierarchy

Structure	Top down	Emphasise on what is more important to drive the outcome.
	Bottom up	Emphasise on the virtues of the actions to be taken. The actions are influenced by the factors above.
Type	Single	The decision problem is represented by a single hierarchy. All elements are organised in a top down scheme. Single hierarchy is used to represent decisions with linear top down connections.
	Double	The consideration of decisions are separated into two hierarchies. One for benefits and another for costs.
	Complete	Elements in two adjacent levels are all connected.
	Incomplete	Elements in two adjacent levels are partly connected.
	Structural	Complex systems are structured into their constituent parts in descending order according to structural properties such as size, shape, colour or age. For example a structural hierarchy of the universe descend from galaxies to constellation to solar systems to planets, down to atoms, nuclei, protons and neutron.
	Functional	Complex problem is decomposed into constituent parts according to how the parts relate to each other. For example a conflict over school bus service. The problem can be structured into: (i) major stakeholder: communities, city official, board of education and federal government. (ii) stakeholders' objectives: education for children, retention of power. (iii) alternatives: complete, partial or no bus service.

4. Check consistency of the pairwise comparisons. The AHP uses CR to measure decision consistency. A CR of less than or equal to 10 per cent is acceptable. A CR above 10 per cent requires decision makers to revise their pairwise comparison judgements.

5. Calculate priority weight of criteria and alternatives. The AHP uses eigenvalues and eigenvectors to calculate the priority weight of the criteria and alternatives (Saaty, 1977). The eigenvector techniques require solving the equation $\mathbf{A}.\mathbf{p} = \lambda_{max}.\mathbf{p}$ to obtain the priority vector $\mathbf{p}$. $\mathbf{A}$ is the pairwise comparison matrix, $\mathbf{p}$ is the priority vector and λ_{max} is the eigenvalue. $\mathbf{A} = a_{ij}, i, j = 1, 2, \dots, n$. $a_{ij} = \frac{w_i}{w_j}$ is the ratio scale of the weight.

$$\begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} \begin{bmatrix} p_1 \\ p_2 \\ \vdots \\ p_n \end{bmatrix} = \lambda_{max} \begin{bmatrix} p_1 \\ p_2 \\ \vdots \\ p_n \end{bmatrix}$$

$$\begin{bmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \dots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \dots & \frac{w_2}{w_n} \\ \vdots & \vdots & \vdots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \dots & \frac{w_n}{w_n} \end{bmatrix} \begin{bmatrix} p_1 \\ p_2 \\ \vdots \\ p_n \end{bmatrix} = \lambda_{max} \begin{bmatrix} p_1 \\ p_2 \\ \vdots \\ p_n \end{bmatrix}$$

The unknown is $\mathbf{p}$. $\mathbf{A}$ is the consistent pairwise matrix. $a_{ij}, ij = 1, \dots, n$ is the judgement scale entered by the decision maker. λ_{max} is the sum of diagonal elements in matrix $\mathbf{A}$. λ_{max} is the principal eigenvalue of matrix $\mathbf{A}$.

The eigenvector associated with the principle eigenvalue of $\mathbf{A}$ is calculated as follows (Saaty and Vargas, 1982):

$$\lim_{k \to \infty} \frac{A^k e}{e^T A^k e} = Cw$$

e is the column vector unity, e^T is its transpose and C a positive constant. The results approximate λ_{max} and $\mathbf{p}$ accurately within computational capabilities.

The priority vectors can be approximated using average of normalized column (ANC), normalization of row averaged (NRA) or normalization of the geometric means of the rows (NGM).

Let $\hat{p}$ be the priority estimate.

$$\hat{p}(ANC) = \frac{1}{n}\sum_{j=1}^{n}\frac{a_{ij}}{\sum_{k=1}^{n} a_{ij}}$$

$$\hat{p}(NRA) = \frac{\sum_{j=1}^{n} a_{ij}}{\sum_{i,j=1}^{n} a_{ij}}$$

$$\hat{p}(NGM) = \frac{\prod_{j=1}^{n} {a_{ij}}^{\frac{1}{n}}}{\sum_{k=1}^{n}(\prod_{j=1}^{n} a_{kj})^{\frac{1}{n}}}$$

6. Aggregate the weights to obtain the overall priority weight of the alternatives. To calculate the overall or global ranking of the alternatives, combine the priority vector of each criterion into a single matrix. Multiply row of the matrix with the priority vector of the criteria and normalised. p_{ij} is the priority vector for criterion i against alternative j, $i, j = 1, \ldots, n$. $c_i, i = 1, \ldots, n$ is the priority vector of the criteria. $\gamma_i, i = 1, \ldots, n$ is the global priority vector of the alternatives.

$$\begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1n} \\ p_{21} & p_{22} & \cdots & p_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ p_{n1} & p_{n2} & \cdots & p_{nn} \end{bmatrix} \begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ c_n \end{bmatrix} = \begin{bmatrix} \gamma_1 \\ \gamma_2 \\ \vdots \\ \gamma_n \end{bmatrix}$$

4.3 AHP Application to Complex Problems

This section discusses AHP application to complex problems. The purpose of this section is to demonstrate how the AHP can deconstruct and disentangle complex problems into sub-problems and structure the problems into hierarchies. The hierarchy organises information relevant to a problem and enables decision makers to see the linkage between factors and alternatives. The hierarchy simplifies a problem without compromising its complexities. Deconstructing the problems enables decision makers to focus their thoughts and judgement on the smaller sub-problems. The judgements are then synthesised to obtain the overall judgement for the whole problem.

Generally, the AHP is used to choose one alternative among a set of alternatives, prioritise alternatives and rank or choose alternatives based on the evaluation of benefit and cost or benefit, cost and risks. Bushan and Rai (2004) reported that the AHP is used to make choices, prioritise or evaluate a set of alternatives, allocate resources, benchmark a process or system, and provide quality management. Forman and Selley (2002), Forman and Gass (2001) reported that the AHP is used to select one alternative from many, allocate resources and provide forecasting, total quality management, business process re-engineering, quality function deployment, a balanced scorecard, cost-benefit and resource allocation, and cost-benefit risk and resource allocation.

This section discusses seven types of problems: prioritisation; predicting; choice; benefit, cost and risk; benefit, opportunities, cost and risk; benefit cost analysis; and conflict resolution.

4.3.1 Prioritisation

Sudan Transport Projects

The earliest application of the AHP was to prioritise transport projects in Sudan (Saaty, 1977). The study aimed to prioritise transport projects and design a transport plan to relieve Sudan from transportation problems to meet the rising demand of an expanding economy. The study ranked the project in the order of priority to be implemented throughout 1985. The purpose of the project was to assist the Sudan government to secure investment funds from outside sources. Thirty individuals were involved in the study. The team members consisted of transportation engineers and economists, air transport specialists, system scientists and operational researches, planners, a management specialist, a financial analyst, econometricians and an agricultural economist. Included in the team were 15 Sudanese experts. The study involved the

Sudanese in every phase of the problem, as they would continue the project after the study ended. The complexities of the problem lay in the physical, economic and trade requirements for transport, and the major political and social needs of the country. Although considered relatively politically stable, the economic viability of South Sudan is poor compared to North Sudan. The current president was working hard to end the civil war and heal wounds through pacification between the opposing parties. Sudan is serviced by four modes of transport: rail, road, river and air. At the time of the study, Sudan's economy suffered from a lack of adequate transport, especially in the agriculture sector. The team identified Sudan's current transport options as follows:

- Air: Some cities are connected by small aircrafts.
- Rail: The British built a 3000-mile railroad network in the late nineteenth century. The track is a narrow, single track lying flat on the desert with no built-up bed or gravel. During the rainy season, from May to September, the tracks are flooded.
- Road: Only a few hundred miles are paved, and one-third is gravel. The rest of the roads are earth tracks and impassable in bad weather.
- River: The Nile is the traditional route for carrying cargo to and from the South. The trip takes nine days to complete. The route passes through the Sudd-the largest swamp in the world. The swamps interrupt the flow of the Nile. In the Sudd area, much of the Nile water is lost through evaporation. A major problem of the Nile is the growth of water hyacinths, which can wind around boat propellers.

The questions that the team needed to answer at the beginning of the study related to:

- For the rail lines, whether to change to standard gauge, to ballast or to raise the bed and double track. Each option would be costly for a poor country.
- Compared to rail lines, the road seems to be a desirable alternative. However, roads are less useful for large haulage and have higher tonne-mileage costs. Building a highway is costly. Which is better over the short run? Improve the rail

lines, build a highway or do both? Which is best for long-term planning and the effect of rising fuel costs?

- Most of the provincial capitals have airports that can accommodate small aircraft. These airports operate satisfactorily in good weather. In bad weather, landing and taking off is risky. The fleet requires navigational aids, and the airports need runway renovations and improvements to both instruments and visual flight rules. Should the airport take priority over other transportation investments?
- How could Sudan be connected to neighbouring countries such as Egypt, Kenya, Ethiopia, Uganda and Zaire for trade purposes? The current connection is by low-quality dirt roads.

The study used the anticipatory scenario construction to plan alternative strategies for Sudan's future transportation system. The problem was structured into a four-level hierarchy:

1. The decision goal was the overall welfare of the nation.
2. The four scenarios were:
    - Reference projection: Conservative 3.5 per cent annual expansion rate of the economy. The economy remains centred on agriculture, and the crops and methods of farming do not change much.
    - Agricultural export-oriented development: Strengthening the agricultural sector for exports. The scenario visualises annual growth from 7 to 8 per cent, implying a more rapid development of all sectors of the economy by 1985 compared to the first scenario. Under this scenario, the emphasis is to increase the capacity of the transportation system rather than improve the interregional connections within Sudan.
    - Balanced regional growth: The policy under this scenario is to increase agricultural production and raise the economic level of poorly developed regions to be similar to better-developed regions. Transportation planning emphasises the creation of efficient corridors connecting the various regions.
    - Arab-African regional expansion: This scenario is based on Sudan's possible

interest in serving as a link between the Arab and African worlds. The transport planning would attract Arab investments and promote economic transfer through Sudan in its role as an interface.

3. The Regions. Sudan has 12 regions: Bahr El Ghazal, Blue Nile, Darfur, East Equatoria, Gezira, Kassala, Khartoum, Kordofan, Northern, Red Sea, Upper Nile and West Equatoria.

4. The alternatives: the transport projects in the regions.

First, the team prioritised the four scenarios. Agricultural exports had the highest ranking, followed by balanced regional growth, Arab-African regional expansion and reference projection. Second, the regions were prioritised against the scenarios. Among the 12 regions, Khartoum is the most important, followed by the Red Sea. To determine the importance of the regions for investment purposes and the importance of the transport projects for each region, the projects were prioritised against the regions. For Khartoum, the highest priority for the transport project was to build a railroad between Atbara and Khartoum.

4.3.2 Predicting

Predicting the Recovery of the US Economy

In 1992, the AHP was used to address two critical issues in order to forecast the recovery of the timing and strength of the US Economy (Saaty, 2010a). The objectives of the study were to forecast the most likely date of turnaround and the strength of the recovery. The timing incorporated the sequence of global events of the previous two and a half years from the date of the study. A global event was defined as an event shaping the restructuring of global resources and institutional arrangements. For the strength of recovery, the study analysed how restructuring acts as a moderating influence on the performance of key macroeconomic variables connected to the US economic cycle.

The problem was structured into a four-level hierarchy.

1. The decision goal was to determine the date of recovery of the US economy.

2. The factors influencing or driving the economy were conventional adjustment and economic restructuring.

3. The sub-factors: Factors at level 2 were deconstructed into sub-factors. Conventional adjustment was deconstructed into consumption, exports, investment, fiscal policy, monetary policy and confidence. Economic restructuring was deconstructed into financial sectors, defence posture and global competition.

4. The alternatives or the timeframe: The adjustment period required for economy turnaround was 3, 6, 12 and 24 months from the study date..

The conventional adjustment and economic restructuring were time-dependent. The relative importance of the factors and sub-factors depended on the four periods representing the forecast timeframe. The bottom level of the hierarchy-the timeframe-was used to compare the factors and sub-factors creating an interactive loop. This type of hierarchy is known as holarchy.

The following list presents the pairwise comparison questions for each level of the hierarchy:

- Determining the relative importance of sub-factors for each factor: For conventional adjustment, the question asked is: Which sub-factors have a greater influence on conventional adjustment, and how strongly? For example, between consumption and exports, which sub-factor has a greater influence on conventional adjustment?

- Determining the relative importance of sub-factors for time: Compare the timeframe against the nine sub-factors; six for conventional adjustment and for economic restructuring. The question asked was: Which timeframe is more likely to indicate a turnaround if the sub-factor is the sole driving force? For example, between three and six months, which timeframe is more likely to indicate a turnaround if consumption is the driving factor?

- Determining the relative important of the two factors to time: The two factors at the top of the hierarchy were compared for the timeframe. The question asked was: Between conventional adjustment and economic restructuring, which factor is more likely to dominate a specific timeframe, and how strongly? For example, compare conventional adjustment and economic restructuring. Which factor is more dominant for the three-month timeframe?

To predict the strength of recovery, a similar but conventional hierarchy was developed. The bottom level was the predicted strength of recovery. The hierarchy was as follows:

1. The decision goal was to determine the strength of the recovery of US economy.
2. The factors influencing or driving the economy: conventional adjustment and economic restructuring.
3. The sub-factors for conventional adjustment and economic restructuring.
4. The alternatives, or the strength of recovery: very strong (5.5-6.5 per cent GNP), strong (4.5-5.5 per cent GNP), moderate (3.0-4.5 per cent GNP) and weak (2.0-3.0 per cent GNP).

The study predicted that the economic turnaround would be 10.45 months from early January 1992, with moderate strength of recovery of 3.6 per cent.

4.3.3 Choice

Selecting Student for Admission to Katz Business School.

The AHP was used to model student admissions to Katz Business School, University of Pittsburgh (Saaty et al., 1991). The purpose was to assist the graduate school admission committee to handle the complexities of admission procedures and reduce processing time, and to assist the committee in making trade-offs on both the measurable and intangible attributes of the applicants. The study developed a five-level hierarchy student admission model as follows:

1. The decision goal was to select the best applicant.
2. The criteria were qualitative and quantitative attributes of the applicants.
3. The criteria were deconstructed into sub-criteria.

  - The quantitative criteria were deconstructed into undergraduate information and GMAT score.
  - The qualitative were deconstructed into applicant information and work experience.

4. The sub-criteria were deconstructed into sub-sub-criteria.
  - Undergraduate information was deconstructed into school, major and GPA.
  - GMAT score was deconstructed into verbal, maths and total.
  - Application information was deconstructed into essay, letter of recommendation, academic awards and activities.
  - Work experience was deconstructed into number of years and type of work.
5. The Attributes. Level 5 was the groups or attributes for each sub-sub-criteria
  - School was categorised into extremely competitive, very competitive, competitive, average and below average.
  - Undergraduate major was grouped into engineering, business, liberal/arts and science.
  - GPA was divided into over 3.6, 3.25-3.60, 3.0-3.24, 2.75-2.90 and under 2.75.
  - GMAT verbal score was divided into 30 and over, 24-29, 20-23 and below 20.
  - GMAT Math score was divided into 30 and over, 24-29, 20-23 and below 20.
  - GMAT total score was divided into 600 and up, 550-599, 510-549, 480-509 and under 480.
  - Essay was graded into outstanding, very good, average, below average or poor.
  - Letter of recommendation was categorised into outstanding, very good, average, below average or poor.
  - Academic awards was categorised into outstanding, very good, average, below average or poor.

- Student activities was categorised into outstanding, very good, average, below average or poor.
- Number of years was divided into 5 or more, 3-5, 1-2 or less than 1 year.
- Type of work was grouped into business professional, business non-professional, other professional or other non-professional

The admission committee judged the importance of the criteria, sub-criteria and attributes. After the overall weights were generated, the applicants were rated against the criteria. The maximum score for the applicants was 1.00 and the minimum score was 0.124. The model provided a systematic and consistent decision-making process. Applicants were evaluated on a single set of weighted criteria. Applicants with the highest score were chosen and admitted to the graduate school. The AHP reduced the subjectivity of the decision-making process and the time taken to make admission decisions.

4.3.4 Benefit Cost Risk

Prioritise Alternatives to Sustain Metropolitan Growth

Saaty (1999) demonstrated AHP application to a sustainable metropolitan growth problem. Choosing alternatives to sustain metropolitan growth is a complex issue. Decision makers need to consider several potential alternatives, evaluate the alternatives in term of costs and benefits, and consider risks that could arise from the alternatives. The problem had nine alternatives, which were evaluated in terms of benefit, cost and risk effects to sustain metropolitan growth. The goal was to determine the best alternative to support growth. The best alternative was the alternative with maximum benefits and minimum costs, and risks justifying the benefits and costs. To make a decision by considering benefits, costs and risks, the problem was structured into three hierarchies. The benefit hierarchy evaluated the alternatives for the largest benefit. The cost hierarchy evaluated the alternatives for the lowest cost. The risk hierarchy evaluated the alternatives for the lowest risk.

The following shows how the AHP deconstructed and structured the problem. The benefit, cost and risk hierarchies had the same alternatives but different criteria. The alternatives of the problem are as follows:

- support industries.
- expand port.
- build infrastructures such as roads, telecommunication or banking.
- improve regional connections.
- improve quality of life.
- reduce taxes.
- foster increased tourism.
- provide lands for expansion.
- status quo or do nothing.

The benefit hierarchy had three levels:

1. The decision goal was to rank alternatives with the highest benefit.
2. The criteria were to create jobs, increase tax base, increase quality of life and improve infrastructure.
3. The alternatives.

The first comparison was to evaluate the criteria for the decision goal. The question asked was: Which criterion is a more important benefit? For example, compare creating jobs and increasing the tax base. Which criterion is a more important benefit? The second comparison was to evaluate the alternatives against each criterion and decide which alternative would yield the highest benefits with respect to the criterion. For example, in terms of job creation, compare building more infrastructures and improving quality of life. Which alternative would yield a greater benefit for jobs creation?

The cost hierarchy had four levels:

1. The decision goal was to rank alternatives with the highest cost.
2. The cost criteria were physical, social and environmental.
3. Sub-criteria: The cost criteria at level 2 were deconstructed into sub-criteria:

- Physical costs were deconstructed into roads, sewage, water, police, fire safety, schools and power.
- Social costs were deconstructed into crime, traffic, deaths, poverty and government.
- Environmental costs were deconstructed into ecosystem, air pollution, water pollution, noise pollution and waste management.

4. The alternatives.

The questions that the decision makers had to answer were: Which criterion is a more important cost? Which sub-criterion is a more important cost for a criterion? Which alternative incurs a greater cost for a sub-criterion?

The risk hierarchy had four levels:

1. The decision goal was to rank alternatives with the highest risks.
2. The risk criteria were economic, social and environmental.
3. Sub-criteria: The risk criteria at level 2 were deconstructed into sub-criteria:

- Economic risks were deconstructed into recession, decreased job, no growth, business failure and negative rate of return
- Social risks were deconstructed into decreased health, increase crime and quality of life decreased.
- Environment risks were deconstructed into increased traffic, emissions and garbage.

4. The alternatives.

The questions that the decision makers had to answer were: Which criterion is a more important risk? Which sub-criterion is a more important risk for a criterion? Which alternative incurs a greater risk for a sub-criterion?

Table 4.2 shows the ranking of the alternatives according to benefit, cost, risk, benefit-cost ratio, and benefit-cost-risk ratio.

Table 4.2: Priority Weight of Alternatives

	Industry	Port	Infra	Region	Life	Tax	Tourism	Land	Status
Benefit (B)	0.191	0.128	0.125	0.113	0.104	0.103	0.092	0.091	0.052
Cost (C)	0.235	0.172	0.104	0.135	0.085	0.060	0.098	0.066	0.044
Risk (R)	0.204	0.164	0.088	0.189	0.054	0.044	0.106	0.070	0.082
B/C	0.813	0.744	1.202	0.985	1.224	1.717	0.939	1.379	1.182
(B/C)/R	3.984	4.537	13.659	5.212	22.667	39.023	8.858	19.70	14.415

4.3.5 Benefit Opportunities Cost Risk

Choosing the Best Strategy Towards Iran

Saaty (2010b) demonstrated the AHP benefit-opportunities-cost-risk (BOCR) approach to analysing strategies regarding Iran. The AHP was used to determine the strategic policy to pursue towards Iran seeking to obtain weapon-grade nuclear material. The threat of war in Iran is a complex and controversial issue. The problem involved several stakeholders and possible strategic policies. It involved 40 people divided into groups of four and five. The goal of the decision was to determine a strategic policy to pursue regarding Iran. The following demonstrates how the AHP deconstructed the problem:

1. Strategic Criteria. The group identified four strategic criteria: world peace, regional stability, reduce volatility and reduce escalation of the Middle East problem. The strategic criteria were used to evaluate the BOCR merits. The criteria were overriding criteria to determine which decision to make first, as well as the relative advantages and disadvantages of the decision. The priorities of the strategic criteria were: world peace (0.361), regional stability (0.356), reduce escalation of the Middle East problem (0.196) and reduce volatility (0.087). The values in the parentheses are the weight of the criteria. The priorities were obtained from a pairwise comparisons matrix for a decision goal of long-term peace. The results showed that world peace had the highest priority. The BOCR merits were then evaluated against the strategic criteria. The ranking of the merits was as follows: benefit (0.254), opportunities (0.118), cost (0.314) and risk (0.314). Cost and risk had the equal and highest weight. Therefore, decisions on the cost and risks

of the alternatives were given the highest priority.

2. Control Criteria. The group identified four criteria: economic, political, rule of law and security. The alternatives were evaluated using the criteria.

3. Actors. The stakeholders or countries mainly concerned with the problem were the United States, Iran, Russia and China, Middle Eastern countries and Israel.

4. Alternatives. The group identified six alternatives or policies:

    - undertake aerial strike towards Iran.
    - apply economic sanctions against Iran.
    - conduct a ground invasion of Iran.
    - Israel undertakes actions towards Iran.
    - do nothing: leave the situation as it is.
    - make an effort to make a regime change.

The group developed four hierarchies for the benefit, opportunities, costs and risk. The benefit hierarchy was to determine which alternative would be more beneficial. The opportunities hierarchy was to determine which alternative would have the greatest potential for benefits. The cost hierarchy was to determine which alternative would be more costly. The risk hierarchy was to determine which alternative would have the highest potential risks. Each hierarchy had four levels. The first level was the decision goal, the second level was the control criteria, the third level was the actors and the fourth level was the alternatives.

For example, the cost hierarchy was:

1. the decision goal was to determine the alternative with the least cost

2. control criteria.

3. actors or countries affected

4. alternatives.

The study produced four rankings of alternatives for each merit. Table 4.3 shows the weight of the alternatives. The ranking of the alternatives from each merit, and the local ranking of the merit were synthesised to obtain the overall ranking of alternatives.

Table 4.3: Weight of Alternatives for BOCR Merit

Alternative	Benefit	Opportunities	Cost	Risk
Aerial strike	0.402	0.891	0.179	0.259
Economic sanction	0.586	0.496	0.271	0.221
Ground invasion	0.258	0.378	1.000	0.368
Israeli action	0.414	0.136	0.365	1.000
Do nothing	1.000	0.666	0.124	0.112
Regime change	0.651	1.000	0.189	0.165

Table 4.4: Overall Ranking of the Alternatives

Alternative	Benefit	Opportunities	Cost	Risk	BO/CR	bB+oO-cC-rR
	b=0.254	o=0.118	c=0.314	r=0.314		
Aerial strike	0.402	0.891	0.179	0.259	7.711	0.069
Economic sanction	0.586	0.496	0.271	0.221	4.841	0.053
Ground invasion	0.258	0.378	1.000	0.368	0.265	-0.319
Israeli action	0.414	0.136	0.365	1.000	0.155	-0.308
Do nothing	1.000	0.666	0.124	0.112	48.077	0.258
Regime change	0.651	1.000	0.189	0.165	20.814	0.172

Table 4.4 shows the overall ranking. Benefit and opportunities were positive merits. Cost and risk were negative merits. Based on the ranking, doing nothing was the best, and ground invasion was the worst alternative.

4.3.6 Benefit Cost Analysis

Benefit and Cost of Riverboat Gambling

The AHP addressed the issue of whether riverboat gambling should be permitted on Pennsylvania rivers and lakes Saaty and Vargas (2012a). The Pennsylvania House of Representative was considering a bill to authorise riverboat gambling. Saaty and Vargas (2012a) used the AHP to answer the questions: What are the effects on the state? What are the potential benefits? What are the possible costs? Answers to these questions provided a recommendation of whether to legalise riverboat gambling.

Supporters of the bill stated the following benefits to legalising riverboat gambling: stimulate local business; encourage economic development; provide additional tax revenue for the government; create new jobs; increase tourism; and reduce illegal gambling. Opponents of the bill stated the following problems: increased illegal gambling, social problems and street crime; prostitution; drug trafficking; increased corruption, extortion and bribery among public officials; and organised crime. To address the concerns of both groups, two hierarchies were developed: benefit and cost.

The benefit hierarchy had seven levels as the following:

1. The decision goal was whether to legalise riverboat gambling.

2. The criteria were gambling benefits for economic, political, social and government.

3. The decision makers were the state government, citizen and lobbies.

4. The benefits were:

    - increased social opportunities, which are defined as improved standard of living and access to a variety of entertainment.

    - increased economic development in terms of more employment and business opportunities

    - more revenue gains for local business and the government.

5. Groups affected by the bill were citizens of Pittsburgh, riverboat operators, local business and government.

6. Objectives or issues of each group were:

    - For citizens of Pittsburgh, the objectives were a variety of entertainment, potential tax relief and increased job opportunities.

    - For riverboat operators and local businesses, their objectives were business development opportunities and increased employment, tourism and national recognition.

- For the government, the objectives were increased tax revenue, reduced illegal gambling and, improved the image of Pittsburgh and Pennsylvania.

7. The alternatives were to authorise or not authorise riverboat gambling.

The cost hierarchy had seven levels:

1. The decision goal was whether to legalise riverboat gambling.
2. The criteria were gambling costs to economic, political, social and environment.
3. The decision makers were the state government, citizen and lobbies.
4. The costs were damage to environment, potential economic loss to small gamble operators, social problems and regulation difficulties
5. The groups affected by the bill were riverboat operators, citizens of Pittsburgh, local gambling businesses, government, other river users and environmentalists.
6. Objectives or issues of each group were:
    - For riverboat operators, the issues were regulation of gambling activities and competition for gambling operations.
    - For citizens of Pittsburgh, the issues were safety and increased crime, increased traffic and crowds, and moral addiction.
    - For local gambling businesses, the issues were cannibalism of other legal gambling operations, the cannibalism of Pennsylvania state lottery, government services and law enforcement and waste services.
    - For the government, the issue was regulation of gambling operations.
    - For other river users, the issues were increase river usage and the need for safety.
    - For the environmentalists, the issue was increase pollution.
7. The alternatives were to authorise or not to authorise riverboat gambling.

The decision makers were interviewed to determine the importance of the costs and benefit factors. The groups affected by the bill were also interviewed on the respective issues. The following outputs from the study were noted:

- Criteria: For gambling benefits, economic had the highest priority. For gambling cost, social had the highest priority.
- Decision makers: State government and citizens were rated equally important for benefit and cost.
- For gambling benefits, social opportunities had the highest priority. For gambling cost, social problem had the highest priority.
- Group affected by riverboat gambling: For gambling benefit, Pittsburgh citizens were most affected by social opportunities. Riverboat operators and local businesses were most affected by economic development and revenue gain. For gambling cost, Pittsburgh citizens and environmentalists were most affected by damage to the environment. Citizens of Pittsburgh were most affected by potential economic loss and social problems. Riverboat operators and the government were most affected by regulation costs.

The final part of the judgement was to rate the alternatives against the objectives or issues of each group. For the benefit hierarchy, the alternative to legalise riverboat gambling was weighted most heavily under increased tax revenue, diversification of services for riverboat operators and varieties of entertainment for citizens. For the cost hierarchy, the alternative to legalise riverboat gambling was weighted heavily under moral addiction to gambling, regulation and government services. The weighted judgements were synthesised to obtain a benefit-cost ratio for the alternatives. The process produced a benefit-cost ratio of 0.851/0.877 for authorising riverboat gambling and a ratio of 0.149/0.123 for not authorising riverboat gambling. The results indicated that riverboat gambling should not be authorised. Six months after the study, the Pennsylvania House of Representatives rejected the bill to legalise riverboat gambling by a vote of 118 to 81.

Benefit and Cost of Medical Service Alternatives

Westmore County Hospital in Western Pennsylvania employed the AHP to develop medical service alternatives and to choose the best alternative from the standpoint of patients, hospital, the community and society (Saaty, 2001). The hospital was concerned with the costs of facilities and workers to take care of terminally ill patients. Normally, terminally ill patients do not need major medical attention compared to other patients. They need medical attention occasionally, and most of the time they need psychological support. The limited resources of the hospital should be utilised for patients requiring medical attention from specialists and advanced technology equipment.

Two hierarchies were developed for the hospital: benefit and cost. The hierarchies provided a clear and straightforward description of the problem to the representatives of the hospital. The benefit hierarchy had five levels:

1. The decision goal was to choose the best hospice.
2. The criteria were recipient, institutional and societal benefits.
3. The sub-criteria: The benefit criteria at level 2 were deconstructed into sub-criteria, except for societal benefit, which remained a single criterion:
   - The recipient benefit was deconstructed into physical, psycho-social and economic.
   - The institutional benefit was deconstructed into psycho-social and economic.
4. Tertiary criteria. The sub-criteria at level 3 was deconstructed into tertiary criteria.
   - Physical was deconstructed into direct care of patient and palliative care.
   - Psycho-social was deconstructed into volunteer support, networking with families, relief of post death distress, emotional support to family and patient, and alleviation of guilt.
   - Recipient economic was deconstructed into reduced costs and improved productivity.
   - Psycho-social was deconstructed into publicity and public relations, volunteer recruitment and, professional recruitment and support.
   - Institutional economic was deconstructed into reduced length of stay, better utilisation of resources and, professional recruitment and support.

- The criteria societal benefit at level 2 was deconstructed into two tertiary criteria, death as a social issue, re-humanisation of medical, professional, and health institution.

5. The alternatives were Model 1-hospital provides full care to the patients, Model 2- the family cares for the patient and the hospital provides emergency care and Model 3- the hospital and home share patient care.

The cost hierarchy had five levels:

1. The decision goal was to choose the best hospice.
2. The cost criteria were the community, institution and society.
3. The sub-criteria. The criteria at level 2 were deconstructed into sub-criteria as follows. Institutional cost was deconstructed into capital, operating, education, bad debt and recruitment. Community and society costs remained as single criteria.
4. Tertiary criteria. Education was deconstructed into community and staff training. Recruitment was deconstructed into staff and volunteers. Capital, operating and bed debt remained as a single sub-criteria.
5. The alternatives were the same alternatives as the benefit hierarchy: Model 1, 2 and 3.

Members of the hospital planning association answered the pairwise comparison questions and evaluated the alternatives. The alternatives were evaluated with respect to each criteria, sub-criteria and tertiary criteria. It was a process to trade off one criterion against another to arrive at the best hospice model for the hospital. Model 3 had the highest benefit cost ratio, and the hospital chose this model to treat terminally ill patients.

4.3.7 Conflict Resolution

Saaty (1999) stated that conflict problems are deeply entrenched. Even though none of the parties like the conflict, they are reluctant to compromise for fear that compromising might weaken their position and undermine their existence. The following

Table 4.5: Conflicting Parties and Objectives

Party	Objectives
British	Maintain sphere of influence.
	Maintain good relations with Northern Ireland.
	Maintain good relations with the Republic of Ireland.
	Maintain good relations with any newly formed government.
	Power shares between the majority and minority communities.
The Protestant Allegiants	No links with the Republic of Ireland.
	Maintain Northern Ireland as a separate state.
	Maintain British connection.
	No Irish nationalist in policy making positions.
	Economic well-being of the state.
The Catholic Moderates	Power sharing in the government.
	Political structure to reflect Irish dimension.
	Economic well-being of the state.
Dublin	Stability of the Republic of Ireland.
	Joining the two countries together,
	Re-election
	British markets in Dublin.
Ireland Republican Army	A United Ireland and drive British out.

application of the AHP to conflict resolution shows that addressing a conflict requires a productive debate between conflicting parties, deconstructing issues of the conflict into small sub-issues, and promoting give and take between the parties to find the best way out of the conflict.

Conflict in Northern Ireland.

Alexander and Saaty (1977), Saaty (1999) used the AHP to resolve the conflict in Northern Ireland. The conflict in Northern Ireland involved several parties pursuing different outcomes. Table 4.5 presents parties to the conflicts and their objectives.

The alternatives or political structures were:

- a united Ireland

- integrated parliament of Great Britain and Northern Ireland
- a colonial assembly with a strong Council of Ireland
- a colonial assembly without a strong Council of Ireland
- a totally sovereign legislature with a strong Council of Ireland
- a totally sovereign legislature without a strong Council of Ireland

The information was organised in a four-level hierarchy:

1. The decision goal was to determine the political structure for Northern Ireland.
2. The conflicting parties.
3. The objectives of each party.
4. The alternatives.

The first pairwise comparison was judgement on the relative power of the conflicting parties. The second was judgement on the relative strength of the objectives of each party. The objectives of each party were compared and evaluated against the party. The last part was to evaluate the alternatives or political structures against the objectives of each party to determine which political structure was more satisfactory to the objectives.

The study produced the ranking of the political structures as the following:

1. a totally sovereign legislature without a strong Council of Ireland
2. a totally sovereign legislature with a strong Council of Ireland
3. a colonial assembly with a strong Council of Ireland
4. an integrated parliament of Great Britain and Northern Ireland
5. a united Ireland
6. a colonial assembly without a strong Council of Ireland

Conflict in South Africa.

Tarbell and Saaty (1980) used the AHP to analyse conflict in South Africa. For more than 75 years, black people in South Africa struggled to organise opposition to legislate policies of the apartheid regime. The policies included citizenship and voting restrictions, mixed marriage restrictions, jobs reservations laws, separation of residence, blacks' basic rights of free assembly, political self-determination and social justice. The recent emergence of independent black-ruled Zimbabwe ignited the movement of black youth in South Africa. The youth were aiming for a possible similar transition in South Africa.

The study developed a four-level hierarchy:

1. The decision goal was to determine the best possible outcome to solve the conflict.
2. Parties involved in the conflict were the South African government, black majority, white minority, the US, Western Europe (which had more business interests in South Africa compared to the US), external and internal business interests (particularly investors in gold, diamond, chrome, iron ore and uranium), and the Soviet Union.
3. Each party objectives with respect to the conflict:
   - South African Government:
     - appease white electorate
     - consolidate apartheid by commitment to racial separation and subordination
     - suppress black revolutionary opposition
     - protect economic interests
     - gain worldwide sympathy through propaganda
     - resist communist intrusion.
   - Black Majority:
     - provide for majority rule and abolishes apartheid
     - insure economic equality.
     - provide for basic human rights for blacks
     - oppose intrusion of big-power politics.
   - White Minority:

  - maintain apartheid in the economic and political sense
  - minimize outside intervention into internal matters
  - abolish petty apartheid
  - protect profitability of business interests.
- United States:
  - maintain commitment to human rights
  - curb communism
  - secure peaceful settlements in region surrounding South Africa
  - protect US investments and trades with South Africa
  - assure transition to equal power sharing with minimal violence.
- West:
  - protects investment and trade
  - assure black self-determination
  - curb communism
  - ensure human rights
  - remain neutral in the conflict.
- Business:
  - protect trade and internal investments
  - ensure continuation of economic situation
  - curb communism.
- Soviet Union:
  - support revolutionary blacks and leaders
  - gain political influence in South Africa
  - minimise Western and Chinese influence
  - disrupt economic trade and investment by West in South Africa.

4. The alternatives.
   - Bantustan policy: This policy maintains the homelands where black people are allowed to reside. The difference from the status quo is that this policy allows ownership of land by black people, as well as citizenship in their

respective homelands or Bantustans.

- Abolition of apartheid: This policy relates to the reduction of social discrimination against black people, who are allowed access to basic services, facilities and social organisations.
- National conference: Representatives from each group decide on the power sharing and transitional arrangements for the equitable governing of South Africa.
- Three parliaments: A constitutional reorganisation of three parliaments formed by black people, Indians and white people. An executive president presides instead of a prime minister.
- Revolution: The aim is to create a violent uprising by the black community. The goal is to overthrow the apartheid regime and bring about heavy violence against white people.

Each level of the hierarchy was evaluated with respect to the elements of the next higher level. At the second level, the parties involved in the conflict were evaluated against the decision goal to determine which parties had more influence on the outcome of the conflict. At the third level, each party objective was evaluated against each party to rank the objectives for each party. At the fourth level, the alternatives were evaluated against each objective to prioritise the contribution of the alternatives to the objectives.

From the pairwise comparisons, the ranking of the alternatives were: (1) Bantustan policy; (2) abolish apartheid; (3) national conference; (4) three parliaments; and (5) revolution. The study produced 18 recommendations. The top recommendations were to release Nelson Mandela, remove apartheid and grant full citizenship and equal rights to the black majority.

Conflict in Middle East

Saaty and Zoffer (2013)applied the AHP to the Israeli-Palestinian conflict. Saaty and Zoffer (2013) defined the conflict as retributive. A retributive conflict is one in which both sides profess to desire a solution, but are actually committed to inflicting pain on the other party.

The study speculated that the following factors have impeded the Israeli-Palestinian conflict solutions: (i) the difference in power between the parties involved-major power resides in the Israeli community; (ii) delaying the settlement has advantages for both sides; (iii) the Israeli government places a higher priority on addressing threats by Iran compared to making immediate peace with the Palestinians; (iv) both parties feel that the current US administration is not totally supportive of either the Israeli or Palestinian parties; and (v) most analysts believe that only a two-state solution has the chance of resulting in long-lasting peace. The Palestinians agreed with the solution; however, the Israelis felt that the solution was unacceptable

The first task for the participants was to identify all of the possible issues to be addressed, and to categorise the issues according to similar attributes. The categories were geographic and demographic, political, political behaviour, economy and business, education, social, military, security, and religious and ideological. The second task was to identify all of the possible concessions to the issues. To develop measurements for the prioritisation of the concession, the gains and losses of each concession for both parties were identified. The participants determined: (i) gains from the other party's concessions; (ii) costs from their own concessions; (iii) perceptions of the other party's costs from the other party's own concessions; and (iv) perceptions of the other party's gains from their own concessions. Based on the gains and losses, the participants developed eight hierarchies, and each hierarchy had different goals. For example, the Israeli benefits from the Palestinian concessions were one decision goal, and the Palestinian benefits from the Israeli concession were another decision goal. Four hierarchies were for the Israelis, and four were for the Palestinians.

The second level of the hierarchies was the criteria for judging the contributions of the concessions to benefits, costs, perceived benefits and perceived costs of both parties. The third level was the concessions. Each participant made pairwise comparisons of the criteria in terms of how important the criterion was for achieving the goal. Next, the participants rated the importance of each concession with respect to each criterion to determine how strongly the concessions contributed to the criteria.

The ratio of benefits and costs, and the ratio of perceived benefits and perceived costs for the Israelis and Palestinians were then calculated. A ratio of less than one was made equal to zero to signify that a trade-off was not acceptable. The ratios measured trade-offs among concessions based on two criteria: (i) both parties receive as much as possible from the concessions; and (ii) gains from the concessions for both parties must be as close as possible (Saaty and Vargas, 2012b).

The study produced the Israeli-Palestinian Pittsburgh Declaration of Principles August 2011 (also known as the Pittsburgh Principle), which is outlined below (Saaty and Zoffer, 2013, pg. 1321):

- A two-state solution on the borders from 4 June 1967, with mutually agreed upon land swaps.

- Israel must respect the integrity of the West Bank and Gaza by allowing free and safe passage between the two areas. The Palestinian State must guarantee that any agreement reached with Israel will be accepted and supported by the majority of the Palestinian people, both in Gaza and in the West Bank.

- East Jerusalem will be the capital of the Palestinian State. Both parties will maintain the status quo of the holy places in Jerusalem.

- Acknowledge Israel's existence as a Jewish State without jeopardising the rights of its minority Israeli citizens.

- Evacuate Israeli settlers from the Palestinian territories not included in the land swaps.

- Palestine gains full control of the borders of the Palestinian State and its outlets. Deployment of a temporary agreed upon multinational military monitoring system in the Jordan Valley.

- Solve the Palestinian refugee problem in a fair and agreed upon manner.

- A demilitarised Palestinian state.

- Agreed upon international monitoring mechanism and binding international arbitration mechanisms.
- The full implementation of these principles concludes the end of the conflict and the claims of the two parties.

4.4 AHP Strengths and Limitations

This section discusses the AHP's strengths and limitations.

4.4.1 Strengths

Easy to Use

Saaty (1999, pg. 32) compiled the following ease-of-use reasons given by AHP users:

- It is a natural way to make decisions. People are attracted rather than alienated by the AHP.
- It does not need advanced technical knowledge; therefore, everyone can use it. It takes approximately an hour to introduce the AHP to students and for them to complete substantial examples.
- It takes into consideration judgements based on feelings and emotions, as well as thoughts.
- It deals with both intangibles and tangibles.
- It derives scales through reciprocal comparisons rather than by assigning numbers directly from the mind.
- It does not take scale measurements for granted; instead, it interprets scale values according to the objective of the problem.
- It relies on simple but elaborate hierarchic structures to represent decision problems. This enables decision makers to handle problems of risks, conflict and prediction.

- It is useful for resource allocation, benefit cost analysis, resolving conflicts, and designing and optimising systems.
- It uses an approach that describes how a good decision is made rather than prescribing how a decision should be made.
- It is a simple and effective procedure for arriving at an answer. The AHP is useful for group decision making that requires the consolidation of diverse expertise and preferences.
- It is useful for conflict negotiations. The AHP decision-making process focuses on relative relations between the benefits and costs of the conflicting parties.

Simplify Complex Problems.

The AHP provides a simple approach to decision making (Saaty, 2010b). It is designed for decision makers to use intuition and rational thinking to choose relevant alternatives and criteria for a problem. The AHP structures the alternatives and criteria in a hierarchy. Saaty (2010b) stated that a hierarchy is a basic device used to deconstruct a complex situation. The hierarchy organises information from the general at the highest level to the particulars at the bottom level. An example of complex problems simplified by the AHP is financial decision making. Firms and financial institutions face complex problems, such as mergers and acquisitions, complicated swap contracts, mortgage-backed securities, capital budgeting, and foreign investments. Spronk et al. (2005) stated that although there is a range of financial decision problems, they all have the following common characteristics: multiple actors, multiple policy constraints and multiple risks. The multi factors force financial decision makers to employ a multi-criteria decision aid (MCDA) to improve decision making. The AHP is an MCDA, and it has been used to address problems such as bank acquisition strategies, selecting financing instruments for foreign investment, capital budgeting, and mergers and acquisitions (Stuer and Na, 2003).

Flexible

The AHP is flexible and can be integrated with other techniques such as mathematical programming, quality function deployment (QFD), meta-heuristics, SWOT analysis and Data Envelopment Analysis (DEA) (Ho, 2008). For example, Douglas Clinton and Hassel (2002) used the AHP to select appropriate metrics for each Balance Scorecard (BSC) perspective. They stated that users of BSCs face a dilemma in choosing the appropriate metrics and measure for the four BSC perspectives. The AHP provides a systematic approach to choosing the right metrics and measurement. Leung et al. (2005) demonstrated the AHP and ANP's applications for facilitating the implementation of BSCs to choose appropriate measures for each BSC perspective. The study showed that the AHP and ANP are MADM techniques and adaptable into BSC decision environments.

Quantifying Intangibles

The AHP is useful for evaluating intangibles that have no specific scale. Nieto et al. (2011) used the AHP to measure the social aspects of projects' credit applications. Normally, a project credit application is evaluated based on financial aspects. However, the study developed a model for social credit scoring. The study argued that institutions funding a project should evaluate the project based on both financial aspects and the effect of the project on society. Nieto et al. (2011) stated that each funder has different concerns. The study used the AHP to measure funders' preference for intangible factors and develop a social credit score for a project. Hafeez et al. (2002) used the AHP to determine the key capabilities of a firm. Identifying key capabilities enabled a firm to plan strategic investment decisions such as outsourcing, producing a new product or focusing on the current product. The study aimed to have a balance measure of capabilities using both financial and non-financial criteria. According to Hafeez et al. (2002), the study used the AHP because of its ability to accommodate both qualitative and quantitative measures.

Support Group Decision Making

An important issue for group decision making is to aggregate individual judgements into a single representative judgement. The AHP supports group decision making by calculating the geometric mean of individual pairwise comparison judgements (Saaty, 2008a). Lai et al. (2002) used the AHP for group decision making to select software. The study used two techniques to make group decisions: AHP and Delphi. The study documented five significant AHP contributions to group decision making: (i) the AHP hierarchy is an efficient technique for eliciting and utilising information compared to the Delphi technique; (ii) the AHP is preferable to the Delphi technique in clarifying decision problems; (iii) AHP decision makers can exchange ideas and correct their decisions at any decision stage, while Delphi participants can only modify their decisions before submitting their responses; (iv) the AHP allows decision makers to discuss the problem comprehensively and repeatedly, resulting in a thorough and systematic analysis of the problem, while Delphi decision makers do not have the opportunity to discuss the problem; and (v) the participants are more satisfied with AHP's outcomes than Delphi's outcomes.

4.4.2 Limitations

Decision Fatigue

The number of pairwise comparison for a decision matrix with n elements is $n(n-1)/2$. A problem with many criteria requires decision makers to make many pairwise comparison judgements. A problem with seven criteria and four alternatives has seven 4x4 matrices for the alternatives and one 7x7 matrix for the criteria. The alternative matrix has six pairwise comparisons. In total, the alternatives have 24 pairwise comparisons and the criteria have 21. Pairwise comparison questions are repetitive. Decision makers compare the same pair of alternatives for the criteria. Forman and Gass (2001) stated that too many pairwise comparisons cause decision makers to: (i) ignore the rest of the questions, resulting in missing values; or (ii) answer the questions without careful judgement, resulting in inconsistency in judgement.

Saaty and Ozdemir (2003) suggested limiting the number of criteria to nine to improve consistency and decision accuracy. Forman and Gass (2001) suggested clustering the criteria into similar groups to reduce the number of pairwise comparisons.

Rank Reversal

Rank reversal refers to changes in the ranking of a set of alternatives because of the addition of a new alternative (Saaty, 2010b). A relative measurement is unlike a measurement on a scale with an arbitrary unit. In a scale measurement, the value assigned to an alternative is independent to other alternatives. In a relative measurement, alternatives are compared against several criteria to determine their relative weights. The weights are then aggregated to obtain a ranking of the alternatives. Adding or deleting an alternative could change the ranking of the alternatives.

Millet and Saaty (2000) proposed a variation of the AHP, called the ideal mode AHP, to preserve the ranking. In the ideal mode, the local priority weights of a decision matrix are calculated by dividing each element with the largest elements. The original AHP used the distributive mode. For the distributive mode, local priority weights are divided by the total column sum to normalise the weights.

Saaty (1994) proposed another variant of the AHP, called the absolute measurement or absolute rating, to preserve rankings. First, the standard or grades for each criterion are determined. For example, one of the criteria used to evaluate students was their performance in mathematics. The ratings could be excellent, good, average or poor. Next, pairwise comparisons are used to set the priorities of the ratings. The alternatives or students were graded under each rating, and the grades were summed to obtain the overall grades. Absolute rating is suitable for problems with many alternatives.

However, the question is: Should a rank always be preserved (Saaty, 2010b)? The AHP has one technique to allow a rank to change, and two techniques to preserve the ranks:

- To allow rank reversal, use the distributive mode of the relative measurement.
- To preserve rank for irrelevant alternatives, use the ideal mode of the relative measurement.

- To preserve rank absolutely, use the absolute measurement or rating mode.

4.5 Using AHP for Risk Management Decision Making

This section discusses why the original AHP need to be modified for risk management decision making. The discussion starts by explaining the elements of risk management decision making, followed by how the AHP can accommodate the elements.

4.5.1 Elements in Risk Management Decision Making

From the discussion on risk management decision making and decision-making challenges in Chapter 3, this thesis identifies the following elements of decision making in risk management:

- Making trade-offs: Judging the importance of risks is about making trade-offs between the risks. Every time risk managers decide that a risk is important, they are unconsciously comparing the risks and assigning preference to them. Risk management decision making requires risk managers to be explicit about their preference. To be explicit, they have to make careful and deliberate judgements on the importance of risks.

- Time frame: Time is important for risk management decision making, as the risk environment is constantly evolving and changing. It should be stated clearly that risk managers should not make decisions at one point in time.

- Quality of decision: The quality of the decision depends on the input or data, and the decision makers or risk assessors. For risk management decision making, making a decision should start with identifying and gathering information that is relevant to the problem. The people involved in the decision-making process should have the same understanding of the information and use the information to make judgements. The person assessing the alternatives and making the decision determines the accuracy of the decisions. Therefore, the risk assessors and decision makers should be knowledgeable about the problem.

- Approval of decision: Generally, a risk management problem requires the involvement of three different people: the decision maker, risk assessor and risk manager. Decision makers can be the management team, board of directors or relevant stakeholders. They are the risk bearers who have to be responsible for the outcomes of the decision. Risk assessors are the risk owners who judge which risks are important. Risk managers are responsible for assisting the risk owners and decision makers in the decision-making process. Although risk assessors decide which risks are important, the decision needs to be approved by the decision makers before it is implemented.

4.5.2 Modifying AHP for Risk Management Decision Making

To use the AHP for risk management decision making, it has to accommodate the following elements of risk management decision making:

- Support trade-off analysis: The AHP must help risk managers to make risk trade-offs, and to make conscious and explicit preferences. In particular, in situations where all risks are considered important, the AHP must be able to assist risk managers to set priorities on the risks.
- It must force risk managers to use a reflective thinking system and make a controlled, deductive and deliberate decision.
- It must force the gathering of relevant information, and the organisation of the information must be understandable by everybody involved in the problem.
- Consider the decision timeframe: The risk or alternative assessment period must be clearly stated.
- Consider separation between risk assessors and decision makers: The AHP should have a platform for risk assessors and decision makers to discuss and debate the decision.

Therefore, to use the AHP for risk management, the following steps must be included in the decision-making process:

- an explicit instruction to make trade-offs to assess the importance of risks or alternatives.
- a decision time frame.
- a platform to discuss the assessment made by the risk assessors with the decision makers.

4.6 Summary

This chapter demonstrated how the AHP simplifies a complex problem by structuring the criteria and alternatives of the problem in a hierarchy. It also demonstrated the application of the AHP to different types of decisions, such as prioritising the alternatives, choosing an alternative based on costs and benefits, choosing an alternative based on risk effects, costs and benefits, predicting the future outcomes of an alternative, and choosing the best action to resolve conflict. However, to use the AHP for risk management decision making, the original AHP had to be modified, and new steps were added. This chapter also discussed the justifications for the modifications.

The next chapter discusses RP, which is a decision-making tool developed for risk management. RP exploits the AHP and is developed with the modifications discussed in this chapter.

5

Risk Prioritisation (RP)

5.1 Introduction to Chapter 5

This chapter explains the decision making tool developed in this thesis. RP is developed based on the AHP with the modifications discussed in Chapter 4. This chapter also discusses the differences and similarities between RP and the AHP. Understanding RP is important to the understanding of how RP structures the risk management problems discussed in the next chapter.

The goals of this chapter are to:

- provide the theoretical framework of RP. (Sections 5.2 and 5.4)
- propose potential RP applications for risk management. (Section 5.5).
- compare RP and the AHP. (Section 5.3)

5.2 RP

RP is a decision-making tool developed in this thesis for risk management problems. RP exploits the AHP (Saaty, 1977) and combines decision-making theory, decision-making behaviour and risk analysis in making judgements, and it uses mathematics to quantify soft decisions.

Making decisions under conditions of uncertainty is an integral part of risk management. Risk managers face difficult tasks when making far-reaching decisions on complex issues in uncertain environments. The question is: What tool can be used to improve the decision-making process and produce reliable decisions? The answer is RP. RP is a systematic decision-making framework that supports risk management decision making. The framework can be used for any risk management problems, from the simplest to the most complex.

As a decision making tool for risk management RP need to be able to do the followings:

- Addresses the decision making challenges. RP need to address the heuristic judgement, decision framing and interaction between thinking systems biases. The following discusses how RP could mitigate the biases:
  - Bias in Heuristic Judgement.
    - RP should forces the gathering of relevant information to a problem. Risk managers should consider all possible alternatives to a problem before making judgement. Information gathering should be an essential activity. RP need to be able to mitigate the WYSIATI bias and avoid risk managers to make judgement based on the first information available.
    - Personal and actual experience, educational background, imagination and personal preference affect rational judgement. RP need to be able to mitigate or monitor how the biases affect decisions.
    - RP should be able to perform an effective group decision making. It

should support individual values and decisions, and aggregate judgements to achieve an overall group decision.

- Bias in Decision Framing.
  * RP should structure alternatives using broad framing. The alternatives should be presented to risk managers in combination of choices and displayed simultaneously to the risk managers. Therefore, they could simultaneously evaluate the alternatives to judge which alternative is more preferable.
  * RP should avoid using probability or frequencies to determine the importance of alternatives.
- Bias in Human Thinking Systems.
  * RP should exploit both thinking systems. It should forces risk managers to use both thinking systems to identify, collect information, organise and structure a problem. Using RP, risk managers should be able to use the fast thinking of system 1 to identify and collect information relevant to the problem, and system 2 to check the authenticity of the information, and organise and structure the information.

• Address problems, questions and make decisions for risk management.
  - RP should enables risk managers identify the right risk management problem. It should assist risk managers to articulate the problem to decide whether the problem needs to be addressed.
  - RP should provide a framework for risk managers to make risk management decisions. The decision could be prioritising or choosing alternatives from a set of alternatives.
  - Risk managers should be able to use RP to organise and categorised risks.
  - RP should emphasises on collecting relevant information to a problem and managing the information before making decisions. Managing the information means the information should be adequate both in terms of quality and quantity. Irrelevant information should not be included and relevant

information should be ignored.

- RP should produce objective results.
- RP should provide a transparent decision making process.
- RP should be simple and easy to use.
- RP should be a logical and practical decision making process.
- RP decision making process should clearly reflect risk managers judgement, preference or degree of beliefs.
- The output produces by RP should be in an understandable format to risk managers and decision makers.
- RP should include sensitivity analysis.
- RP should consider separation between risk assessors and decision makers.
- The reason risk management has risk monitoring is because risk evolve. RP need to consider time frame in risk management problems. Risk managers' judgement or preference of an alternative is for a specific time frame.

5.3 Differences and Similarities between AHP and RP

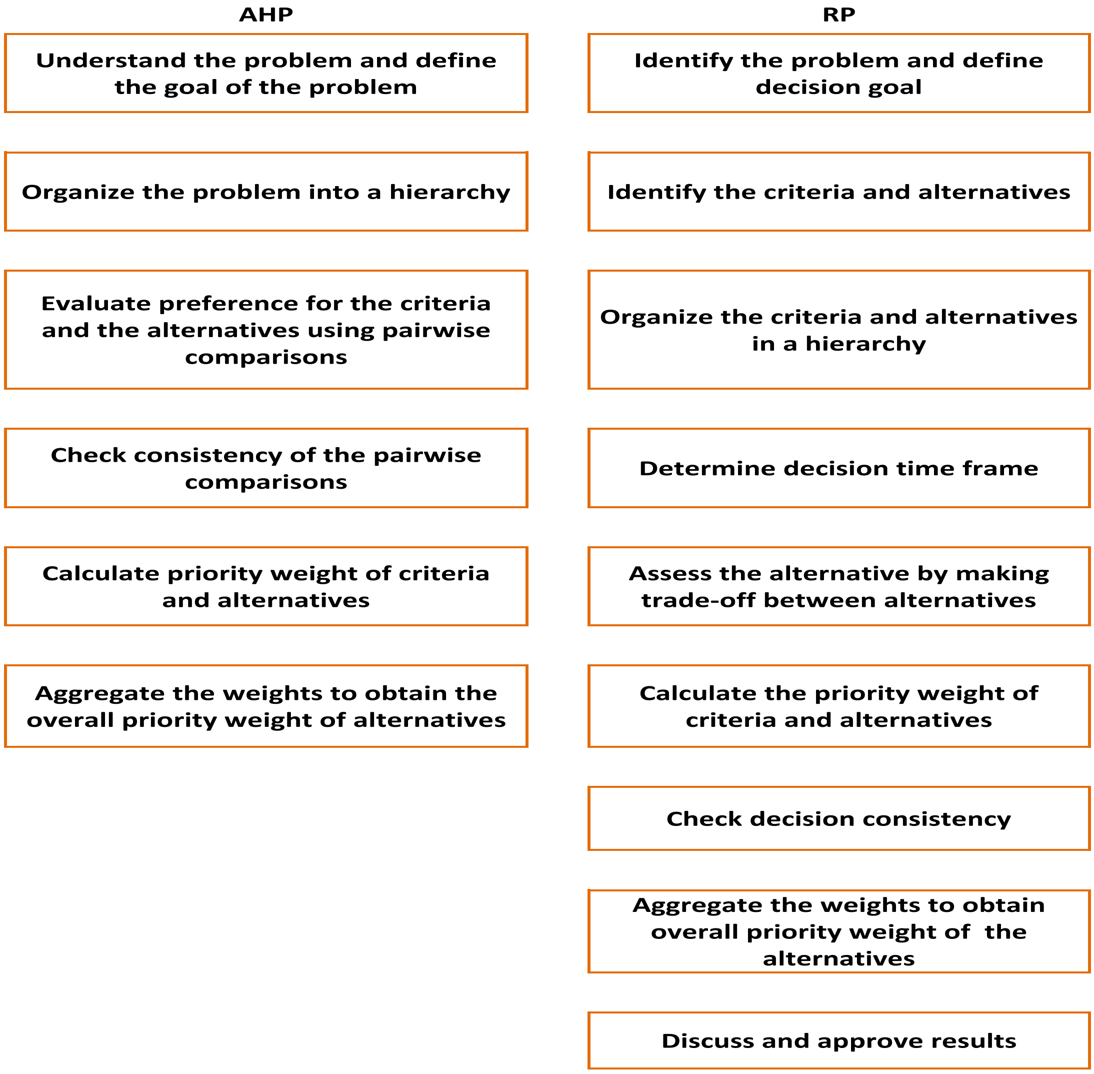
To use the AHP for risk management, a few steps must be added to the original AHP. Figure 5.1 shows the steps for AHP versus RP decision making. The differences and similarities between the AHP and RP are outlined below.

5.3.1 Differences

Decision Making Steps

- Determine the Decision Making Time Frame. To make a risk assessment, the first step is usually to determine the assessment period-for example, a one-year timeframe. Therefore, risk managers assess the importance of the risks for the

Figure 5.1: Decision Making Steps: AHP versus RP



year. The risks will be re-evaluated at the end of the year. RP is a tool used to support risk management decision making, and risk assessment is an important part of risk management. A decision timeframe needs to be set before risk managers assess risks or alternatives. Certain risks are more threatening in the short term, while other risks are more threatening in the longer term. Certain risks are more likely to occur over the short term, while other risks are more likely to occur over the longer term. The timeframe helps risk managers to focus their assessment and avoid making assessments at one point in time. Some business activities have a fixed lifecycle. For example, a loan could be for one year or 10 years. A derivative transaction timeframe starts with developing and designing the contract until the contract is delivered, and insurance contracts have different maturity periods. A decision timeframe needs to be set to use RP for risk management problems that have a specific lifecycle or duration.

- Assess the Alternatives by Making Trade-off between the Alternative RP emphasises making trade-offs between alternatives to determine the more important or preferable alternatives. In good risk management, risk managers should compare a wide range of alternatives to a problem and make trade-offs in order to determine the best solution to the problem.
- Discuss and Approve Results This step takes into consideration the separation between risk assessors and decision makers, which is common in risk management. The discussion and results approval step is a platform for risk assessors and decision makers to communicate, challenge, debate and provide a rationale for RP output.

Area of Applications

RP is designed as a decision-making tool for risk management. Its purpose is to improve decision making in risk management. The risk management process is a tool used to manage risks, while RP is a tool used to make decisions for risk management. RP complements the risk management process. It assesses or evaluates risks or alternatives of risk management problems to rank the risks or alternatives. In contrast, the AHP can be used for any complex problems. It provides a systematic decision-making framework for any complex problems with multiple conflicting factors.

Priority Weight Calculation

AHP uses the eigenvalue technique to calculate the priority weight. RP uses LLSM to calculate the priority weight. The LLSM calculation is easier. RP aims to provide a simple and reliable decision-making tool for risk managers. A simple priority weight calculation is preferred. Risk managers can calculate the priority weights by developing spreadsheet software such as Microsoft Excel or using a hand calculator.

Preference Scale

RP uses a five-point preference scale, and the AHP uses a nine-point preference scale. RP is still at its developement stage. A five-point scale is simple and forces risk managers to explicitly make trade-offs between two risks. Risk managers need to decide whether a risk is equally, moderately, strongly, very strongly or extremely important compared to another risk. RP avoids in between or middle judgement in determining the importance of risks. For example, $Risk_i$ is in between equally and moderately important compared to $Risk_j$ and assigned a scale 2. It creates ambiguity whether the risks are slightly equally important or slightly moderately important. RP aims to minimise ambiguity in making judgement and increased the accuracy of risk ranking. A five-point scale forces risk managers to make careful and deliberate judgement.

Sensitivity Analysis

AHP decision making process consists of problem structuring or modelling, assigning weights to criteria and alternatives of the problem, aggregating the weights to obtain priority weights of the alternatives and sensitivity analysis. Sensitivity analysis test the sensitivity or responsiveness of the ranking of the alternatives to changes in the priorities of the criteria. For AHP, sensitivity analysis can be done using software such as Expert Choice.

Unlike AHP, at this stage of the thesis, RP does not have sensitivity analysis. As stated previously, the aim of this thesis is to investigate whether RP can structure and simplify complex risk management problems. Further, RP aims to be a simple and easy to use decision making tool which can be implemented by using a simple spreadsheet software or even hand calculator. Therefore, at this stage, RP focused on three important components of a decision making process: problem structuring, weights assigning and weights aggregating.

5.3.2 Similarities

Hierarchies as a Framework to Structure Complex Problem

RP and the AHP use hierarchies to structure and organise complex problems. A hierarchy is an efficient way to structure the factors that are relevant to a problem. A hierarchy organises information that is relevant to a problem from the most general to the most specific and linked criteria, alternatives and decision goal.

Setting Priorities Using Priority Weights

RP and the AHP use a priority weight to establish the importance of alternatives. Both RP and the AHP are decision-making tools used to rank alternatives based on decision makers' evaluation of the alternatives on selected criteria. Decision makers' judgement is translated into values, and the values are used to obtain the priority weights of the alternatives.

Pairwise Comparison to Elicit Preference

Similar to AHP, RP uses pairwise comparisons to elicit risk managers' judgement on the importance of risks or alternatives. Pairwise comparison is a natural and easy way to make trade-offs between two elements.

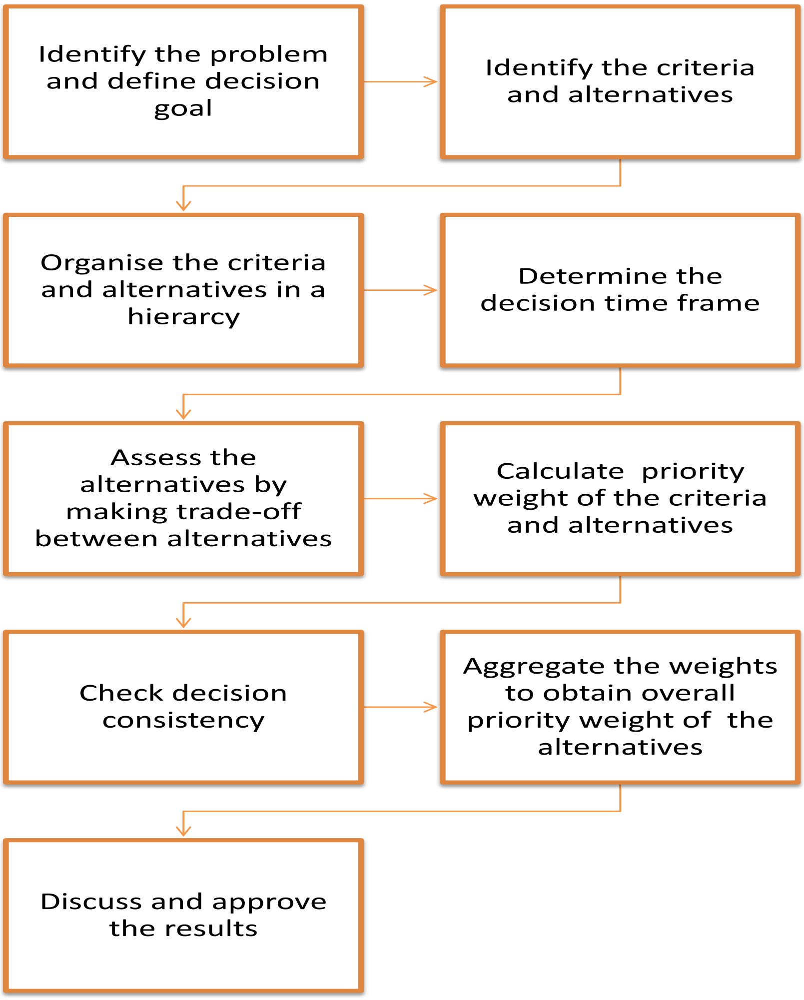
Consistency Ratio to Measure Consistent Judgement

Similar to the AHP, RP requires consistency of thought and judgement. Both RP and the AHPs inconsistent tolerance is measured using the CR. A CR that is equal to or less than 10 per cent is acceptable. A CR above 10 per cent is unacceptable and requires risk managers to revise their judgement.

5.4 RP Decision Making Process

Figure 5.2 presents the decision-making steps of RP. These steps are outlined below.

Figure 5.2: RP Steps



1. Identify the Problem and Define the Decision Goal

The first step of RP is to identify the problem. Risk managers need to discuss and communicate the problem to relevant stakeholders in order to provide an understanding of the problem. The purpose of the communication is to agree that the problem needs to be solved. Risk managers and stakeholders then need to define the decision goal, which is the statement of the objective to solve the problem. RP proposes that risk managers should write the problem statement, and that risk managers, decision makers and stakeholders must understand and agree with the problem statement. A basic problem statement consists of problem definition, reasons why the problem needs solving, and the decision goal.

Next, risk managers determine the problem's dateline. A complex problem that is of strategic importance may require a week or a month to formulate. A difficult non-strategic problem may require hours or a few days.

Risk managers need to collect information that is relevant to the problem. They need to ask three questions: (i) What do we know? (ii) What do we not know? (iii) What else do we need to know?. Risk management problems have many dimensions, and involvement with people from different backgrounds is valuable to understanding the problems and establishing a clearly defined decision goal.

RP proposes using the following questions to understand a problem:

- What risks and alternatives currently exists for the problem?
- What risks have not been considered or could be overlooked? What other alternatives exist, but have not been considered?
- What factors are influencing assessment of the alternatives? Are the factors reasonable and relevant to the alternatives?
- On what basis alternatives is ruled in or out?
- What is the decision to be made?
- What is the purpose of the decision?
- Who is the decision-maker?
- Who is involved and on what basis?
- For problems with more than one decision-maker, are the decisions based on consensus or majority?

The questions assist risk managers in understanding the problem and communicating it to the relevant stakeholders or to other people who are not directly involved in the decision-making process. Answering the questions enables risk managers to overcome ambiguity and confusion relating to the problem. The first step is a long iterative process. However, it is a crucial and necessary step to the subsequent steps. The information gathered in this step is used to determine the alternatives and criteria used to evaluate the alternatives.

2. Identify the Criteria and Alternatives

The alternatives can be the risks faced by an organisation, business unit, business project or investment. They can also be risk actions or policies. The alternatives are evaluated against referents or criteria. Criteria are the factors or attributes used to judge or evaluate the alternatives.

The criteria should have the following characteristics (Baker et al., 2001):

- They should reflect the goal of the problem.
- They should be non-redundant.
- They should be few in numbers to keep the problem dimensions manageable.
- They should be independent from other criteria.
- They should be operational and meaningful so that risk managers and decision makers can understand the implications of the criteria to the alternatives.
- They must significantly discriminate the alternatives. For example, when choosing the most preferred risk control action, if the costs to implement the actions are the same, or if the risk manager or decision maker is indifferent about cost, cost cannot be a criterion.

The following techniques can be used to identify criteria (Baker et al., 2001)): (i) brainstorming; (ii) ask each member of the decision group for decision goals and criteria associated with the goals, and if the members differ in rank or position, ask the lowest-ranking member first in order to avoid influences by higher-ranking members; or (iii) together, group members consider the available alternatives, identify differences among the alternatives and develop criteria that reflect the differences.

3. Organise the Criteria and Alternatives in a Hierarchy

The purpose of structuring a problem in a hierarchy is to study, evaluate and prioritise the influence of the criteria on alternatives to satisfy the decision goal (Saaty and Vargas, 1982). A hierarchy presents a relationship between the decision goal, criteria and alternatives. The arrangement of the criteria and alternatives in a hierarchy depends on how risk managers perceive the problem. A basic hierarchy has three levels. The first level is the decision goal, the second level is the criteria and the third level is the alternatives. A complex hierarchy may contain sub-criteria, scenarios or players. Adding sub-criteria makes the hierarchy more specific. Scenarios enable risk managers to consider decisions under different circumstances. For group decisions, risk managers could include players in the hierarchy to incorporate each member's view into the decisions.

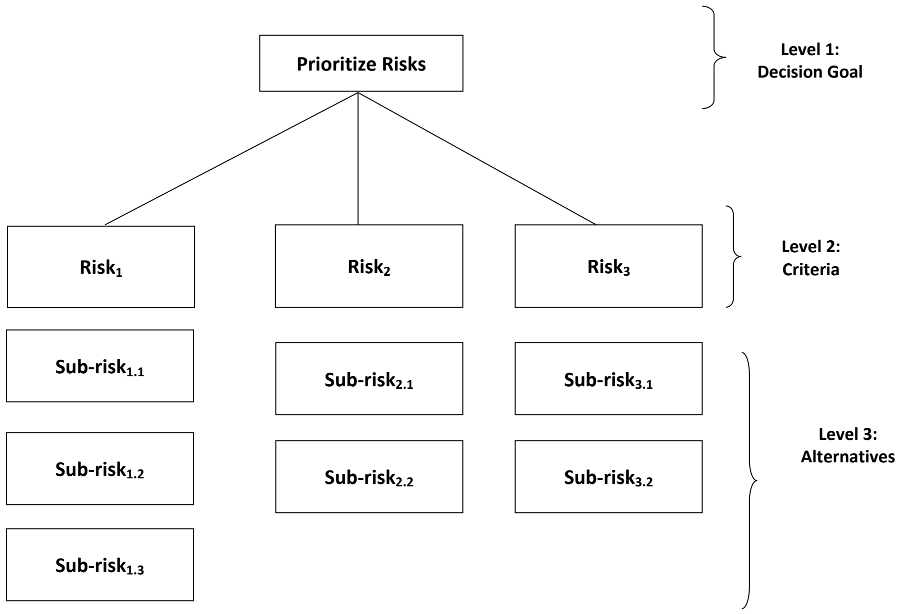
Figure 5.3 presents a basic three-level hierarchy for a problem to prioritised risks faced by a firm. The first level is the decision goal, the second level is the risk category and the third level is the sub-risk.

A hierarchy needs to include enough relevant detail to (Saaty, 1990):

- present the problem as thoroughly as possible.
- consider the environment surrounding the problem.
- include attributes that are relevant to the solution of the problem; the attributes must be in the same order of magnitude in order to compare homogeneous items accurately.
- include participants associated with the problem.

A hierarchy structures risk managers' thoughts by organising a complex problem into a framework that is easy to follow and understand. The strength of a hierarchy is its ability to present a clear, organised and logical view of a problem. There is no one right way to develop a hierarchy. Risk managers can present problems in a variety of ways and exert creativity in structuring the problem.

Figure 5.3: Hierarchy to Prioritise Risks Faced by a Firm



4. Determine the Decision Time Frame

Risk evolves and therefore requires constant monitoring. According to Sweeting (2011), when dealing with risks it is important to consider the time horizon over which they occur. The time horizon could be the period an organisation is exposed to risks or the way a risk is likely to change overtime. Risk managers need to determine decision timeframe to evaluate how long a firm is exposed to the risks. The timeframe could be six months, one year or one financial year. Setting a decision timeframe avoids making decisions at one point in time.

5. Assess Alternatives by Making Trade-off between the Alternatives

RP uses pairwise comparisons to assess alternatives. This assists risk managers to make logical and deliberate trade-offs between two alternatives. A pairwise comparison requires risk managers to compare two alternatives against a criterion in order to judge which alternative is more preferred or important. Pairwise comparisons require risk

TABLE 5.1: RP Pairwise Comparison Scale

Value	Definition	Explaination
1	Equally important or preferred	Two risks are equally important.
3	Moderately important or preferred	Experience and judgement slightly favour one risk over another.
5	Strongly important or preferred	Experience and judgement strongly favour one risk over another
7	Very strongly important or preferred	A risk is favoured very strongly over another.
9	Extremely important or preferred	Experience and judgement extremely affirmed that one risk is more important over another.
Reciprocals	Reciprocals for inverse comparison	If $Risk_i$ has one of the above number assigned to it when compared with $Risk_j$, then $Risk_j$ has the reciprocal value when compared with $Risk_i$.

managers to make two judgements: (i) dominance: which alternative is more preferred or important compared to the other alternative; and (ii) intensity: the strength or level of preference or importance. Risk managers judge the intensity of preference or importance using a five-point scale of 1 to 9. Table 5.1 presents the scale.

The following list presents pairwise comparison questions for the hierarchy, as shown in Table 5.3. The pairwise comparison starts from the bottom level of the hierarchy - from the alternatives to the criteria. The first compares the sub-risks and then the risks.

In terms of $Risk_1$:

- Compare $Sub - risk_{1.1}$ and $Sub - risk_{1.2}$. Which sub-risk is more important? And how much more:

Table 5.2: Decision Matrix for Sub-Risks of $Risk_1$

Weights	$Sub-risk_{1.1}$	$Sub-risk_{1.2}$	$Sub-risk_{1.3}$
$Sub-risk_{1.1}$	1	5	7
$Sub-risk_{1.2}$	1/5	1	1
$Sub-risk_{1.3}$	1/7	1	1

Answer: $Sub-risk_{1.1}$ is strongly more important compared to $Sub-risk_{1.2}$.

- Compare $Sub-risk_{1.1}$ and $Sub-risk_{1.3}$. Which sub-risk is more important? And how much more?

  Answer: $Sub-risk_{1.1}$ is very strongly more important compared to $Sub-risk_{1.3}$.

- Compare $Sub-risk_{1.2}$ and $Sub-risk_{1.3}$. Which sub-risk is more important ? And how much more?

  Answer: $Sub-risk_{1.2}$ is equally important to $Sub-risk_{1.3}$.

The answers are translated into numerical values based on the five-point scale shown in Table 5.1. The values are used to develop a decision matrix presented in Table 5.2.

From Table 5.2, for $Risk_1$, $Sub-risk_1.1$ is strongly more important compared to $Sub-risk_1.2$. The numerical value for strongly more important is 5. The relative scale of $Sub-risk_1.2$ to $Sub-risk_1.1$ is the inverse, 1/5. The diagonal is 1 to express neutrality between same risks. The pairwise comparisons questions are repeated for sub-risks of $Risk_2$ and $Risk_3$.

The following are the pairwise comparisons questions for the alternative or risks. Table 5.3 shows the decision matrix for the risks.

In terms of the decision goal:

- Compare $Risk_1$ and $Risk_2$. Which risk is more important? And how much more:

  Answer: $Risk_1$ is moderately more important compared to $Risk_2$.

- Compare $Risk_1$ and $Risk_3$. Which risk is more important? And how much more?

  Answer: $Risk_1$ is extremely more important compared to $Risk_3$.

- Compare $Risk_2$ and $Risk_3$. Which risk is more important? And how much more?

TABLE 5.3: Decision Matrix for Risks

	$Risk_1$	$Risk_2$	$Risk_3$
$Risk_3$	1	3	9
$Risk_2$	1/3	1	5
$Risk_3$	1/9	1/5	1

Answer: $Risk_2$ is strongly more important compared to $Risk_3$.

In the pairwise comparison, the risk is the referent or criterion and the sub-risks are the alternatives. The referent or criterion gives meaningful judgement of the alternatives. For example, a risk manager needs to evaluate the importance of two sub-risks under strategic risk: unexpected changes in the regulation and changes in market preference resulting from the competitive environment. Instead of directly asking: Which risk is more important? The pairwise comparisons ask: With respect to strategic risk, compare changes in regulation and changes in market preference. Which sub-risk is more important and by how much?

To obtain the right judgement, questions must make sense and be clear. Pairwise comparison questions depend on the decision goal. For example, for a decision goal to rank opportunities, the question is: Which is more preferred? For a decision goal to rank possibilities, the question is: Which is more likely?

Pairwise comparisons are deliberate, effortful and orderly. They force risk managers to focus on the decision goal, think carefully and devote attention to make a judgement. The aim is to make explicit and conscious trade-offs. Risk managers explicitly state how much they are willing to trade off one risk over another. Instead of a fuzzy or simple perceived preference, risk managers use a scale of 1-9 to express their level of preference or belief.

6. Calculate Priority Weight of the Criteria and Alternatives

RP is a semi-quantitative decision-making tool. Data and information that are relevant to a problem can be qualitative or quantitative. Risk managers' judgements are subjective, and these subjective judgements are translated into numerical values. The priority weights of the alternatives are calculated from the values. They are numerical ranks measured on a ratio scale (Saaty, 2001). RP uses Log Least Square Method (LLSM) to derive the priority weights of the criteria and alternatives. LLSM is statistically better and easier to calculate. This section explains the LLSM (Crawford, 1987, Crawford and Williams, 1985, Jong, 1984).

The LLSM is used to minimise the following equation:

$$min \sum_{j=1}^{n} \sum_{i=1}^{n} (log(a_{ij}) - log(\frac{w_i}{w_j}))^2$$

Writing $log(a_{ij}) = Y_{ij}$ and $p_i = log(w_i)$ produces the equation

$$min \sum_{j=1}^{n} \sum_{i=1}^{n} (Y_{ij} - p_i + p_j)^2$$

under the condition

$$\sum_{j=1}^{n} p_j = 0, \quad Y_{ij} = -Y_{ji} \quad , Y_{ii} = 0$$

Taking partial derivatives set equal to zero:

$$-2 \sum (Y_{ij} - p_i + p_j) = 0$$

$$-2(\sum_{i=1}^{n} Y_{ij} - np_i + \sum_{j=1}^{n} p_j) = 0$$

$$\sum_{i=1}^{n} Y_{ij} = np_i$$

$$p_i = \frac{\sum_{i=1}^{n} Y_{ij}}{n}$$

$$log(w_i) = \frac{\sum_{i=1}^{n} log(a_{ij})}{n}$$

The antilog is the LLSM solution. The minimise vector is given by:

$$w_i = \prod_{i=1}^{n} (a_{ij})^{1/n}$$

Consider Matrix **A**, the decision matrix for risks from Table 5.3

$$\mathbf{A} = \begin{pmatrix} 1 & 3 & 7 \\ 1/3 & 1 & 5 \\ 1/7 & 1/5 & 1 \end{pmatrix}$$

Priority weights for **A** are calculated as:

$$\mathbf{w_i} = \begin{pmatrix} (1 \times 3 \times 7)^{1/3} = 2.76 \\ (1/3 \times 1 \times 5)^{1/3} = 1.19 \\ (1/9 \times 1/5 \times 1)^{1/3} = 0.31 \end{pmatrix}$$

Normalised priority weights for **A** are calculated as:

$$\mathbf{P_i} = \frac{w_i}{\sum_{i=1}^{3} w_i}$$

$$\mathbf{P_i} = \begin{pmatrix} 0.65 \\ 0.28 \\ 0.07 \end{pmatrix}$$

The weights correspond to the relative value of $Risk_1$, $Risk_2$ and $Risk_3$. $Risk_1$ is most important, followed by $Risk_2$ and $Risk_3$.

7. Check Decision Consistency

RP uses subjective judgement to make trade-offs between risks or alternatives. One difficulty of subjective judgement is maintaining a consistent judgement. Decision consistency measures whether judgements on alternatives are logically compared and evaluated or simply randomly decided. The purpose of decision consistency is to ensure that risk managers are making deliberate trade-offs between alternatives instead of simply assigning a number to the alternative, and to capture random versus careful and deliberate judgements.

The consistency of a pairwise comparison is measured by computing the CR and consistency index (CI).

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RCI}}\ , \quad \mathrm{CI} = \frac{\lambda_{\max} - n}{n - 1}$$

The random consistency index (RCI) is a pre-defined average random index derived from a sample size of 500 randomly generated reciprocal matrices. Table 5.4 presents the RCI values (Saaty, 1999). RCI depends on the number of elements being compared (Triantaphyllou, 2000). n is the number of elements in the decision matrix.

Table 5.4: Random Consistency Index

n	1	2	3	4	5	6	7	8	9	10
RCI	0	0	0.52	0.89	1.11	1.25	1.35	1.4	1.45	1.49

Table 5.5: Calculating λ

A	$Risk_1$	$Risk_2$	$Risk_3$	**p**	**A.p**	λ
$Risk_1$	1	3	7	0.65	1.99	3.06
$Risk_2$	1/3	1	5	0.28	0.85	3.04
$Risk_3$	1/7	1/5	1	0.07	0.22	3.14

To calculate the consistency index, risk managers need to determine $\lambda_{\max}$. Table 5.5 shows how to derive λ. The values of λ will be used to calculate $\lambda_{\max}$. On the left hand side of Table 5.5 is the decision matrix **A**. It consists of ratio scale of a risk assessor pairwise comparison judgement on $Risk_1$, $Risk_2$ and $Risk_3$. **p** is the priority weight of the risks calculated from the decision matrix. The priority weight shows $Risk_1$ is the most important risk. To find λ requires solving the equation $\mathbf{A}.\mathbf{p} = \lambda.\mathbf{p}$. Both **A** and **p** are known. Solving the equation using power method of matrix algebra derives λ.

$$\lambda_{\max} = \frac{\sum_{i=1}^{n} \lambda_i}{n} = \frac{3.06 + 3.04 + 3.14}{3} = 3.08$$

RP proposes the following ways to maintain consistency Saaty and Vargas (1982):

- Consistency in transitivity: For example, risk managers judge that Risk A is more important than Risk B, and that Risk B is more important than Risk C. Therefore, Risk A must be more important than Risk C.

- Consistency in strength: For example, Risk A is four times more important than Risk B, and Risk B is twice as important as Risk C. Therefore, Risk A must be eight times more important than Risk C.

However, RP acknowledges that the relationships do not always hold in practice, so it allows a certain level of inconsistency. RP tolerates inconsistency of 10 per cent or

TABLE 5.6: Priority weight of sub-risks and risks

	$Risk_1$	$Risk_2$	$Risk_3$	Global weight
	c_1	c_2	c_3	
$Sub - risk_{1.1}$	$p_{1.1,1}$			$\gamma_{1.1}$
$Sub - risk_{1.2}$	$p_{1.2,1}$			$\gamma_{1.2}$
$Sub - risk_{1.3}$	$p_{1.3,1}$			$\gamma_{1.3}$
$Sub - risk_{2.1}$		$p_{2.1,2}$		$\gamma_{2.1}$
$Sub - risk_{2.2}$		$p_{2.2,2}$		$\gamma_{2.2}$
$Sub - risk_{3.1}$			$p_{3.1,3}$	$\gamma_{3.1}$
$Sub - risk_{3.2}$			$p_{3.3,3}$	$\gamma_{3.2}$

lower. A CR that is equal to or less than 10 per cent is acceptable, indicating that the judgement is consistent. A CR exceeding 10 per cent indicates inconsistent judgement; the elements are not properly compared. A CR of more than 10 per cent requires a revision of the pairwise comparison judgement.

8. Aggregate Weights to Obtain Overall Priority Weight of the Alternatives

Table 5.6 shows an example of local priority weights of risks and sub-risks, and global priority weight of sub-risks. Multiply priority weights of alternatives with priority weights of criteria to obtain global or overall priority weights of the alternatives. p_{ij} is the priority weight of alternative i against criterion j, $i, j = 1, \ldots, n$. $c_i, i = 1, \ldots, n$ is the priority weight of the criteria. $\gamma_i, i = 1, \ldots, n$ is the global priority weight of the alternatives. For example, to obtain $\gamma_{1.1}$, $Sub - risk_{1.1}$ is multiply by c_1.

9. Discuss and Approved the Results

Discuss the results with the decision group, board of directors, management team or relevant stakeholders. Generally, in risk management, the risk assessor and the decision maker are two different people. This step requires risk managers to explain the results to the decision-making group. The discussion should include explaining the decision-making process, who the risk assessors are and who the relevant stakeholders are. The purpose is to obtain the decision-making group's approval of the result before actions to address the problem are implemented.

5.5 RP Potential Applications

This section discusses the potential application of RP to risk management. RP proposes two potential applications to risk management: making a choice among a set of alternatives and prioritising the alternatives.

5.5.1 Choosing an Alternative from a Set of Alternatives

Decision making in risk management is seldom about choosing one alternative from a number of alternatives. However, it is useful to consider this possibility. An example of a decision-making situation that requires risk managers to choose one alternative is the problem of whether to adopt or develop a risk management framework. The firm needs to decide whether to adopt a risk management standard as a framework for the risk management program or develop its own risk management framework. A standard risk management framework is developed for general use. A firm that plans to adopt a standard framework usually needs to modify the framework to accommodate the firm's business process and policy. Alternatively, the firm could develop its own risk management framework.

Making the decision requires a multi-criteria decision-making tool because of the conflicting factors influencing the decision. Planning to adopt or develop a risk management framework raises several issues, such as resources to implement or develop the standard, management commitment, and ensuring that employees understand and support the standard. Instead of debating the problem, the firm can structure the problem in a hierarchy. The issues can be the criteria to evaluate the alternatives, which are either to adopt a standard risk management framework or develop a risk management framework for the firm.

The following steps show how to structure the problem in a hierarchy:

1. The first level is the decision goal: The decision goal is to determine the best risk management framework.

2. The second level is the criteria: Four criteria are identified to evaluate the alternatives: (i) available resources to develop or implement the framework; (ii) management commitment to the implementation or development of the framework; (iii) employees' understanding of the framework; and (iv) employees' support of the implementation or development of the framework.

3. The third level is the alternatives: The alternatives are to adopt a standard risk management framework or develop a risk management framework for the firm.

5.5.2 Prioritising Alternatives

This thesis anticipates that one of the major RP potential applications in risk management is prioritisation. Many problems in risk management require the decision maker to prioritise risks or alternatives.

In conducting business, a firm is exposed to many risks, which produce unwanted outcomes that affect business performance. The risks could have the same effect on the firm, but with different magnitudes. For example, operational, credit, market and regulatory risks could cause an increase in earnings volatility. However, the effect of credit risks to earnings volatility could be more severe compared to operational risks. The following example shows how RP can prioritise the risks faced by a firm. The problem is commonly addressed using a risk matrix, which ranks the risks based on their likelihood and severity. The RP approach to the problem is to prioritise the risks based on the severity of the risks' effects on the firm. Assessing the risks based on the severity of their effects enables risk managers to determine the risks' effects on the firm, as well as which risk could severely affect the firm. The advantages of using RP are that risk managers do not have to assign monetary values or probability estimations to the effects. Instead, they used their experience and intuition to provide a judgement on the effects.

Consider that the firm has identified the following risks: operational, credit, market and regulatory. Next, the firm needs to determine how the risks affect the firm. The firm identified the following potential effects of the risks: (i) reduction in revenue; (ii) increase in default probability; (iii) increase in earnings variability; (iv) increase in cost of capital; and (iv) damage to reputation.

The following steps show how to structure the problem in a hierarchy:

1. The first level is the decision goal: The decision goal is to prioritise the risks in terms of severity of effect.
2. The second level is the criteria: The criteria are the potential risk effects.
3. The third level is the alternatives: The alternatives are the risks.

5.6 Summary

This chapter explained RP decision-making steps and discussed the potential application of RP to risk management. RP has the potential to be applied to risk management problems such as choosing an alternative or ranking alternatives from a set of alternatives. The chapter also discussed the differences and similarities between the AHP and RP. RP is similar to the AHP in terms of using a hierarchy to structure a problem, a priority weight to determine the priority of the alternatives, pairwise comparisons to make trade-offs between alternatives, and a CR to measure decision consistency. A discussion of the differences explained the new steps added to the original AHP, areas of AHP and RP applications, the technique used to calculate the priority weight, and the scale used to assign preferences to the alternatives.

The next step of the thesis is to see whether the RP framework presented in this chapter can structure and simplify real and complicated risk management problems. The next chapter demonstrates RP applications to risk management problems.

6

RP Application to Risk Management

6.1 Introduction to Chapter 6

This chapter demonstrates how the RP framework outlined and theoretically explained in Chapter 5 can structure risk management problems. In Chapter 5, the thesis proposed applying RP to two types of problems: prioritisation of alternatives and selection of an alternative from a set of alternatives. This chapter demonstrates how RP structures a prioritisation and selection problem. It is important at this stage of the thesis to understand how RP structure risk management problems because the problems will be presented to risk managers for them to evaluate the practical usability of RP. Chapter 7 discusses how risk managers evaluate RP practical usability.

The goal of this chapter is to demonstrate how RP can be used to structure risk management problems.

6.2 Prioritise Risks of an Insurance Company

An insurance company faces many risks. All of them are important, but not equally important. Therefore, priorities must be set. More threatening risks should receive the highest priority. The reasons for prioritising risks are outlined below (Hargreaves, 2010):

- To decide which risks to focus on: Each risk has a different magnitude. It is useful to places risks into classes of relative importance in order to determine high-priority risks.
- Knowing which risk is important helps to decide whether to spend money to mitigate the risk. Firms need to know whether implementing the risk action is worthwhile.
- The presence of risk will reduce the economic value of the corresponding business activity. Prioritising risks helps firms to decide whether to stop financial contributions to the activity.
- Firms need to know how a particular risk contributes to total risks.

Using RP to prioritise risks provides the following advantages:

- Instead of direct ranking, trade-offs can be used to assess risks.
- It is an easy-to-understand technique of risk assessment. RP does not require estimating the probability distribution or complicated calculations.
- It improves risk managers' understanding of the linkage between risks.
- It improves data management. RP categorises and structures the risks instead of just listing them.
- It forces risk managers to answer the difficult question of which risks they are willing to give up for other risks.
- Deliberate action is used to determine significant risks. RP imposes careful thinking before making a decision.
- It provides a systematic risk assessment process. First, risk managers make an

assessment within the risk category. Next, they make an assessment across the risk category.

- It forces risk managers to examine the problem closely to determine the decision goal, alternatives and criteria. Does the decision goal answer the problem? Do the alternatives meet the decision goal? Are the criteria the right criteria to evaluate the alternatives?

RP produces four outputs: (i) ranking of risks; (ii) ranking of sub-risks; (iii) overall ranking of sub-risks; and (iv) top 10 risks. The following section describes RP's decision-making process.

1. Identify the Problem and Determine the Decision Goal

First, risk managers need to determine the level or situation of RP activity. The level can be business unit, firm-wide, strategic or operational. The situation can be mergers and acquisitions, venturing into a new market or introducing a new product. The next step is to determine the decision goal. A clear definition of the decision goal is important to produce the answers sought by the risk managers. For example, is the goal to rank inherent or residual risks, or to rank the risks that are more likely to occur in the next six months? A clear definition of the decision goal also ensures that decision makers are judging the risks based on the same understanding and perspective.

For this application, the decision goal is to prioritise inherent risks faced by an insurance company. Inherent risks refer to gross risks-that is, risks before any action or control is implemented to mitigate them.

To produce a valid and reliable ranking, risk managers need to determine the people involved in the RP process. Risk managers need to identify risk assessors, decision makers and relevant stakeholders. Risk assessors should be people who have knowledge and experience of the subject matter.

2. Identify the Criteria and Alternatives

Alternatives are elements to be judged, and criteria are the elements used to judge the alternatives. For this application, the alternatives are risks and the criteria are risk categories. This section explains how RP identifies the alternatives and criteria for the problem.

Identify and list all risks. Identify all risks faced by the company. For this application, the risks are identified by reviewing risk management literature and the insurance company's annual reports. In practice, the risks can be identified using brainstorming, interviews or survey questionnaires. RP proposes to relate the risk identification activity to the decision goal. For example, for the decision goal to prioritise risks faced by a business unit, risk managers identify the risks that are relevant to the business unit. Identifying specific risks for a specific problem promotes in-depth analysis of the issue, forces risk managers to focus on the issue at hand and enables comprehensive data collection. For this application, RP first identifies the scenarios that are threatening the company. Identifying and analysing the scenarios provides thorough risk identification and assists risk managers to answer three questions: What is known? What is unknown? What else needs to be known?

Analysis of the risk management literature and the insurance company's annual reports produces the following potentially threatening scenarios:

- Failure to comply with existing laws and regulation: The insurance industry is highly regulated. The laws and regulation govern the business in the country in which the insurance company operates or obtains funding. For example, an insurance company operating in Australia, New Zealand and the US is governed by the laws of these countries. Compliance risk is a failure to comply with the laws and regulations. A failure to comply arises because of an inability to keep up with the regulations, which are continually changing. Changing regulations affect operations such as increased level of liquidity, higher level of capital, investment restrictions and business restrictions, resulting in an insurance company altering its products or services sold to customers. As a result, there is restricted business operation flexibility, a higher cost of operations and reduced profitability.

- Adverse credit and capital market: Insurance companies rely on capital markets to fund business and provide liquidity. Deteriorating capital market conditions increases funding costs and decreases liquidity. Consequently, this affects the insurance company's financial conditions and customer confidence in the industry. An inability to secure sufficient funds relates to compliance risk. For example, regulators increase the required quantity and quality of the capital held by insurance companies. In a volatile and uncertain capital market, complying with the regulatory capital standard could result in an increasing cost of funding. Paying a high cost of capital could affect the cost of business operation.
- A systemic shock to the financial systems: A difficult economy and financial conditions cause decreased consumer and business spending, and increased unemployment. The situation reduces demand for product and services, and therefore reduces earnings.
- Inability to obtain sufficient investment income: Market risks such as volatility in interest rates and equity risks could reduce investment returns or result in a failure to achieve the target return.
- Environmental factors or natural catastrophe: The frequency and severity of natural disasters are difficult to predict. Therefore, a reserve amount is difficult to determine. Reserve miscalculations may result in the insurance company having inadequate funds to pay claims.
- Reputation damage: Reputation damage subjects the insurance company to regulatory enforcement actions, fines and penalties, reduced customer and investor confidence and decreased market share. Subsequently, there is a loss of business and an increase in legal costs.
- Technology failure: The reliability and security of the IT infrastructure and customer database are important to the insurance company. A system failure can result in business interruptions, theft of customer data and theft of intellectual property.

- Employee conduct and behaviour: The insurance company's business operations depend on employees' conduct. Human error, inadequate or failed processes, and fraudulent conduct adversely affect the business's prospects and reputation.

Categorised the risks From the scenarios, RP identifies the sources of risks and sub-risks related to the sources. The sub-risks are then categorised into similar characteristics or attributes. Figure 6.1 presents the sources of risk, sub-risks and risk categories.

Figure 6.1: Source of Risks, Sub-Risks and Risk Categories

No.	Source of risks obtained from risk scenarios	Sub-risks	Risk
1	Credit and capital market disruptions	Inability to meet financial obligations and higher financing rates	Liquidity
2	Global financial disruption	Foreign exchange rate volatility	Market
3	Insufficient investment income	Changes in interest rate and real estate price	Market
4	Stock market downturn	Changes in equity and financial derivatives prices	Market
5	Higher mortality rate than the premium charged	Product pricing	Insurance
6	Higher sickness rate than the premium charged	Product pricing	Insurance
7	Administrative costs exceeded from what can be earned from policies.	Expense overrun	Insurance
8	Inability to offer product matching customer preference	Competitor risks	Strategic
9	Human error or misconduct	Peopl e or process risks	Operational
10	IT or system failure	IT or System risks	Operational
11	Reinsurer fails or delay in meeting obligations	Credit risk	Credit
12	Insufficient fund to meet obligations to counter parties	Credit risk	Credit
13	Slowing of the economy	Decrease product demand and increase lapse/termination/surrender	Insurance
14	Increase claims frequency and severity	Claims risks	Insurance
15	Extreme events causing deviations in claims level	Underwriting risks	Insurance
16	Lack of data to model risks	Underwriting risk	Insurance
17	Unforeseen management expenses	Expense overrun	Insurance
18	Investment in high proportion in specific equities	Concentration risk	Insurance
19	Business concentration on specific geographical area or economic sectors.	Concentration risk	Insurance
20	Changing regulation	Inability to keep up with the regulation	Strategic
21	Change in customer preference	Market changes	Strategic
22	Failure to implement strategic business planning	Business Planning	Strategic
23	Business strategy does not work out as planned	Business Planning	Strategic

The purpose of risk categorisation is to prepare for the risk assessment. Categorising the risks involves deconstructing a complex and unstructured list of risks into a smaller and simpler manageable number of risks. Categorising the risks enables easier pairwise comparisons; it is easier to compare risks with similar attributes. The process of categorising risks requires value judgement. Therefore, different companies may have different perspectives. For example, a company could perceive that interest rate risk belongs to strategic risk instead of market risk.

Identify the criteria to assess risks. For this application, the criteria are the risk categories. However, for easy pairwise comparisons, the risk category is defined as risk. The criteria are operational, strategic, insurance, market and liquidity risks. The alternatives are the sub-risks - the risks under each risk category.

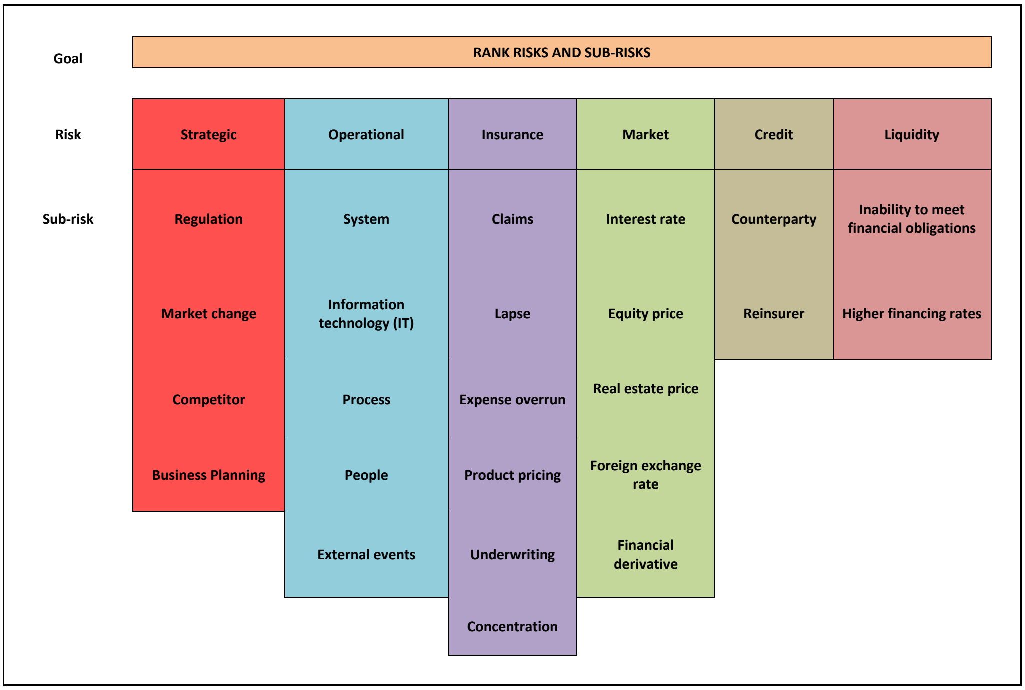
3. Organise the Criteria and Alternatives in a Hierarchy

The third step is to structure the risks and sub-risks in a hierarchy. The hierarchy has three levels. The first level is the decision goal, the second level is the risks and the third level is the sub-risks. Figure 6.2 presents the hierarchy. The hierarchy presents the linkage between the decision goal, risks and sub-risks. It also provides a holistic view of the risks, enabling risk managers to see all of the risks that need to be prioritised and the trade-offs they have to make.

Structuring the risks and sub-risks in a hierarchy offers the following benefits:

- Risks and sub-risks are divided into groups or categories. Therefore, trade-offs can be facilitated between the risks. It is easier to compare risks with similar attributes in order to determine which risk is more important.
- Present linkage between risk and sub-risks.
- Enable risk managers to view all risks faced by the company and detect missing risks.
- Present a holistic view of the problem.

Figure 6.2: Risks Hierarchy of An Insurance Company



4. Determine Decision Time Frame

Risk managers need to determine the risk assessment timeframe. Identifying the timeframe helps to avoid making a risk assessment at one point in time. For this application, the timeframe is one year. Therefore, the risk assessors evaluate the importance of the risks for one year. Risk managers need to advise the risk assessors, decision makers and relevant stakeholders of the timeframe.

5. Assess the Alternatives by Making Trade-off between the Alternatives

The pairwise comparisons start from the alternatives to the criteria. First, the sub-risks are compared within their category. Second, the risks are compared across categories. Risk assessors evaluate the detailed components of the risks, before evaluating the risks in general. Risk managers need to identify the decision makers or risk assessors to do the pairwise comparisons. The risk assessors should be people that are knowledgeable or experts in the field. They should involved in the decision making process from the beginning - identifying the problem and determining the decision goal.

The pairwise comparison questions are listed below:

The following presents the pairwise comparison questions:

- Compare sub-risks within their category. For example:
  - In terms of strategic risk, compare regulation (change in regulation) and market change (change in market preference). Which sub-risk are you more worried about, and by how much more?
  - In terms of strategic risk, compare regulation (change in regulation) and competitor (competitor activities). Which sub-risk are you more worried about, and by how much more?
- Compare risks across categories. For example:
  - Compare strategic and operational risks. Which risk are you more worried about, and by how much more?
  - Compare strategic and insurance risk. Which risk are you more worried about, and by how much more?

6. Calculate the Priority Weight of Risks and Sub-risks

The judgements should be translated into scores and recorded in a decision matrix. From the matrix, the local priority weight of the sub-risks and risks is recorded. The local priority weight presents the order of importance of the risks and sub-risks. Table 6.1 shows the decision matrix and the local priority weight of the sub-risks within their category. For strategic risk, change in regulation is the most important sub-risk, followed by competitors, business planning and market change. Table 6.2 shows the decision matrix and local priority weight for risks. The most important risk is strategic, followed by insurance, operational, market, credit and liquidity.

Table 6.1: Decision Matrix and Local Priority Weight of Sub-risks within Category

Strategic	Regulation	Market Change	Competitors	Business	Weight
Regulation	1	3	3	3	0.49
Market change	1/3	1	1/3	1	0.13
Competitors	1/3	3	1	1	0.22
Business planning	1/3	1	1	1	0.16
$\lambda_{\max}$=4.15	CI=0.05	CR=0.06			

Operational	System	IT	Process	People	External	Weight
System	1	3	3	5	5	0.05
IT	1/3	1	1	3	3	0.46
Process	1/3	1	1	3	1	0.10
People	1/5	1/3	1/3	1	1	0.21
External	1/5	1/3	1	1	1	0.18
$\lambda_{\max}$ = 5.15	CI=0.04	CR=0.03				

Insurance	Claims	Lapse	Expense Overrun	Product Pricing	Under-writing	Concen-tration	Weight
Claims	1	3	3	3	3	3	0.36
Lapse	1/3	1	1/3	1/3	1/3	1/3	0.06
Expense overrun	1/3	3	1	1	1/3	1	0.12
Product pricing	1/3	3	1	1	1	3	0.17
Underwriting	1/3	3	3	1	1	3	0.20
Concentration	1/3	3	1	1/3	1/3	1	0.10
$\lambda_{\max}$ = 6.41	CI=0.08	CR=0.07					

Market	Interest rate	Equity price	Real estate price	Foreign exchange	Financial derivatives	Weight
Interest rate	1	3	3	3	1	0.33
Equity price	1/3	1	3	3	1	0.22
Real estate price	1/3	1/3	1	1/3	1/3	0.07
Foreign exchange	1/3	1/3	3	1	1/3	0.11
Financial derivatives	1	1	3	3	1	0.27
$\lambda_{\max}$ = 5.30	CI=0.07	CR=0.07				

Credit	Counterparty	Reinsurer	Weight
Counterparty	1	3	0.75
Reinsurer	1/3	1	0.25
$\lambda_{\max}$ = 2	CI=0.00	CR=0.00	

Liquidity	Financial Obligation	Financing Rate	Weight
Financial Obligation.	1	5	0.83
Financing Rate	1/5	1	0.17
$\lambda_{\max}$ = 2	CI=0.00	CR=0.00	

Table 6.2: Decision Matrix and Local Priority Weight of Risks

Risk	Strategic	Operational	Insurance	Market	Credit	Liquidity	Weight
Strategic	1	3	3	3	3	5	0.36
Operational	1/3	1	1/3	1/3	3	3	0.11
Insurance	1/3	3	1	3	3	5	0.25
Market	1/3	3	1/3	1	3	3	0.16
Credit	1/3	1/3	1/3	1/3	1	1	0.06
Liquidity	1/5	1/3	1/5	1/3	1	1	0.05
$\lambda_{\max} = 6.47$	CI=0.09	CR =0.08					

7. Check Decision Consistency

A CR of more than 10 per cent indicates an inconsistent decision. In this case, risk managers need to have a discussion with the risk assessors to revise their judgement.

8. Aggregate Weights to obtain Overall Priorities of Risks

Table 6.3 shows the global or overall priority weight of sub-risks. The local priority weight of sub-risks with risks is multiplied to obtain the global priority weight of the sub-risks.

9. Discuss and Approve Results

Figure 6.3 shows the results. The priority weights of the risks and sub-risks are presented in bar charts. Presenting the results in graph forms foster clear communication and discussion. Therefore, the decision makers, management team and relevant stakeholders can debate, discuss and challenge the results.

The following results are presented in the discussion and approval step:

- ranking of risk.
- ranking of sub-risks within the risk category.
- overall ranking of sub-risks
- top ten risks are identified from the overall ranking of sub-risks.

Figure 6.3: RP Risk Prioritisation Results

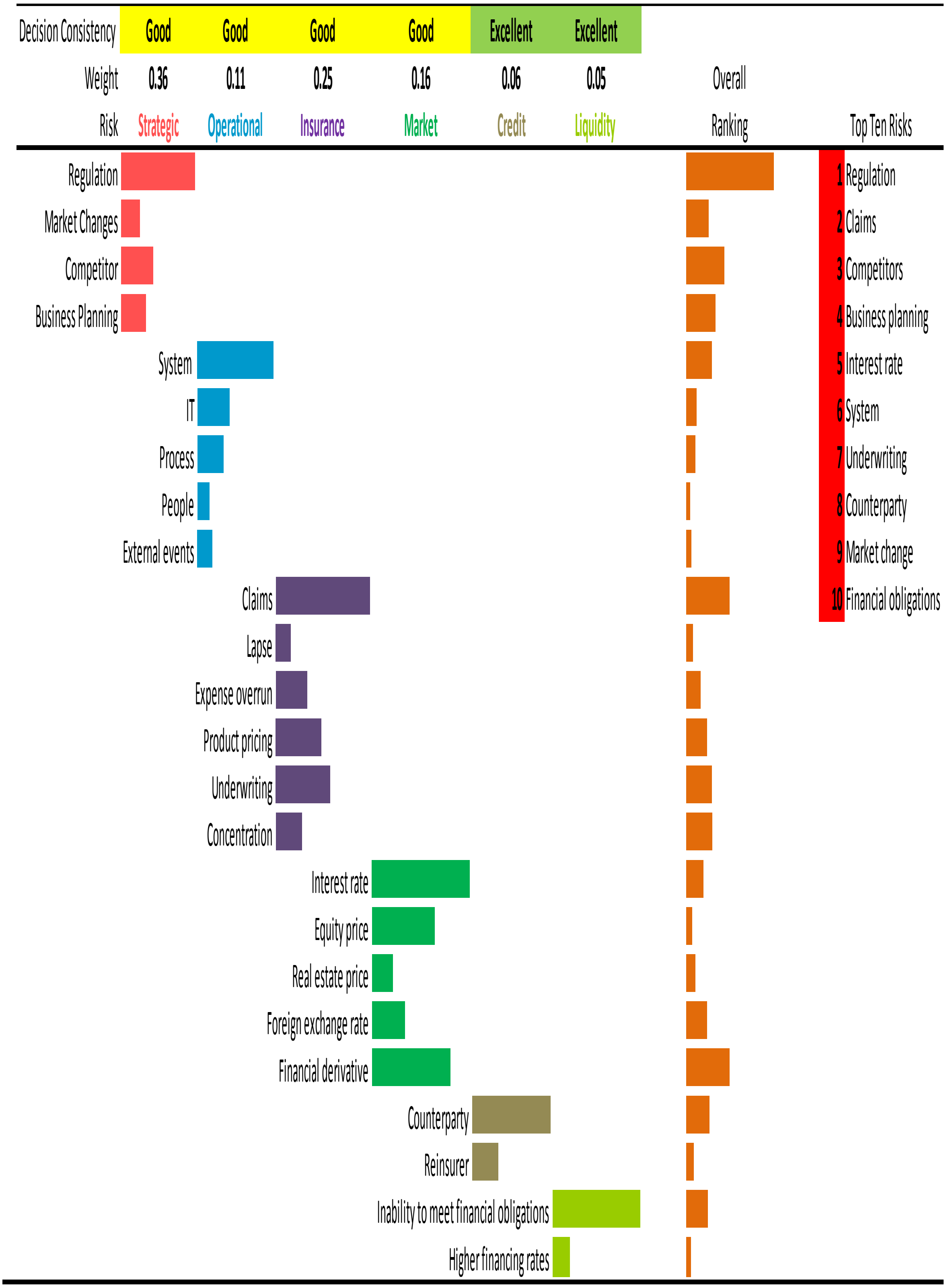


Table 6.3: Global Priority Weight of Sub-Risks

Risks	Strategic	Operational	Insurance	Market	Credit	Liquidity	Global
Local Weight	0.36	0.11	0.25	0.16	0.06	0.05	Weight
Regulation	0.49						0.18
Market change	0.13						0.05
Competitor	0.22						0.08
Business Planning	0.16						0.06
System		0.47					0.05
IT		0.20					0.02
Process		0.16					0.02
People		0.07					0.01
External events		0.09					0.01
Claims			0.35				0.09
Lapse			0.06				0.01
Expense overrun			0.12				0.03
Product pricing			0.17				0.04
Underwriting			0.20				0.05
Concentration			0.10				0.02
Interest rate				0.33			0.05
Equity price				0.22			0.03
Real estate price				0.07			0.01
Foreign exchange rate				0.11			0.02
Financial derivatives				0.27			0.04
Counter party					0.75		0.05
Reinsurer					0.25		0.02
Financial obligations						0.83	0.04
Financing rates						0.17	0.01

6.3 Determining Insurance Company Line of Business with the Highest Risk

Consider an insurance company with four lines of business (LOB): Accident and Health, Motor Non-Liability, Motor Liability and General Liability. Insurance companies' main risks are underwriting, credit, market, liquidity and operational (IAA, 2009). Each main risk has sub-risks. Insurance companies measure LOB risks to determine the solvency margin or amount of capital for the LOBs.

Sandstrom (2006) identified three types of risk measures that are usually used by insurance companies:

- Standard deviation.
- VaR.: VaR is a standard approach used to measure financial risks. It gives the amount of capital required to ensure that a company remains solvent with a particular degree of certainty.
- Expected Shortfall or Tail VaR: The expected shortfall or the Tail VaR, is the conditional tail expectation in the upper α per cent of the right-hand tail of a distribution.

This section demonstrates how an insurance company calculates total capital (Koller, 2011). An insurance company has three risks: financial, operational and regulatory. Table 6.4 presents the risks and the required capital for each risk. The required capital is calculated using 99.5 per cent VaR. According to Koller (2011), the diversification effect depends on how the insurance company builds the risks and capital models and links the models together. The required capital represents the amount of capital considered when linking the different risks together.

The objective of this application is to demonstrate how RP can be used to determine which LOB has more risks. The results can be used by the insurance company to allocate capital or plan strategic risk actions for the LOBs . RP produces the following output:

Table 6.4: Risk and Required Capital

Risk	Required capital
Financial	7680
Operational	900
Regulatory	450
Total	9030
Diversification	-3010
Required capital	6020

- local ranking of risks and sub-risks of each LOB.
- overall or global ranking of risks and sub-risks.
- global ranking of the LOBs., which determines the LOB with the largest risk.

1. Establish Problem and Determine Decision Goal

The goal is to determine which LOB has more risks. In this application, instead of measuring the LOB risks individually, RP considers the LOBs and risks faced by the LOBs simultaneously.

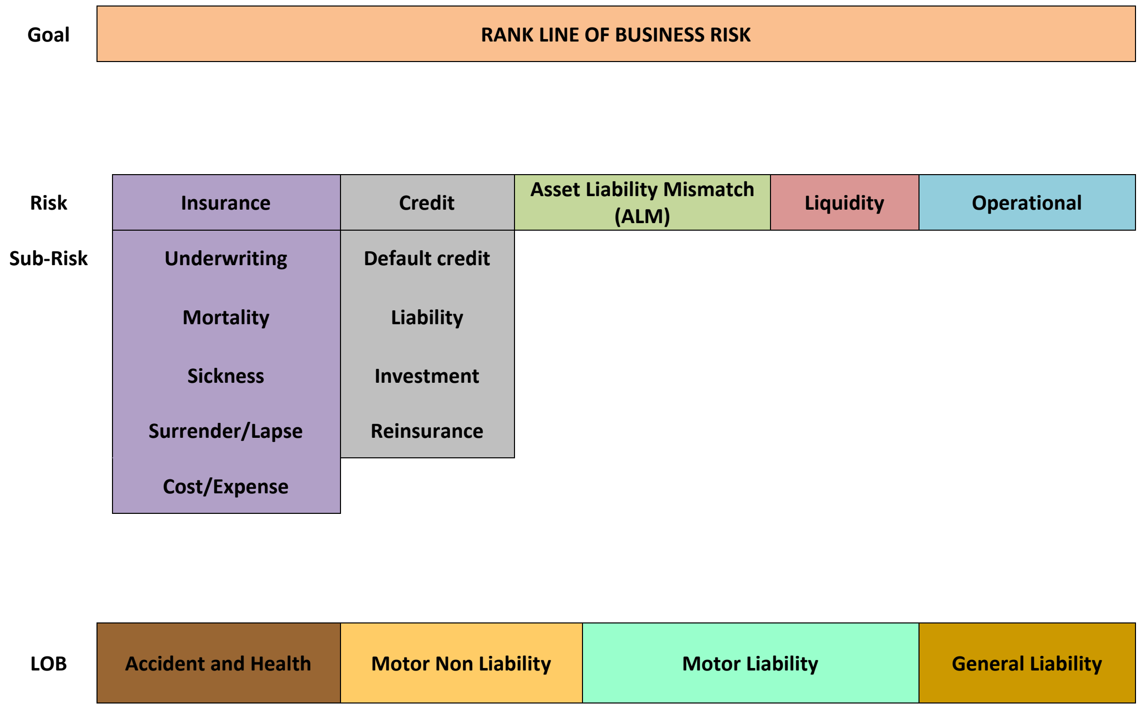
2. Identify Criteria and Alternatives

The alternatives are the LOBs: Accident and Health, Motor Non-liability, Motor Liability and General Liability. The criteria are risks faced by each LOB: insurance, credit, market, liquidity and operational. Insurance risk is deconstructed into underwriting, mortality, sickness, surrender and lapse, and cost and expense. Credit risk is deconstructed into credit default, liability, investment and reinsurance. For market risk, only asset liability mismatch (ALM) is relevant to the LOBs. Liquidity and operational risks remain as single risks.

3. Organize the Criteria and Alternatives in a Hierarchy

Organise the risks, sub-risks and LOBs in a hierarchy. The first level is the decision goal, the second level is risks, the third level is sub-risks and the fourth level is LOBs. Figure 6.4 presents risks hierarchy of the LOBs.

Figure 6.4: Hierarchy of Risks of Line of Business



4. Determine Decision Time Frame

RP assumes that all policies written by the LOBs take effect at 12.01 am on 1 January and expires at 12.00 am on 31 December. Therefore, the decision timeframe is one year.

5. Assess the Alternatives by Making Trade-off between the Alternatives.

From the hierarchy, the pairwise comparisons start from the risks, followed by sub-risks and LOBs. The first pairwise comparison is to assess the risks for the decision goal. The second is to assess the sub-risks within their category. The third is to assess the LOBs for sub-risks and risks. The purpose of the top-down sequence is to create awareness and expose the risk assessors to the risks and sub-risks affecting the LOBs before judging the LOBs. The pairwise comparisons should be conducted by people who are experts in the area, such as actuaries, financial managers and underwriters. It is risk managers responsibility to identify the risk assessors or decision makers.

The pairwise comparisons are presented below:

- Assess the importance of risks. For example, in terms of the decision goal:
  - Compare insurance and credit risks. Which risk is more important, and by how much more?
  - Compare insurance and ALM risks. Which risk is more important, and by how much more?
- Assess the importance of sub-risks within their category. For example, for insurance risk:
  - Compare underwriting and mortality. Which sub-risk is more important, and by how much more?
  - Compare underwriting and sickness. Which sub-risk is more important, and by how much more?
- Assess the LOBs for risks and sub-risks. For example, for underwriting risk:
  - Compare accident and health, and motor non-liability. Which LOB is more affected, and by how much more?
  - Compare accident and health, and motor liability. Which LOB is more affected, and by how much more?

6. Calculate the Priority Weight of Criteria and Alternatives

Table 6.5 shows the decision matrix and the local priority weight of the risks. Table 6.6 shows the decision matrix and the local priority weight for the sub-risks within their

Table 6.5: Decision Matrix and Local Priority Weight of Risks

Risk	Insurance	Credit	ALM	Liquidity	Operational	Weight
Insurance	1	3	3	3	3	0.41
Credit	1/3	1	3	3	3	0.26
ALM	1/3	1/3	1	3	1	0.14
Liquidity	1/3	1/3	1/3	1	1	0.09
Operational	1/3	1/3	1	1	1	0.11
$\lambda_{max} = 5.30$	CI=0.07	CR=0.07				

Table 6.6: Decision Matrix and Local Priority Weight of Sub-risks

Insurance	Underwriting	Mortality	Sickness	Surrender/ Lapse	Cost/ Expense	Weight
Underwriting	1	1/3	1/3	3	3	0.17
Mortality	3	1	1	3	3	0.33
Sickness	3	1	1	3	3	0.33
Surrender/Lapse	1/3	1/3	1/3	1	1	0.09
Cost/Expense	1/3	1/3	1/3	1	1	0.09
$\lambda_{max} = 5.20$	CI=0.05	CR=0.04				
Credit	Default credit	Liability	Investment	Reinsurance	Weight	
Default credit	1	3	3	3	0.49	
Liability	1/3	1	1/3	1	0.13	
Investment	1/3	3	1	1	0.22	
Reinsurance	1/3	1	1	1	0.16	
$\lambda_{max} = 4.15$	CI=0.05	CR=0.06				

categories. Table 6.8 shows the decision matrix and the local priority weight of the LOBs.

7. Check Decision Consistency

For a CR of less than 10 per cent, risk managers need to ask the risk assessors to review and revise their assessments.

8. Aggregate Weights to Obtain Overall Priority Weight of Alternatives

Table 6.7 presents the global priority weight of the sub-risks and risks. To obtain the global priority weight of the sub-risks, their local priority weight is multiplied with the local priority weight of the risks. To obtain the global priority weight of the LOBs, RP constructs a matrix of local priority weight of each LOB for the sub-risks and risks. Each row of the matrix is multiplied with the global priority weight of the sub-risks and risks.

The following shows the matrix of local priority weight of each LOB for the sub-risk and risks, and global priority weight of the sub-risks and risks:

$$\begin{bmatrix} 0.49 & 0.10 & 0.63 & 0.49 & 0.48 & 0.10 & 0.49 & 0.50 & 0.09 & 0.49 & 0.50 & 0.50 \\ 0.13 & 0.22 & 0.13 & 0.13 & 0.09 & 0.22 & 0.13 & 0.17 & 0.16 & 0.13 & 0.17 & 0.17 \\ 0.22 & 0.39 & 0.13 & 0.22 & 0.21 & 0.39 & 0.22 & 0.17 & 0.37 & 0.22 & 0.17 & 0.17 \\ 0.16 & 0.29 & 0.13 & 0.16 & 0.21 & 0.29 & 0.16 & 0.17 & 0.37 & 0.16 & 0.17 & 0.17 \end{bmatrix} \begin{bmatrix} 0.07 \\ 0.13 \\ 0.13 \\ 0.04 \\ 0.04 \\ 0.13 \\ 0.03 \\ 0.06 \\ 0.04 \\ 0.14 \\ 0.09 \\ 0.11 \end{bmatrix} = \begin{bmatrix} 0.39 \\ 0.16 \\ 0.24 \\ 0.20 \end{bmatrix}$$

9. Discuss and Approve Results

For the discussion, the priority weights were used to develop the bar charts, which present the level of risks. Figure 6.5 presents the level of risks and sub-risks for each LOB, the overall or global level of the risks and sub-risks, and the risk level of the LOBs. A discussion of the results is presented below:

- Local ranking of risks and sub-risks of each LOB. The local ranking or contribution of the risks and sub-risks to the LOBs is as follows:

Table 6.7: Global Priority Weight of Sub-risks and Risks

	Insurance	Credit	ALM	Liquidity	Operational	Weight
Weight	0.41	0.26	0.14	0.09	0.11	
Underwriting	0.17					0.07
Mortality	0.33					0.13
Sickness	0.33					0.13
Surrender/Lapse	0.09					0.04
Cost/Expense	0.09					0.04
Default credit		0.49				0.13
Liability		0.13				0.03
Investment		0.22				0.06
Reinsurance		0.16				0.04
ALM						0.14
Liquidity						0.09
Operational						0.11

– Accident and Health: Sickness risk has the highest level, suggesting that the risk has the largest contribution the LOB.

– Motor Non Liability: Mortality and credit default risks have the same level. These risks make the largest and equal contribution to the LOB.

– Motor Liability: Mortality and credit default risk both have the same level of risk. Similar to motor non-liability, the risks have the largest and equal contribution to the LOB.

– General liability: Reinsurance risk has the highest level of risk and therefore the largest risk contributor to the LOB.

Risk managers also need to point out that mortality and credit default are two of the most important risks for Motor Non-Liability and Motor Liability. However, the level of risk is higher for Motor Liability compared to Motor Non-Liability. Therefore, the contribution of mortality and credit default risks is larger for Motor Liability compared to Motor Non-Liability.

- Global ranking of the LOBs, which determines the LOB with the largest risk. The LOBs risk level is as follows: The result shows that Accident and Health has the highest level of risk, followed by Motor Liability, General Liability and Motor Non-Liability. This can be seen by comparing the LOBs in terms of the level of risks and sub-risks. The risk levels (the bars) are higher for Accident and Health compared to the other LOBs.
- Overall or global ranking of risks and sub-risks: The global level of risks and sub-risks shows that liquidity and operational risks are the most important risks.

6.4 Summary

This chapter demonstrated how the RP structured and organised risk management problems into an easy-to-follow and analyse framework. Structuring problems into hierarchies provides a clear, organised and logical view of the problem. This chapter also demonstrated the RP decision-making steps, which are systematic, logical and easy to understand.

Chapter 7 evaluates RP's practical usability. The risk management problems structured using RP in this chapter are presented to risk managers to be evaluated.

Table 6.8: LOB Decision Matrix & Local Priority Weight

	Accident and Health	Motor Non Liability	Motor Liability	General Liability	Weight
Underwriting					
Accident and Health	1	3	3	3	0.49
Motor Non Liability	1/3	1	1/3	1	0.13
Motor Liability	1/3	3	1	1	0.22
General Liability	1/3	1	1	1	0.16
$\lambda_{max} = 4.15$	CI=0.05	CR=0.06			

Continued on next page

Table 6.8 – *Continued from previous page*

	Accident and Health	Motor Non Liability	Motor Liability	General Liability	Weight
Mortality					
Accident and Health	1	1/3	1/3	1/3	0.10
Motor Non Liability	1/3	1	1/3	1	0.22
Motor Liability	3	3	1	1	0.39
General Liability	3	1	1	1	0.29
$\lambda_{max} = 4.15$	CI=0.05	CR=0.06			
Sickness					
Accident and Health	1	5	5	5	0.63
Motor Non Liability	1/5	1	1/3	1	0.13
Motor Liability	1/5	3	1	1	0.13
General Liability	1/5	1	1	1	0.13
$\lambda_{max} = 4.00$	CI=0.00	CR=0.00			
Surrender/Lapse					
Accident and Health	1	3	3	3	0.49
Motor Non Liability	1/3	1	1/3	1	0.13
Motor Liability	1/3	3	1	1	0.22
General Liability	1/3	1	1	1	0.16
$\lambda_{max} = 4.15$	CI=0.05	CR=0.06			
Cost/Expense					
Accident and Health	1	3	3	3	0.48
Motor Non Liability	1/3	1	1/3	1/3	0.09
Motor Liability	1/3	3	1	1	0.21
General Liability	1/3	3	1	1	0.21
$\lambda_{max} = 4.15$	CI=0.05	CR=0.06			
Default credit					
Accident and Health	1	1/3	1/3	1/3	0.10

Continued on next page

Table 6.8 – *Continued from previous page*

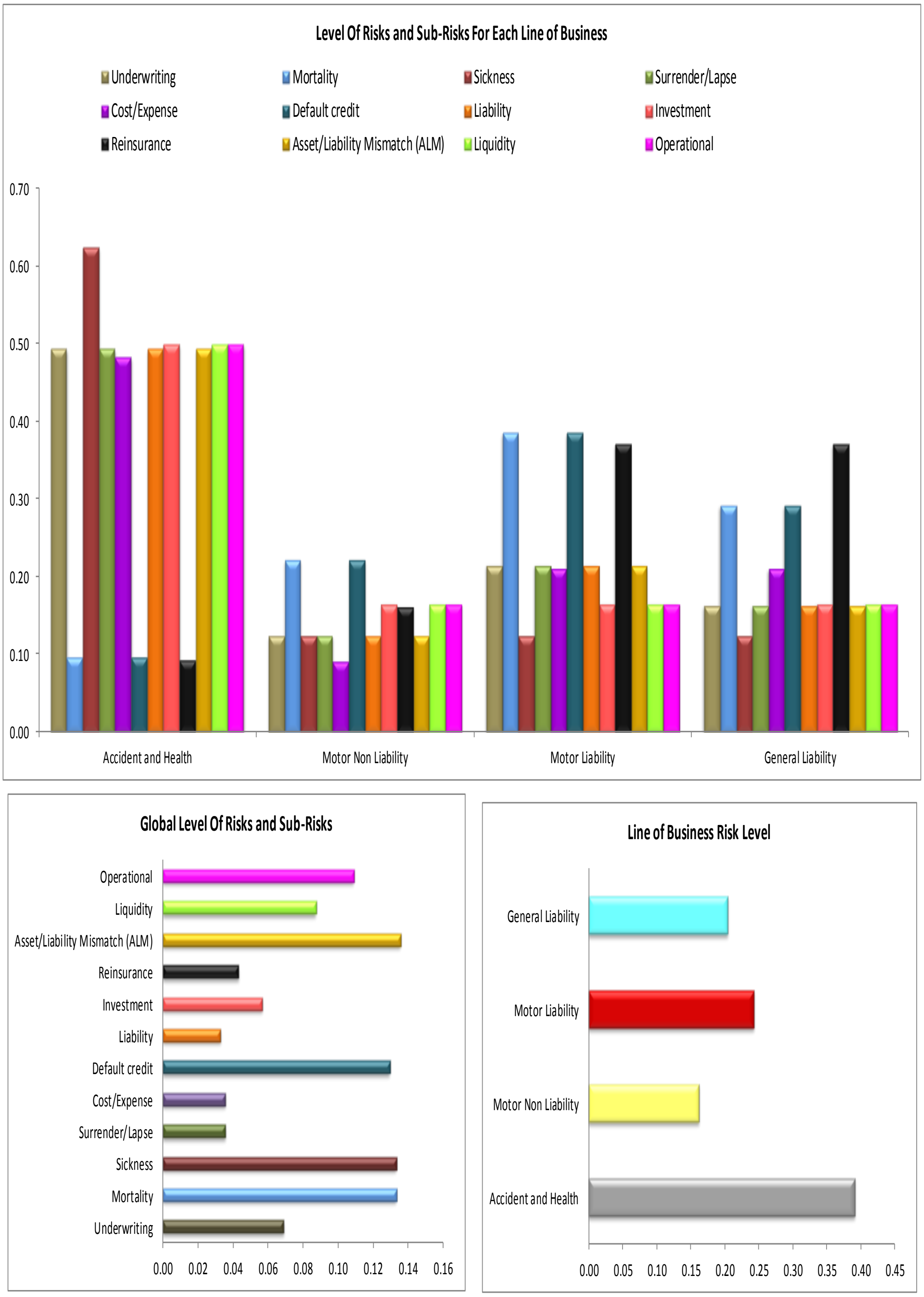
	Accident and Health	Motor Non Liability	Motor Liability	General Liability	Weight
Motor Non Liability	3	1	1/3	1/3	0.22
Motor Liability	3	3	1	1	0.39
General Liability	3	1	1	1	0.29
$\lambda_{max} = 4.15$	CI=0.05	CR=0.06			
Liability					
Accident and Health	1	3	3	3	0.49
Motor Non Liability	1/3	1	1/3	1	0.13
Motor Liability	1/3	3	1	1	0.22
General Liability	1/ 3	1	1	1	0.16
$\lambda_{max} = 4.15$	CI=0.05	CR=0.06			
Investment					
Accident and Health	1	3	3	3	0.50
Motor Non Liability	1/3	1	1	1	0.17
Motor Liability	1/3	1	1	1	0.17
General Liability	1/ 3	1	1	1	0.17
$\lambda_{max} = 4.00$	CI=0.00	CR=0.00			
Reinsurance					
Accident and Health	1	1/3	1/3	1/3	0.09
Motor Non Liability	3	1	1/3	1/3	0.16
Motor Liability	3	3	1	1	0.37
General Liability	3	3	1	1	0.37
$\lambda_{max} = 4.15$	CI=0.05	CR=0.06			
ALM					
Accident and Health	1	3	3	3	0.49
Motor Non Liability	1/3	1	1/3	1	0.13
Motor Liability	1/3	3	1	1	0.22

Continued on next page

Table 6.8 – *Continued from previous page*

	Accident and Health	Motor Non Liability	Motor Liability	General Liability	Weight
General Liability	1/3	3	1	1	0.16
$\lambda_{max} = 4.15$	CI=0.05	CR=0.06			
Liquidity					
Accident and Health	1	3	3	3	0.50
Motor Non Liability	1/3	1	1	1	0.17
Motor Liability	1/3	1	1	1	0.17
General Liability	1/3	1	1	1	0.17
$\lambda_{max} = 4.00$	CI=0.00	CR=0.00			
Operational					
Accident and Health	1	3	3	3	0.50
Motor Non Liability	1/3	1	1	1	0.17
Motor Liability	1/3	1	1	1	0.17
General Liability	1/3	1	1	1	0.17
$\lambda_{max} = 4.00$	CI=0.00	CR=0.00			

Figure 6.5: RP Results for Line of Business Risk



7

Evaluating the Practical Usability of RP

7.1 Introduction to Chapter 7

This thesis has developed RP, which is a decision-making tool based on the AHP. Chapter 5 explained RP and the differences and similarities between RP and the AHP. The primary aim of this thesis is to explore whether RP is relevant for risk management. To support the aim, this thesis investigates how and in what way RP is useful and not useful for risk management, how RP can be used for risk management, and how risk managers can use RP effectively.

In this phase, the thesis brings RP to the practical setting. The risk management problems developed in Chapter 6 are presented to the risk managers, who evaluate RP's practical usability. The risk managers or evaluators were recruited from members of the Malaysian Association of Risk and Insurance Management (MARIM). This chapter explains the approach taken by the thesis to collect feedbacks from the risk managers.

The goals of this chapter are to:

- justify the methodology for data collection. (Section 7.2)
- describe how the methodology is used to collect feedback on RPs usability. (Section 7.3)
- describe the research participants and how the feedbacks were obtained from them. (Sections 7.4.1, 7.4.2 and 7.4.5)
- describe the instrument used to support data collection. (Sections 7.4.3 and 7.4.4)
- report the feedbacks obtained from the research participants. (Section 7.5)

7.2 Overview of Evaluation

This section discusses the methodology of the thesis. The aim of this thesis is to develop a decision making tool for risk management. The tool called RP exploits the AHP developed by Thomas L. Saaty in 1972. To realise the aim, the thesis need to find answers to the following questions: how and in what way RP is useful as a decision making tool for risk management; how and in what way RP is not useful and what can be done to minimise its non-usefulness; how or in what way RP can be used for risk management and what do risk managers requires to use RP effectively. Answers to the questions will be use to identify RP strengths, weaknesses and practical usability, with the aim to improve and refine RP.

To obtain the answers, this thesis used utilisation-focused formative evaluation approach to answer the research questions. The following discusses the definition of evaluation, different types of evaluation, differences between evaluation and research, and how to conduct evaluation. Evaluation is an activity used to judge the value, merit or worth of something (Clarke and Dawson, 1999). Evaluation can be formal or informal. Examples of formal evaluation are judging the aesthetic value of an art, determining the rehabilitative impact of prison sentences or assessing the quality of services provided by a company. Examples of informal evaluation are comparing holiday destinations or self-evaluation against personal-merits. Clarke and Dawson (1999) defined formal evaluation as a form of disciplines inquiry using scientific procedures to collect and analyse information about content, structure and outcomes of programmes, projects or interventions. Patton (1997) defined evaluation as a systematic collection of information about the activities, characteristics, and outcomes of programs to make judgements about the program, improve program effectiveness, and/or inform decisions about future programming.

Suchman (1967) differentiated evaluation and evaluation research. Evaluation aims to establish the value or worth of an action, and evaluative research is a scientific method that is employed to carrying out the evaluation. Evaluation research is presented as a form of applied social research. The primary purpose is to study the effectiveness of existing knowledge to inform and guide practical actions. Patton (1997) stated evaluation differs fundamentally from research in the purpose of data collection. Scientific research is undertaken to discover new knowledge, test theories, establish truth, and generalise across time and space. Evaluation is undertaken to inform decision, clarify options, identify improvements, and provide information about programs and policies within contextual boundaries of time, places, values and politics. Patton (1986) supported using scientific method to conduct the evaluation. Patton (1986) stated that evaluators should use research methods to gather data for specific programs. The primary intention is to provide critical information for decision makers about the future developments of programs. Stufflebeam and Shinkle (1985) stated that the most important purpose of evaluation research is not to prove but to improve. In contrast, the purpose of basic research is to discover new knowledge. Evaluation research aims to help improve programming and policy making (Weiss, 1997). Riddick and Russell (1999) stated that evaluative research is not triggered by the desire to examine a theory; rather, it is conducted to provide information to determine the future course of action for a program or service. Evaluative research answers questions of immediate, practical concern, and it is conducted in a real-world setting.

Evaluation is divided into two types: formative and summative (Scriven, 1967).

Formative evaluation is an evaluation that provides feedback to people who are trying to improve something. The evaluation is conducted to identify the strengths and weaknesses of a program or an intervention to support the process of improvements. The aim of formative evaluation is to ascertain if any changes are needed to improve the program. In contrast, summative evaluation is an activity that determines the overall effectiveness of a program or project. The aim of summative evaluation is to recommend whether or not to continue a program or a project. Patton (1986) stated that summative evaluation is conclusion-oriented, whereas formative evaluation is action-oriented. As for data collection methodology Patton (2002) stated formative evaluations rely heavily and even primarily on qualitative methods. On the other hand, summative evaluations seldom rely on entirely or even primarily on qualitative data or naturalistic enquiry. In summative evaluation, the evaluator's interest is in measuring a program, policy or product standardised outcomes and making judgement about effectiveness of the program from relatively larger samples with statistical pre, post, and follow up results. In formative evaluation, the evaluator's interest is in improving a program, policy or product. A formative evaluation does not attempt to generalise findings beyond the setting in which the evaluation takes place.

Patton (1986) developed utilisation-focused evaluation approach, which emphasises utility, relevance, practicality and meeting the needs of specific users. Use is central in utilisation-focused evaluation. The goal of utilisation-focused evaluation is intended use of the evaluation results by intended users. Therefore, the primary criterion by which a program or product is judged is the intended use of the program by the intended users (Patton, 1997). The evaluation process and design should consider everything that needs to be done from the beginning to the end that affects use. The steps of the evaluation are developed with the aim of facilitating use by the intended users or stakeholders. Intended users are people who are interested, knowledgeable, credible, teachable and available for interaction throughout the evaluation process. Stakeholder is defined as people having a stake or interest in the evaluation findings. According to Ramrez and Brodhead (2013), utilisation focused evaluation does not prescribe any specific content, method or theory. It is a guiding framework, as opposed to methodology, and people- and context- dependent. Utilisation-focused evaluation can be used for: a formative or summative evaluation, qualitative, quantitative or mixed data; naturalistic or experimental research design; and processes, outcomes, effects or cost-benefit evaluation focus (Patton, 1997). To conduct utilisation-focused evaluation, four items need to be clarified for the intended users of the evaluation:

- purpose of evaluation. The person conducting the evaluation needs to determine the purpose of the evaluation. The purpose could be to improve a program or to decide whether to terminate a program.

- evaluation criteria. The evaluation criteria are the criteria used to judge the program. For example, customers satisfaction can be used to evaluate whether to terminate or maintain a program or policy.

- evaluation method. The evaluation method is the methodology used in the evaluation. The method can be quantitative such as historical data of sales or customers' complaints, or qualitative such as interviews or questionnaires.

- time line. The evaluation time line is determined by when the decision makers or product developers need the evaluation output.

Saunders (2012) proposed the following evaluation design to enhance the usability of the evaluation outputs:

- Reasons or purposes of the evaluation. Discuss with potential users the issues associated with why an evaluation needs to be conducted.

- The potential uses of the evaluation. The evaluation could be used to improve staff development, to provide data for strategic planning or to improve current process or practice.

- The focus of the evaluation. Choose a relevant and salient focus. The selected activity, aspect or criterion should connect to the priority areas being evaluated.

- The nature of data and evidence. Data and evidence could be numerical, qualitative, observations or case studies. Evidence and data should be readable and understandable by potential users and stakeholders.

- Audience for the evaluation output. Identify the readers of the evaluation outputs. The readers could the practice community, commissioners or evaluators. Discriminate the output style, form and content between different readers. The core content of the evaluation output should reflect the different interests of the readers.

- Timing of the release of the evaluation output. The timing should coincide with decision-making cycles or lifecycle of the projects.

- Agency for undertaking the evaluation. Discuss with stakeholders and users of the evaluation to select the person to perform the evaluation.

The intended use of RP evaluation is to generate knowledge on RP practical usability as a decision making tool for risk management, and how the knowledge can contribute to improving RP. RP evaluation is people and context dependent. The evaluation is conducted by intended users - risk managers. The context of evaluation is on practical usability of RP as a decision making tool for risk management problems described in detail in Chapter 6. Therefore, adopting the utilisation focused evaluation approach, the steps of RP evaluation are developed with the aim of facilitating RP as a decision making tool for risk managers. The purpose of the evaluation is formative, therefore qualitative data collection will be used.

7.3 The Design of RP Evaluation

This thesis has defined evaluation as a systematic collection of judgements by risk managers on the merits, worth, advantages and disadvantages of RP. The purpose of evaluation is formative to improve and refine RP. The RP evaluation design provides detail planning of the evaluation. It is based on the evaluation context discussed in Section 7.2. The RP evaluation design consists of the purpose of conducting an evaluation on RP, the focus of the evaluation and the potential use of the evaluation feedbacks.

RP evaluation design is outlined below.

7.3.1 Purpose of Evaluating RP

The purpose of conducting an evaluation on RP is to answer the research questions:

- How or when is RP useful for risk management?
- How or when is RP not useful for risk management?
- How is RP used for risk management?
- What do risk managers require to use RP effectively?

Specifically, the purpose is to enhance knowledge on RP with the intention to refine the RP decision making process and improve its usability. The purposes are broken down as follows:

- To see whether the risk management problems developed and structured using RP, as presented in Chapter 6, is how risk managers would use RP. Risk managers' feedback is used to answer how and in what way RP is useful or not useful to risk managers.
- To obtain information on practical usability of RP. Risk managers' feedback is used to answer how RP is used for risk management and what risk managers require to use RP effectively.

7.3.2 Criteria Used to Evaluate RP

The aim of the thesis is to investigate whether RP is useful for risk management decision making. To answer the question, the core components of RP are evaluated. The core components represent the criteria used to evaluate RP.

The following outlines the criteria:

- Structuring a problem using a hierarchy. The evaluation aims to find out whether a hierarchy is a useful technique for structuring risk management problems.
- Pairwise comparisons and decision consistency: The evaluation aims to find out whether the pairwise comparison is a useful technique to make risk trade-offs, and the CR enables risk managers to make consistent judgements.
- RP decision-making steps: The evaluation aims to find out whether the steps guide risk managers to achieve the decision goal.
- Results produced by RP: The evaluation aims to find out whether the results are useful and meaningful.
- Using RP as a decision tool for risk management: The evaluation aims to find out whether risk managers would consider RP as a decision-making tool for risk management.

7.3.3 Potential Use of RP Evaluation Feedbacks

The feedbacks are used to understand RP from risk managers' perspectives and improve RP usability. The evaluation feedbacks are used in the following way:

- to modify, refine and improve RP.
- to learn and understand RP in a new way, from risk managers' perspectives.
- to add knowledge to the application of RP to risk management.

7.4 Conducting the RP Evaluation

7.4.1 Description of the Risk Managers

This thesis has defined the evaluator or research participant as a person whose professional activity involves managing risks or making decisions under conditions of risks and uncertainties. The evaluators were recruited from members of the MARIM. Twenty-three email invitations were sent to the members. Seven members responded and agreed to take part in the evaluation session. After the first evaluation session, one of the participants recommended a potential evaluator from a risk management unit in a government agency that handles business registration for companies or individuals conducting business in Malaysia. The business information is stored in a central database. The risk management unit was recently set up, and it consists of three staff members. The unit is in the initial stage of planning disaster risk management and business continuity to protect the database. Ten evaluators or research participants took part in the evaluation. The evaluators had a minimum of three years and a maximum of 15 years' work experience in risk management.

The thesis used the focus group approach to collect feedbacks on RP usability. The focus group is risk managers practising in Kuala Lumpur, Malaysia. The focus group approach provides the following benefits (Finch and Lewis, 2003, pg. 171):

- It enables the participants to present their views and opinions, and they could also hear views and opinions of other participants. Therefore, they can reflect on what the others said on their standpoint. This method could trigger additional material from the participants as they response to other participants view, and discussed and debate their views and opinions.

- It enables the participants to ask questions of each other, seek clarification, comment on what they have heard and prompt others to reveal more. As the discussion progresses the individual response becomes sharpened and refined, and moves to a deeper and more considered level.

- It encourages the participants to work as a group. In responding to each other, the participants question and interact with each other, taking over some of the interviewing role of the researcher. Therefore, the participants' opinions and perspectives are less influenced by the researcher.

7.4.2 Evaluation Session with the Risk Managers

The evaluation session was conducted in a group meeting in June 2014 in Kuala Lumpur, Malaysia. The first group consisted of the seven MARIM members, and the second group consisted of the three risk managers from the government agency.

The duration of the meeting was four hours for the first group and seven hours for the second group. The seven-hour meeting with the second group took place in two meetings. The first meeting lasted for four hours and second meeting was three hours. The first meeting consisted of learning and evaluating RP for the thesis. The second meeting was conducted because the risk management unit planned to use RP for their disaster risk management planning. However, due to confidentiality, the hierarchy of disaster risks is not discussed in the thesis. Only their feedbacks on RP usability on developing and planning disaster risk management is used in the thesis. Nevertheless, the meeting offered mutual benefits. RP had the opportunity to be applied to an actual risk management problem, and the risk managers learnt a new technique to assess and prioritise risks.

7.4.3 Tool Supporting RP Evaluation

To facilitate the evaluation process, the thesis developed a decision support tool for RP to give the participants hands-on learning experience and to expedite the learning and understanding of RP. The tool facilitates learning by presenting the structure of the problem in a hierarchy, allowing the participants to input judgements in the pairwise comparisons and check the decision consistency of their judgements, and to produce the ranking of risks or alternatives for the participants to see the output of their judgements.

The tool was developed using an Excel spreadsheet. The interface of the decision support tool consists of an introduction to RP, three simple examples and the two risk management problems described in Chapter 6. The interface is explained below:

- Introduction to RP. Brief explanation of RP and RP decision-making steps.

- Three examples. The first example was a simple problem to choose a city for relocation. The example has three criteria and four alternatives. The second example was a complex problem that selected factors for the successful implementation of Malaysia Vision2020 (Islam, 2009) which is an ideology known to every Malaysian. The ideology is taught at school, debated and discussed in the media. Although the problem is complex, it does not require a long explanation. The participants could quickly understand the problem and complete the example. The third example was to select effective risk management actions. The third example aimed to familiarise the participants with RP application to risk management problems.

- The two risk management problems developed in Chapter 6 consist of:
  - A short description of the problems.
  - Steps to address the problem as discussed in Chapter 6.
  - The hierarchy of the problem as presented in Chapter 6
  - Pairwise comparisons of criteria and alternatives as presented in Chapter 6. The tool enables the participants to input their judgements, and the priority weight is automatically calculated.
  - Ranking of criteria and alternatives. The rankings are immediately produced after a set of pairwise comparisons. They are presented in bar charts. The purpose is to motivate the participants to answer all of the pairwise comparisons to see the overall ranking result.
  - Decision consistency. Decision consistency is automatically calculated and immediately produced after each set of pairwise comparisons. The participants can immediately check the consistency of their decisions and review inconsistent decisions. The decision consistency has three levels: excellent, good and poor. Excellent means the CR is less than 5 per cent, good is less than 10 per cent and poor is more than 10 per cent.
  - Result. The local weight of criteria and alternatives, and global weight of alternatives, are automatically produced after the completion of all pairwise comparisons. The weights are presented using bar charts, as presented in Chapter 6. The results are interactive. The bar in the charts changes as risk managers changes their judgements in the pairwise comparison.

7.4.4 RP Evaluation Questionnaire to Collect Feedbacks

RP uses open-ended questionnaire to obtain feedbacks from the participants. A sample of the questionnaire is provided in the Appendix. The questionnaire consisted of the following questions:

1. Problem structure. A hierarchy was used to structure a risk management problem. Hierarchy presents a problem in a multilevel structure and shows linkage between factors and sub-factors. For the hierarchy, the participants are required to evaluate RP as follows:
   - Does the hierarchy helps better understanding of the problem?
   - Does the hierarchy makes the problem more structured and organised.
   - Does disagreement be constructively managed by presenting the problem in a hierarchy.
   - Can overlook or missing information easily detected?
   - Does the hierarchy makes communication about the problem more focused?
   - Does structuring and organising the problem in a hierarchy promote creative thinking?
2. Making risk trade-offs: RP uses pairwise comparison to make trade-offs between risks or alternatives. Decision consistency measures the consistency of the judgement. The participants were required to evaluate the pairwise comparisons as follows:
   - Paired comparison is a natural way to make trade-offs between risks.
   - The pairwise comparison question is easy to follow and understand.
   - The scale (1,3,5,7 and 9) is easily understood.
   - Decision consistency assists in making consistent judgement.
3. RP consists of the following components: brief explanation of the problem or problem statement, decision-making steps, hierarchy, pairwise comparisons and

results. The participants were required to evaluate the usefulness of each component.

- Decide whether RP is easy to use and the decision-making steps are easy to follow.
- Decide whether the components are useful.
- Identify the most useful component.
- Suggest new components to be added to RP.
- Suggest a new RP structure with the new component.

4. Usefulness of result and potential RP implementation challenges. The final part required the participants to evaluate the results produced by RP and provide their views on using RP as a decision making tool.

   - Is the result produces by RP useful?
   - Suggest other results that could be produced by RP.
   - Would you consider using RP for risk management decision making?
   - Do you anticipate challenges to using RP?
   - Suggest RP applications to other risk management problems.

7.4.5 RP Evaluation Session Procedure

The following outlines the RP evaluation session procedure:

- The RP decision support tool was downloaded onto the participants' computers.
- The purpose of the evaluation session was explained.
- The participant information and consent form were distributed, and the participants' rights were explained.
- The open-ended evaluation questionnaire was distributed and explained. The questionnaire was to guide the participants to focus their thoughts on the evaluation criteria. The participants had a choice to either write or give oral feedback,

and to answer the questions at the end or during the session. They were encouraged to give their own opinions based on their knowledge and experience. The sessions were audio recorded. The risk managers were encouraged to speak their thoughts during the sessions. This method allows the participants to effectively comment on how they are interacting with the risk management problem, what they are attempting to do and how does RP assists them to achieve it, how they feel about RP and what problems they encounter.

- RP was introduced, and RP decision-making steps were explained.
- The participants were instructed to try the simple example of choosing a city to relocate. After trying the example, the participants could either try the other examples or move straight on to one of the risk management problems.
- Evaluate RP: First, the problem was explained to the participants. The participants were encouraged to discuss and debate how RP could structure the problem. After the participants understood how RP structures the problem, they answered the pairwise comparisons questions and evaluated and discussed the results produced by the pairwise comparisons. They were also encouraged to discuss their opinions on using RP to make risk management decisions and the potential implementation challenges of using RP for risk management.

7.5 Feedbacks Collected from the Risk Managers

From the evaluation session, it was found that prioritising risks is an important problem for risk management. All participants chose to do Problem 1-prioritising the risks faced by an insurance company. The participants sought an easy-to-use technique to prioritise the risks. They sought alternative techniques other than using likelihood and magnitude to prioritise risks, as well as a technique that could translate subjective judgement into numbers. The risk participants acknowledged that RP offers an alternative way to prioritise risks. According to them, structuring a problem in a hierarchy is a new way of looking at the problem holistically. Overall, the evaluation sessions were successful. It was a learning experience for both parties.

The recorded audio of the risk managers feedbacks from the evaluation sessions were transcribed verbatim. The transcripts were then systematically scanned to identify comments, recommendations, problems, confusion, misunderstandings, or difficulties the participant may have experienced while using RP, and any issues related to risk management and decision making in risk management. The transcripts were divided into three parts: risk management implementation challenges, issues with the current risk assessment tool, and RP practical usability. The transcript on RP practical usability was divided into five themes: hierarchy, pairwise comparison questions, decision consistency, RP decision making steps and results, and RP implementation challenges. The themes represent the core components of RP. This section discusses each parts and themes of the risk managers' feedbacks.

7.5.1 Risk Management Implementation Challenges

The participants reported that risk management implementation is disorganised and the process is unclear, although they could refer to a risk management standard and follow the standard risk management steps. In reality, implementing risk management is not as straightforward as written in the standard. According to the participants, obtaining cooperation from business units or operation managers is difficult. Certain units or operation managers feel defensive when their unit or operation activities are subject to scrutiny and control. Top management and corporate executives did not see the importance of risk management. The participants stated that top management sees risk management as a compliance issue. In contrast, their perspective as risk managers was to build a risk awareness culture. A lack of support from top management causes difficulties in implementing risk management. They stated that the conflict between top management, business unit managers and risk managers slows down risk management implementation in Malaysia.

The following are excerpts of their feedbacks:

- *Actual risk management implementation is not organised.*

- *The problem is the steps are not clear.*
- *I have difficulties to get cooperation from my staffs.*
- *Some staffs feels defensive. They think I want to find their flaws and weaknesses as a manager.*
- *They think I want to take control and I know more than them about their department.*
- *Top management does not care about risk management. To them we just follow what the regulators wants.*

7.5.2 Current Risk Assessment Tools

The participants reported limitations in using the risk matrix to rank risks. Although commonly used to rank risks, the participants said that the risk matrix has the following limitations: (i) it cannot clearly explain how a risk assessor makes a judgement on the importance of risks; (ii) participants face difficulties in explaining how a risk is judged as low likelihood and high impact, or high likelihood and low impact, to top management; and (iii) it cannot aggregate group decisions.

The participants needed techniques to quantify subjective opinion. For example, a subjective judgement of Risk A is more important than Risk B. The participants need techniques to quantify the subjective judgement and produce a quantitative result. According to the participants, quantitative output is easy to refer and explain to top management. They also need techniques to quantify individual subjective judgement and aggregate the judgements. Each person had a different judgement on the importance of risks. A technique that can aggregate judgements is useful for risk management.

The participants reported difficulties in conducting risk assessments for risks with limited or no data. For example, for a risk assessment on operational risks, they needed a risk-ranking technique for operational risks. According to the participants, they would usually use subjective judgements to assess operational risks.

The following are excerpts of their feedbacks:

- *How do you quantify importance? You say Risk A is more important than Risk B. So far there is still no technique that can quantify subjective opinion.*
- *We are actually looking for risk assessment technique for operational risks.*
- *I used risk matrix, although risk matrix could not clearly explain the importance of risk is made.*
- *When I presented my risk matrix in our meeting, I face difficulties to explain to top management why certain risk has low likelihood/high impact or high likelihood/low impact. They asked a lot of questions which I could not answer.*
- *My manager asked me if we can do group risk ranking with risk matrix. I searched but still could not find out how to use risk matrix for that.*

7.5.3 The Practical Usability of RP

This thesis has defined RP practical usability feedback as questions or issues raised by participants on RP. The feedback is grouped into five themes: hierarchy, pairwise comparisons, decision consistency, RP decision making steps and results, and RP implementation challenges. This section discusses each theme.

The Hierarchy

The participants stated the following benefits of the hierarchy:

- They can see all of the risks to be prioritised.
- They can organise risk in an easy-to-understand diagram. The hierarchy provides a natural way to deconstruct a large problem. Deconstructing and organising risks in hierarchical levels improves their understanding of the problem.
- It is easier to see linkages between risks. The hierarchy presents linkages between risks and sub-risks in an easy-to-see and understand framework.
- It is easier to see errors in categorising the risks or linking the risks and sub-risks.

The following are excerpts of their feedbacks:

- *That's an easy to use diagram.*

- *We could use this to categorise our risks. We have many risks and probably bigger hierarchy than yours.*
- *I understand how it works.*
- *We should present this to the people at the top. So that they could see all the risks. Then they could see why risk management is important.*

Pairwise Comparison

The participants were concerned about the number of pairwise comparisons and the repetitive nature of the questions. Although the participants found that the pairwise comparisons assisted them in making trade-offs between risks, they experienced decision fatigue after many repetitive questions. A few participants admitted to answering the questions randomly after a few repetitive questions.

The pairwise comparisons asked the participants to compare two risks against a criterion, decide which risk was more important or worry about, and determine the level of importance or worry using a scale of 1-9. The phrase 'worry about more' had different interpretations for different participants. They required an explanation of the meaning of the question. According to the participants, deciding which risk was important was easy, as they do it frequently in their professional activity. However, comparing two risks to decide which risk they should worry about more and deciding the level of worry was a new experience. The participants required more explanation on the function and meaning of the verbal scale (equal, moderate, strong, very strong and extreme) and the process of expressing a verbal judgement to producing the priority weight of the risks. According to the participants, to use RP for risk management, they need to understand the process in order to explain it to top management.

The following are excerpts of their feedbacks:

- *Too many pairwise comparisons.*
- *Worry about more or more important, what does they mean? Is it the same?*
- *I have never done this before. I've work as risk managers many years but never make risk comparisons.*

- *Scale of 1 to 9 is confusing. What do you mean by reciprocal or inverse. Does less important means the value is negative?*

Decision Consistency

The purpose of decision consistency is to measure the consistency of the pairwise comparison judgements. The participants acknowledged that decision consistency is a good mechanism to monitor judgement. However, they required an explanation of how the CR determines whether a judgement is consistent or inconsistent.

The participants also wanted to know how inconsistent decisions affect risk rankings. The participants raised an issue-a person believes that he or she is making the correct decision. Although the decision consistency is poor, the person is unwilling to change his or her decision. Is the ranking of the alternatives still valid? Can the ranking be used to make decisions? The participants wanted to know how RP would address the issue.

The following are excerpts of their feedbacks:

- *I am confused. What does decision consistency do?*
- *In a situation where decision consistency is poor but the person believes he is making a correct judgement. And refused to change his decision. How does this effect priority weight? Is the priority weight still correct?*

RP Decision Making Steps and Results

The participants' feedbacks on the decision making steps and results are as follows:

- RP decisions making steps: The participants acknowledged that RP was easy to use and understand. The RP decision-making process was logical, straightforward, clear, easy to understand and follow.
- The results: The risk management problem, prioritised risks faced by an insurance company has four results: (i) ranking of the sub-risks within their risk category; (ii) ranking of the risks; (iii) overall ranking of the sub-risks; and (iv) top 10 sub-risks. The participants acknowledged that the results produced by

RP made sense, useful and easy to understand.

The following are excerpts of their feedbacks:

- *The process make sense and easy to understand*
- *Its easy to use and understand. Not complicated at all.*
- *The results are better than risk matrix. The calculations looks more real.*
- *The results are more presentable in meetings. Its easier to explain the risks.*
- *The results is easier to understand and explain compared to risk matrix.*

RP Implementation Challenges

This section discusses the participants' feedback on the challenges to implementing or using RP for decision making in risk management:

- Getting people or risk assessors to do the pairwise comparisons: The pairwise comparisons are an essential component of RP. The participants asked how to get people to answer the pairwise comparison questions. What are efficient ways to distribute the pairwise comparison questions and to ensure that the questions are all answered?
- Documentation: According to the participants, one of the important parts of risk management is documenting. The purpose of documenting is for easy communication to other staff members and stakeholders. They asked how to use RP for risk management reporting and documentation?
- Changes to problem environment: The participants were concerned about changes to problem situations, such as new risks emerging that are relevant to a problem. Does the decision need to be revised? Do they need to go through the whole decision making process? Do they need to build a new hierarchy?
- RP is useful for problem with limited or no data: The participants stated that RP is useful to support decision making for problems with limited data or requiring subjective judgement. They suggested that RP is useful for operational risks where data are generally not available.

- Group decision making: The participants requested RP for group decision making. According to them, making group decisions is a common practice in risk management. The participants asked whether RP could aggregate individual judgements and produce a group judgement. They raised two important concerns for group judgement: (i) If every member of the decision-making group has different risk rankings, whose ranking should the group follow? (ii) If the top management disagree with the group's judgement, whose decision should they follow? Should they follow the top management's decision and abandon the risk ranking obtained through RP?

- A complete risk assessment: The participants requested to see a complete risk management process using RP, starting from risk identification, risk assessment and risk response. According to them, the risks hierarchy should consist of risks, sub-risks and risk responses or actions.

- Number of risks. The participants were concerned with the number of risks in an actual risk management problem. A firm faces many risks, and to model a problem accurately, all relevant risks need to be included. The participants wanted to know how RP could address this issue.

- RP and Enterprise Risk Management: The participants requested RP to be integrated with risk management processes or standards. They proposed that RP should be integrated with the ISO31000:2009 Risk Management Standard. According to them, a useful decision making tool for risk management, is a tool that can support a risk management standard or process.

- Parties involve in RP: The participants asked whether RP could identify who does what in the decision-making process. They wanted to know the person in charge in every step of RP. For example, who collects the information on risks, who develops the hierarchy and pairwise comparison questions, who performs the risk assessment and who has the final decision on the risk ranking? According to them, risk management requires different individuals performing different tasks. For example, business unit managers are responsible for identifying, ranking and managing the risks of business activities. The management team's concerns were strategic or business planning risks. They wanted RP to identify the person responsible for the tasks in the decision-making process.

The following are excerpts of their feedbacks:

- *I need RP for group decisions.*
- *Can RP combined individual decisions and come out with one ranking?*
- *How group decision making is made?*
- *The hierarchy should have three levels: Goal, risks and sub-risks, and risk management actions. That is the whole process of risk assessment.*
- *RP can handle only limited number of risks maximum ten. If a firm faces many risks, how can we use RP?*
- *How to practically and efficiently do the pairwise comparison?*
- *How can we use RP for enterprise risk management?*
- *Does RP belong to any risk management standards?*
- *How can we use RP with risk management standards such as ISO31000?*
- *Who makes the risk assessment and who make the decisions? Who collect risk information, develop hierarchy and distribute the pairwise comparison?*
- *In practice, who is the decision maker? Who is in charge to collect risks and structured the risks in the hierarchy? Who decide on categorizing the risk? Who make the risk assessment? Who make decisions whether to accept the ranking or not?*
- *Explain more on how you calculate priority weight.*
- *Explain what does equal, moderate, strong, very strong and extreme means. Explain how you decide dominance and intensity and then getting the priority weight.*
- *For future improvement for RP. Before organizing risks into a hierarchy, provide list of risks first. So that we can decide which risks to be included in the hierarchy.*

- *RP is more suitable for operational risks where data is not available.*
- *Can I use RP steps to document risk prioritization process?*
- *If new risk arrives, do I need to revise the ranking? Meaning do the pairwise comparison again? Do the whole RP decision making process?*
- *If I present this result to my risk manager? Do I need to explain to him the whole process? Including the calculation of priority weight?*
- *I want to use RP and show the steps to management team. To convince them I have a technique to prioritize risks. How do I do that?*
- *In group decisions what if everybody's ranking is different? Whose ranking should we follow?*
- *If we aggregate everybody's decision and come out with one ranking. What if the top management does not agree with the ranking? What do we do?*
- *Let say there are two persons making the decision. Both are experts in IT for example, but their expertise is in different fields. They give different ranking on the risks. Whose ranking should we use?*
- *Instead of equal, moderate, strong etc. I like to use numbers 1, 3, 5, etc. You said equal, moderate, strong, later will be translated into numbers and put in a matrix. Why not use the numbers straight away? You said the numbers measure intensity, I like numbers as intensity.*
- *Can RP capture uncertainty?*
- *What does the weight represent? Is it the distance between Risk A and Risk B?*
- *You say if Risk A is 0.8 and risk B is 0.2. Risk A is 4 times more important than Risk B. How is that possible?*

7.6 Summary

This chapter demonstrated the steps taken by the thesis to achieve the aim of the thesis. It used the evaluation approach to obtain feedbacks on RP usability. Members of the MARIM were recruited as the evaluators or research participants. The evaluation feedbacks were obtained from 10 participants. The feedbacks consisted of an evaluation of RP's practical usability in terms of using the hierarchy to structure a problem, using pairwise comparisons to make trade-offs, the clarity and logic of the RP decision-making steps, the usefulness of the results produced by RP, and RP implementation challenges.

The next step is to analyse the feedbacks to answer the research questions: How or when is RP useful for risk management? How or when is RP not useful for risk management? How is RP used for risk management? What do risk managers require to use RP effectively? Chapter 8 analyses the participants' feedbacks.

8

Analysis of the Evaluation Feedback

8.1 Introduction to Chapter 8

Chapter 7 explained the approach to obtaining the risk managers' feedback on RP usability. This chapter discusses the analysis and responses to the feedbacks. It answers the research questions. The analysis and responses made to the feedbacks are used to answer the research questions as follows:

- How or when RP is useful for risk management? Section 8.2 discusses the AHP's strengths. The strengths discuss situations in which RP is useful, and how it is useful for risk management.

- How or when RP is not useful for risk management? Section 8.3 discusses RP limitations. The limitations discuss the situations in which RP is not useful, and how it is not useful for risk management.

- How is RP used for risk management? Section 8.4 discusses how to use RP for risk management, as well as ways to improve RP's practical usability.
- What do risk managers require to use RP effectively? Section 8.5 discusses post-evaluation RP, which is the redesign of RP taking into consideration the risk managers' feedback. The section also discusses the differences between pre-and post-evaluation RP.

8.2 RP Strengths

The risk managers' feedbacks were analysed to identify how and in what way RP is useful for risk management decision making. They represent RP strengths. This section discusses the strengths.

8.2.1 Easy to Use and Understand

RP is easy to use and understand, and its decision-making process is simple and logical. The participants understood how each step is a guide to achieving the decision goal. A systematic decision-making process produces understandable, reliable and defensible decisions.

8.2.2 Improves Understanding of a Problem

Organising criteria and alternatives in a hierarchy enabled the participants to see all of the factors relevant to a problem. A hierarchy is a natural way to organise a large system into its component parts. It provides a holistic view of a problem. For the problem to prioritise risks faced by an insurance company, the hierarchy organises the problem into risks and sub-risks. If necessary, the sub-risks can be deconstructed into smaller and more detailed attributes. The hierarchy links the risks, sub-risks and the decision goal. Using a hierarchy, firm-wide risks are structured based on meaning and relations. The participants already had an underlying understanding of the flow of influence and connections of risks and sub-risks. The hierarchy systematically structured their understanding of the influences, connections and interactions.

8.2.3 Improve Risk Assessment

RP improves risk assessments in the following ways:

- It converts subjective judgement into objective decision. RP translated the participants' subjective judgement into numerical values. The values were used to obtain the priority weights of the risks. The priority weight is a rank of importance of risks based on the participants' knowledge, perspectives and feelings.
- The participants could record and document the risk rankings of every risk assessor.
- RP enables individual risk rankings to be documented. This can be used to facilitate communication between risk assessors.
- It provides a systematic risk assessment process, which increases the participants' confidence of the reliability of the risk rankings.
- It provides a clear and transparent risk assessment, which facilitates communication between risk assessors, risk managers and top management.
- It also facilitates debate and a discussion of the risk rankings with decision makers or stakeholders, and with other stakeholders not directly involved in the risk assessment process.
- The pairwise comparisons assisted the participants to make explicit trade-offs between the risks. They were aware that they had to make trade-offs to determine which risks were more important. The pairwise comparison facilitated them to make logical and thoughtful risk trade-offs.

8.2.4 RP for Problem with Scarce Data

RP is useful for problems with intangibles elements. Therefore, RP can be applied to risk management problems that have scarce or no data and require subjective judgements, such as operational risks. BIS (2004) defined operational risk as potential loss resulting from failures of people, processes, technology and external dependencies. Risks categorised under operational are large and diverse. The list of operational risks given by the Financial Service Authority shows the diversity of the risks (Chapman, 2006):

- Business risk: For example, adverse changes to market, customer or products, changes in the economy and political environment, and strategic risks such as business plan failures or poor business implementation.
- Crime risk: For example, theft, fraud and computer hacking.
- Disaster risk: Natural disasters such as floods, hurricanes and earthquakes, or man-made disasters such as fires and terrorist attacks.
- IT risk: For example, unauthorised access, disclosure or data corruption.
- Legal risk: Risks arise from legal issues.
- Regulatory risk: For example, inability to keep up or unaware of regulatory changes.
- Reputation risk: Risks affecting a companys image.
- System risk: For example, breakdown of procedures, processes or systems.
- Outsourcing risk: Risk arises from outsourcing a business process or unit.

The list of risks shows that the risks lack data. Therefore, risk managers had to use value judgements to assess the risks. RP can be used to perform a systematic value judgement to assess and prioritise operational risks.

8.3 RP Limitations

The risk managers' feedbacks were analysed to identify how and in what way RP is not useful for risk management decision making. They represent RP limitations. This section discusses the limitations.

8.3.1 The Pairwise Comparison

Two limitations that arise from pairwise comparisons are the number of pairwise comparisons and decision fatigue:

- Number of pairwise comparisons: The number of criteria and alternatives determines the number of pairwise comparisons. A hierarchy with m criteria and n alternatives has $q = m(m-1)/2 + m(n-1)/2$ number of pairwise comparison questions. Each decision matrix has $n(n-1)/2$ pairwise comparisons questions. A three-level hierarchy that consists of 4 criteria and 3 alternatives has one 4x4 pairwise matrix for the criteria and four 3x3 pairwise matrices for the alternatives. The criteria matrix has six questions, and each of alternative matrix has three questions. The total number of questions is 18.

  Forman and Selley (2002) stated that the number of elements should be between 5 and 9. The human mind has limited capability to compare more than 9 elements simultaneously (Saaty, 1977, Saaty and Ozdemir, 2003). Goepel (2013) stated that each category must have between four and 10 sub-categories. Subcategories of more than 10 confuse the decision maker. Too many criteria lead to decreased concentration or decision fatigue in making pairwise comparison judgements. Decision fatigue increases decision inconsistency.

  To reduce the number of pairwise comparison, RP clusters the elements based on qualitative similarities (Brugha, 1998, Forman and Selley, 2002). For example, the elements can be clustered based on function or property (Saaty and Vargas, 1982). However, clustering the elements can increase the complexity of the problem, and offsets RP's practical and simple application.

  Clustering has the following advantages: (i) enables risk managers to consider all alternatives and criteria to present a complete and true picture of a problem; (ii) easier to compare the alternatives and criteria; (iii) increases efficiency in making pairwise comparisons; and (iv) reduces decision fatigue and increases decision consistency.

- Decision fatigue: Pairwise comparison questions are repetitive. As a result, the participants experienced decision fatigue. They did not answer all questions, or they randomly answered the questions. Not answering all of the questions created missing values. As a result, RP could not produce the risk rankings. Randomly answering the questions increased decision inconsistency.

RP redesign the pairwise comparison questions to address the repetitiveness of the pairwise comparison questions. Viswanadhan (2005) evaluated five different designs of pairwise comparison questions using three criteria: easy to fill up, clear questions and ability to extract intended responses. The purpose was to determine the best pairwise comparison design. The study found that a detailed and simple question is preferable compared to a compact and less time-consuming question. Designing the pairwise questions in a matrix should be avoided, as the matrix design confused the respondents.

Figure 8.1 compares the AHP and RP pairwise comparisons. RP pairwise comparison design can accommodate many criteria. The design is simple, easy to use, and reduces pressure or boredom of answering repetitive questions.

8.4 Improving RP Practical Usability

This section discusses how to improve RP practical usability. The risk managers' feedbacks on RP implementation challenges discussed in Chapter 7 were analysed to identify how and in what way RP can be improved for risk management decision making. The implementation challenges are grouped into:

- How to do a complete risk assessment or management.
- How to get people to do the pairwise comparisons.
- How to calculate priority weight.
- How to improve decision consistency.
- How to handle a large number of risks.
- How to make group decision.

Figure 8.1: AHP versus RP Pairwise Comparison Question

AHP Pairwise Comparison

Question: In terms of strategic risks, compare sub-risks in pair. Which sub-risk is more important and how much more?

Regulation	☐ 9	☐ 8	☐ 7	☐ 6	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9	Market Changes
Regulation	☐ 9	☐ 8	☐ 7	☐ 6	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9	Competitor
Regulation	☐ 9	☐ 8	☐ 7	☐ 6	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9	Business Planning
Market Changes	☐ 9	☐ 8	☐ 7	☐ 6	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9	Competitor
Market Changes	☐ 9	☐ 8	☐ 7	☐ 6	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9	Business Planning
Competitor	☐ 9	☐ 8	☐ 7	☐ 6	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9	Business Planning

RP Pairwise Comparison

Criterion: Strategic Risk

Sub-risk	Important	Intensity	Compared to
Regulation	equal		Market Changes
	more	moderate	Competitor
	more	strong	Business Planning
Market Changes	more	very strong	Competitor
	more	extreme	Business Planning
Competitor	less	moderate	Business Planning

- How to document a decision.
- Who are the people involved in RP decision making process.
- How to integrate RP with enterprise risk management.

The followings explained each challenge.

8.4.1 Connecting Risk Assessment and Response Decisions

A complete risk management is risk identification, assessment and response. Risk identification is a data gathering activity. Firms identify and list the risks. Risk assessment is a process to determine significant risks. The output of risk assessment is a list of significant risks. Risk response is a process to decide mitigation or control actions for the significant risks. Risk identification, assessment and response are interrelated. Output from risk identification is an input for risk assessment. Output from risk assessment is an input for risk response. Although connected, RP perceives that each decision has different goals. Risk managers should develop a separate hierarchy for each activity and link the decisions.

RP uses the following steps to connect risk assessment and response decisions:

- Identify the problem and define the decision goal.
- Identify risks that are relevant to the problem.
- Develop a hierarchy for the risks.
- Perform pairwise comparisons to make trade-off between the risks.
- Calculate the priority weight of the risks to produce the risk ranking.
- Discuss the ranking with decision makers and stakeholders to determine which risks need to be mitigated.
- Develop a hierarchy of risk response for the chosen risks. Identify risk response alternatives and criteria to evaluate the alternatives. Perform pairwise comparisons to obtain the ranking of alternatives. The alternative with the largest weight is the best response to mitigate the risks.

  The following shows an example of a risk response hierarchy for financial risk. This example assumes that the risk assessment activity ranks financial risk as the most important risk.

  1. Decision goal: The decision goal is to choose the best risk response for financial risk.
  2. The criteria: The following are the criteria to evaluate the alternatives: (i) the cost to implement the response; (ii) the skill or expertise to implement and monitor the response; (iii) increase firm risk exposure; (iv) immediate effect on reducing the risk.
  3. The alternatives. The risk responses for financial risk are hedging, increased debt, credit insurance, diversify and asset liability matching.

8.4.2 Pairwise Comparison Questions

The pairwise comparison questions are an essential part of RP. Getting decision makers or risk assessors to answer the questions can be challenging. To get risk assessors to answer the pairwise comparison questions, the approach must be simple, easy to use and understand, and be able to be completed in a short time. RP uses a spreadsheet template for the pairwise comparison questions. The design of the pairwise comparison is presented in 8.1. The template should include decision consistency and priority weights. Therefore, the risk assessors can immediately see the rankings of the alternatives and criteria, and the consistency of their judgement.

Goepel (2013) successfully used AHP as a decision making tool for a multi-national corporation. Goepel (2013) developed a spreadsheet template and emailed it to the decision makers. Included in the email was basic information on the AHP and an extensive explanation of how to fill out the questionnaires and the comparison scales. The questions were completely filled, consistent and without many requests for clarification on how to do the pairwise comparisons. One of the templates had ten elements, requiring the decision makers to answer 45 pairwise comparisons. The template came back complete and consistent.

8.4.3 Explaining Priority Weight to Decision Makers

Priority weights represent an order of importance of risks. The order of importance is obtained from risk assessors' judgement. The risks and sub-risks that are structured in a hierarchy are all important risks to a firm. RP enables the firm to prioritise the risks by calculating the weight of the risks.

This section discusses how risk managers can explain the priority weights to the decision makers, top management and stakeholders. To obtain the priority weight, risk managers need to develop a pairwise comparison matrix or decision matrix from risk assessors' judgement. For example, to determine the priority weight of risks A, B and C, a decision matrix is developed for the risks, as presented in Table 8.1.

The values between Risk A and B, A and C, and B and C is from risk assessors' judgement on the relative importance of the risks. Judgements are required only for the upper diagonal parts of the decision matrix. The lower parts are inverses of the upper parts of the decision matrix. For example, Risk A is judged moderately more

TABLE 8.1: Decision Matrix for Risk A, B and C

	Risk A	Risk B	Risk C
Risk A	1	3	
Risk B	1/3	1	
Risk C			1

important compared to B. Moderate is translated into 3 and place in the upper part of the decision matrix. The lower part is the inverse 1/3.

Priority weights are the relative importance of risks. For example, the priority weight of Risk A is 0.4 and Risk B is 0.2. Thus, Risk A is twice more important compared to Risk B.

8.4.4 Improving Decision Consistency

RP uses the following ways to improve decision consistency:

- Clearly defined the decision goal to the risk assessors: For example, a pairwise comparison asks risk assessors to compare two risks against a criterion. The pairwise comparison question can be constructed as follows: for strategic risk, compare changes in regulation and changes in market preference. Which risks are you more worried about, and by how much more? Risk managers need to be aware that different risk assessors may have different interpretations of the question. The following present the possible interpretations of the question:
  - risk occurs frequently.
  - risk more likely to occur.
  - risk has large financial impact.
  - risk has a high probability to occur.
  - risk is difficult to measure or quantify.
  - risk cannot be mitigated but cannot be avoided.
  - risk requires firm immediate and absolute attention.

To improve accuracy, the decision goal must be clearly defined to the risk assessors. For example, the goal of the decision is to evaluate and prioritise risks requiring immediate attention. Therefore, the decision goal should stated as: To prioritise risks requiring immediate attention. The pairwise comparison question should reflect the decision goal. The pairwise comparison question should be constructed as follows: For strategic risk, compare changes in regulation and changes in market preference. Which risk requires immediate attention, and by how much more?

- Allow risk assessors to choose their preferred comparison scale: Risk assessors should be allowed to choose their preferred comparison scale. The purpose of the scale is to measure the relative intensity of importance. The scale translates risk assessors' judgement on how much they are willing to trade-off one risk over another. Some risk assessors prefer to use numerical scales to determine the relative intensity of risks. To them, the numbers distinctly represent strength or level of importance. In contrast, some risk assessors prefer verbal comparisons, as words are easy to use and meaningfully represent their feelings and thoughts. Therefore, before preparing pairwise comparisons questions, risk managers need to ask the risk assessors whether they prefer a verbal or numerical scale for the pairwise comparison question.

8.4.5 Organising a Large Number of Risks in a Hierarchy

Organising risks into a hierarchy can be challenging for a firm exposed to a large number of risks. For example, a firm has identified 300 risks and half of the risks are considered highly likely with a high impact. The challenge is to organise the risks into a hierarchy.

To consider a large number of risks, RP categorised risks based on common or unique terminology to the firm (Shenkir and Walker, 2007) or similar attributes as presented in Chapter 6. For example, the risks can be categorised into operational, financial or strategic. Different firms may have different risk terms. The most important is to categorise the risks based on understanding and meaningful definition. Another method to categorise risks is using the explanation-based approach (Morgan et al., 2002). Explanation-based approach categorised risks based on the goal of the firm. Therefore, provides meaningful risk categorisation to be used for risk ranking compared to the similar-based approach. According to Morgan et al. (2002), similarity-based risk categories are ambiguous because risks could have many dimensions.

The following lists the steps to organise a large number of risks in a hierarchy:

- Determine business objectives.
- Identify the risks that are relevant to the objectives.
- Grouped risks into a manageable number of categories. Categories should be mutually exclusives. Each risk should belong to a particular risk category, and risks should not overlap.
- Develop a hierarchy for each risk category. For example, a firm has eight risk categories. Therefore, develop eight hierarchies for the categories.
- Identify the criteria to evaluate the risks for each hierarchy.
- Document the definition of risks and criteria. Give the document to risk assessors, top management, decision makers and stakeholders to ensure that the people involved in the risk assessment process have the same understanding of the meaning of the risks and criteria.
- Conduct pairwise comparisons to obtain the priority weight of the risks. Each risk category should has its own risk ranking.
- Aggregate or synthesize the individual risk ranking to obtain the overall ranking for the firm.

8.4.6 Group Decision

RP can be used for two types of group decision making: reconciling differences and dealing with superior persons.

Table 8.2: Priority Weight of Each Decision Maker and Group Priority Weight

Decision Maker	1	2	3	4	5	6	GPW
Risk 1	0.3583	0.4291	0.3621	0.3987	0.3784	0.3895	0.3768
Risk 2	0.4107	0.3851	0.4712	0.4106	0.3981	0.4472	0.4113
Risk 3	0.2310	0.1858	0.1667	0.1907	0.2235	0.1633	0.2075

Reconciling Differences

A group generally consists of people with different levels of status, expertise, knowledge and experience. Each member has different perspectives and knowledge of risks, and different risks concerned. Consensus is not always the best way to obtain a group decision. For example, corporate-level executives' concern is strategic risks. A front-line supervisor of the operation unit may examine the risk from a different perspective. For a marketing manager, pricing strategy is the most important risk. An IT managers concern is viruses attacking the IT system. Management teams or corporate executives worry about different levels or sets of risks compared to operational staff members.

RP provides the following way to reconcile differences between group members:

- The group identifies alternatives, criteria and structures the hierarchy. The alternatives assessment is conducted individually. The individual assessment is aggregated to obtain an overall judgement.

- The risk manager requests problem information from each member. From the information, the risk manager identifies the alternatives, criteria and structures the hierarchy. The risk manager distributes the pairwise comparisons to group members to obtain judgements and aggregate the individual judgements to obtain an overall judgement.

Table 8.2 shows an example of priority weights of six decision makers. The left-hand side is the individual priority weight. The right-hand side is the group priority weight (GPW). The GPW is derived using the LLSM.

Dealing with a Superior Person

Certain members have more influence on decision implementation compared to others. In ideal group decision making, management and operation come together as a group and decide which risks or alternatives are more important. However, an ideal group is not common in a firm. A superior person may be unwilling to equalise his or her judgement with the subordinates. As a result, the decision-making process become longer and members will not agree on a decision. If a decision-making member produces the result by consensus, the superior person may argue the reliability of the group judgement. As a result, the likelihood that the decision will be implemented is low. To avoid conflict, members of the decision-making group may simply conform to the superior person.

The following shows how RP addresses the superiority issue (Saaty, 1999)

- Design a hierarchy to judge the relative power and merit of the individuals.
- Identify factors or criteria to evaluate the person, such as power, status, experience, political influence, fame, and the ability to withhold or disrupt decision result. Table 8.2 presents an example of hierarchy of decision makers power.
- Compare the individuals based on the criteria.
- Calculate the priority weight, which represents the individual's merit and power.
- Based the final decision on the individual with the highest priority weight.

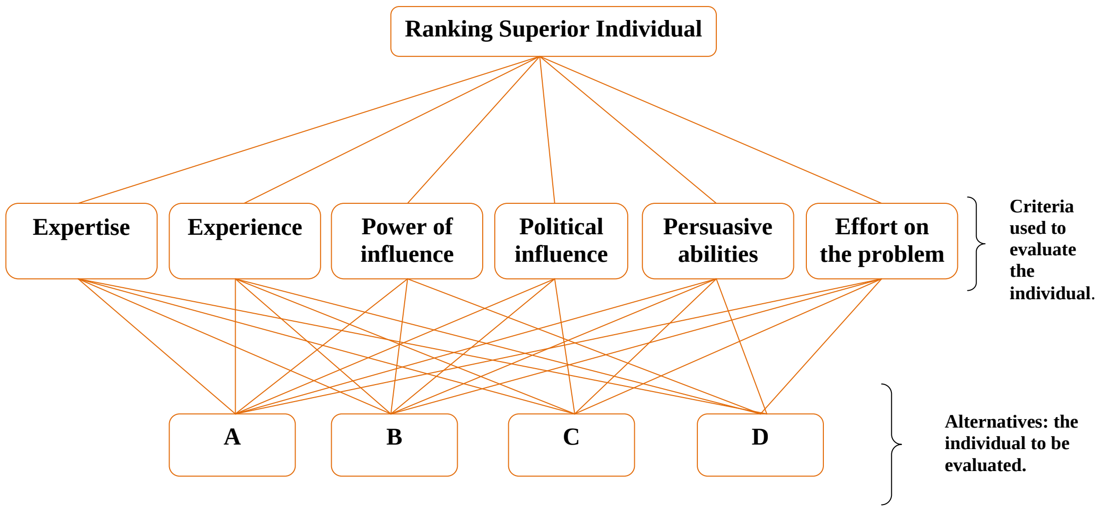
8.4.7 Document a Decision

To document a decision, the RP step-by-step process should be used to develop a decision-making report. Figure 8.3 presents RP decision-making report template.

8.4.8 Parties Involve in RP

Using RP for risk management requires a person or group to perform the following tasks:

Figure 8.2: Decision Making Power Hierarchy



- collect data and information.
- manage and monitor the RP process.
- make assessments or judgements on the alternatives.
- validate or approve ranking of the alternatives.
- monitor changes in the problem environment.

The first step, to identify the problem and define the decision goal, is an information and data gathering activity. At this stage, RP proposes to obtain the involvement of all stakeholders. The activity requires input from various parties, such as business unit managers, the management team and stakeholders. The risk managers or risk management group (RMG) monitors the activity, collects information or data, disseminates information, and ensures that all parties involved have the same understanding of the issues and conflicts of a problem and risks embodied in the problem. Particularly, the risk assessors and the decision makers need to understand the problems, the conflicting issues of the problem and agree on the decision goal. The RMG needs to ensure that

FIGURE 8.3: RP Decision Report Template

No	Section	Description	The content for the section can be obtained from the RP decision making steps as follows:
1	Problem or issue description	Describe the problem or issue to be address. Provide background, history, conflicting issues and decision goal. State who are the people involved in the decision making process and their positions (e.g. decision maker, advisor, risk assessor).	• Identify the problem and define the decision goal.
2	Decision set-up rationale	Explain and provide rationale or justification for alternatives and criteria. Present the hierarchy developed for the problem.	• Identify the criteria and alternatives. • Organise the criteria and alternatives in a hierarchy.
3	Judgement/ Assessment	Explain how judgement or assessment is conduced, and report the assessors or judges making the judgements.	• Assess the alternatives by making trade-offs between the alternatives.
4	Output	Show the local ranking of the alternatives and criteria, and the overall ranking of the alternatives.	• Calculate the priority weight of the criteria and alternatives. • Check the decision consistency. • Aggregate the weight to obtain the overall priority weight of the alternatives.
5	Final decision	Explain the final decision. State who are the decision makers and their rationale for the final decision	• Discuss and approved the decision.
6	Issues with final decision	Document any issues that arise against the final decision and explain how the issues are addressed.	• Document the decision. • Communicate the decision to the stakeholders.
7	References	Provide any references made to the problem.	
8	Appendices	Explain any decision analysis or risk analysis used in the decision making process. For example, explained how priority weight is calculated or for group decisions explained how group priority weight is calculated.	

the decision goal is parallel with strategic or risk management objectives.

For example, a problem is to prioritise the risks faced by a firm. The first step is to identify these risks. The RMG works with business unit managers to find the risks that the managers are most concerned about, and to formulate risk management strategies. With the management team, the RMG coordinates and integrates the risks and identifies any offsetting risks. For a large number of risks, the RMG works with business unit managers and the management team to categorise the risks into a manageable number.

The RMG works with business unit managers and the management team to identify the criteria to evaluate the risks. The RMG organises the risks and criteria into a hierarchy and presents the hierarchy to business unit managers and the management team for review. The RMG also documents and presents the hierarchy to relevant stakeholders and parties involved in the decision-making process. The RMG needs to ensure that all parties involved in the decision-making process understand the elements and structure of the hierarchy. The RMG works with business unit managers and the management team on the risk assessment process. The RMG develops and distributes the pairwise comparison questions. RP proposes to conduct risk judgement or assessment at two levels: operations or business unit and management. Business unit managers are concerned with providing the best possible products or services to customers. Therefore, they are more likely to focus on operation risks. The management team focuses on planning business strategies. Therefore, their focus is more on strategic risks. The risk ranking will be different for both parties. However, both views are important for a firm-wide risk assessment. The RMG needs to reconcile the differences between the two parties, facilitate a discussion between business unit managers and the management team on the risk ranking to produce an overall risk ranking, and present the ranking to the decision-making group.

The decision-making group could include top management, parties affected by the risks, and parties to mitigate or finance the risks, such as legal and treasury departments. The RMG facilitates the discussion on the risk ranking and obtains the groups approval on the ranking. The RMG needs to monitor changing business needs and business objectives, new trends in risk management and changes in compliance and regulation. If the changes are significant, the RMG needs to inform the relevant stakeholders and, if necessary, the risk ranking may need to be revised.

Figure 8.4 presents the players or actors for each RP step.

8.4.9 RP for Enterprise Risk Management

Figure 8.5 presents the ISO31000:2009 Risk Management Standard (ISO31000). This standard is commonly used by firms to implement enterprise risk management (Fraser et al., 2008).

The first step of the ISO31000 is to establish the external and internal environment of the firm. The tasks include identifying both challenges and opportunities relevant to business objectives and operating environment, developing a risk profile, determining risk appetite and risk tolerance level, developing a risk matrix and planning business continuity. After high-level decisions are made at the first step, the risk management process flows down into detailed situations requiring specific decisions. For example, the second step in the ISO31000 is risk assessment. The decision of whether to accept or reject a risk depends on the firm's risk appetite and tolerance decided at the first step of the standard. A decision on a level depends on the decision made at the previous level.

The ISO31000 guides firms to implement enterprise risk management. RP supports enterprise risk management by providing a systematic decision-making process for each step of the standard. Figure 8.6 presents RP and the ISO31000:2009 Risk Management Standard connection.

The information gathered and the decision made at the first step of the ISO31000 is connected to the RP first step of identifying a problem and defining the decision goal. The connection informed the risk managers the decisions made using RP should reflect the decisions made at the first step of the standard. For example, the RP decision goal should reflect the firm's objectives and vision decided at the first step of the standard.

The second and third steps of the standard are risk assessment and treatment. The steps interrelate with RP as follows. RP is used to support risk assessments and treatment decisions, and to document the decisions. The standard requires continuous communication. RP supports communication by providing a standardised communication framework across the firm.

8.5 Post Evaluation RP

The risk managers' feedbacks were analysed to identify how and in what way risk managers can use RP effectively. To use RP effectively, RP needs to be a simple and practical decision-making tool. Therefore, it is important that RP is not cognitively burdensome. Every aspect of RP-input, calculation and output-should be simple and practical. The practical and simple aspects of RP are:

- Reliability: RP works by ensuring only relevant and critical criteria and alternatives to a problem is structured in a hierarchy. Limiting the inputs to only the relevant and critical factors increase reliability of the decision and are easier to maintain and monitor.

- Speed. Simple calculations translate into faster decision-making process. RP simple calculation provides answers in hours instead of requiring days or weeks to run a database or a program.

- Transparency. A simple model is easier for management to scrutinise. Criteria and alternatives relevant to a problem are organised in a hierarchy, which is the visualisation of the problem. Decision makers, top management and stakeholders can directly review the hierarchy and identify errors.

- Validity. A simple model is easier to validate by risk managers, the management team or stakeholders. RP has no market, economic, probability assumptions or complicated formula.

Taking into consideration the simple and practical aspects of RP and the analysis of the feedbacks, the thesis modified, refined and improved RP. Figure 8.7 presents the post evaluation RP decision-making steps.

The new or post-evaluation RP consists of four steps: (1) identify the problem and define the decision goal; (2) assess the alternatives by making trade-offs between alternatives; (3) discuss and approved the results; and (4) monitor and review the decision. The decision-making steps include:

1. **Identify the problem and define the decision goal** The first step is information gathering and organising phase. It consists of the following sub-steps:

    - Identify the alternatives and criteria to assess the alternatives.
    - Structure the decision goal, criteria and alternatives into a hierarchy.
    - Identify decision time frame.

2. **Assess the alternatives by making trade-off between alternatives.** The second step is the judgement phase. Risk assessors evaluate the alternatives by making trade-offs using pairwise comparisons. It consists of the following sub-steps:

   - Use judgements made in the pairwise comparisons to calculate local priority weight of criteria and alternatives.
   - Check the decision consistency of the judgements. Ensure the judgements are consistent before proceeding to the next step.
   - Aggregate local priority weights to obtain overall or global priority weight of the alternatives.

3. **Discuss and approved the results.** The third step is the approval phase. Risk managers discuss the RP outputs with decision makers, top management or stakeholders for approval. It consists of the following sub-steps:

   - Document the decision after the ranking is approved by the decision makers, top management or stakeholders.
   - Use the document to communicate with stakeholders or other relevant parties not directly involve in the decision making process. The document provides a standardised framework to facilitate communications between people with different risk attitudes and across different units in an organisation.

4. **Monitor and review decision.** The fourth step the monitoring phase. Risk evolves, new risks emerge and some risks never materialise. Further, new techniques to manage risks are invented, and new information about a problem arises, or new and better alternatives emerge. Therefore, risk management includes a risk monitoring and reviewing step. The purpose is to monitor the risk environment to ensure that firms are up to date with current risks and mitigation techniques. RP is flexible and supports decision updates. The discovery of new and significant information may require the problem to be updated. The monitor and review decision step is included to support risk monitoring and reviewing.

8.5.1 Differences Between Pre and Post Evaluation RP

Figure 8.8 compares the pre- and post-evaluation RP. This section discusses the differences between pre- and post-evaluation RP:

- Structure: The pre-evaluation RP clusters the decision-making steps into four phases: information gathering and organising - judgement -decision approval - decision monitoring. For example, the first phase consists of identifying the problem and defining the decision goal, identifying and organising the criteria and alternatives in a hierarchy, and determining the decision timeframe. Each cluster represents the tasks that need to be completed before proceeding to the next step. It also represent the activity in the decision making process. For example, the first phase is information gathering and organising. In this phase, risk managers need to focus their activity to gather relevant and critical information to a problem. They should also determine the timeframe to conduct the activity depending on the level of complexity or importance of the problem.

  The purpose of clustering the decision making steps is to identify two pause points in the decision making process. The first pause point is after Step 1: Identify the problem and define the decision goal and before Step 2: Assess the alternatives by making trade-offs between the alternative, which is after information gathering and organising phase before proceeding to the judgement phase. This pause point is for the risk managers to go through the hierarchy. They need to check the decision goal, criteria and alternatives to ensure that the elements and structure of the hierarchy accurately represent the problem. The second pause point is after Step 2: Assess the alternatives by making trade-offs between the alternatives, and before Step 3: Discuss and approve the result, which is after the judgement phase before proceeding to the approval phase. This pause point is for the risk managers to reflect on the judgements. A consistent judgement does not necessarily mean an accurate judgement. The risk managers need to check whether the judgement could be influenced by biases. They also need to reconcile judgement differences among risk assessors and investigate the cause. After the risk managers are convinced on the validity of the judgements, they could proceed to the approval phase.

- Monitor and review the decision. The pre-evaluation RP had monitor and review the decision as the final step. This step is added to connect RP with the risk management final step to monitor and review the risks.

8.6 Summary

This chapter discussed the analysis and responses made to the RP evaluation feedback. The analysis found that RP is useful for risk management because it provides an easy-to-use and understand decision-making process, it improves the understanding of a problem, it improves the risk assessment, and it is useful for risk management problems requiring subjective judgements. The RP limitation is the pairwise comparisons, which pose two challenges: the number of pairwise comparisons and decision fatigue resulting from many pairwise comparisons. This chapter also presented ways to improve RP;s practical usability and for risk managers to use RP effectively.

Chapter 9 discusses RP's strengths and limitations in addressing risk management decision-making challenges and risk management decision making.

Figure 8.4: RP Steps, Actions and Actors

RP Steps	Actions	Actors
Identify the problem and define decision goal	Discuss the problem. Understand the problem, conflicting issues and determine the decision goal.	Risk management group Business unit managers Management team Decision making group Relevant stakeholders
Identify the criteria and alternatives	Identify all risks. Identify criteria to evaluate risks.	Risk management group Business unit managers Management team
Organise the criteria and alternatives in a hierarchy	Organize risks in a hierarchy. If risks are too large categorized risks into manageable numbers.	Risk management group Business unit managers Management team
Determine decision time frame	Determine risk assessment time frame. For example one year or one financial year.	Risk management group Business unit managers Management team Decision making group
Assess the alternatives by making trade-off between the alternatives	Use pairwise comparison to assess risks.	Business unit managers Management team
Calculate priority weight of the criteria and alternatives	Calculate priority weight of criteria and risks	Risk management group
Check decision consistency	Check decision consistency. For inconsistent decision, revise risk assessment.	Risk management group Business unit managers Management team
Aggregate the weight to obtain overall weight of alternatives	Aggregate weight to obtain overall weight of risks	Risk management group
Discuss and approved the results	Discuss and reconcile risk ranking. Present risk ranking to decision makers for approval and implementation.	Risk management group Business unit managers Management team Decision making group
Document the decision	Document the decision and the decision making process.	Risk management group
Communicate the decision to stakeholders	Present risk ranking to relevant stakeholders for approval and implementation.	Risk management group Management team Decision making group
Monitor the decision	Monitor problem environment.	Risk management group

FIGURE 8.5: ISO31000:2009 Risk Management Standard

Step	Description
Establish Context	❖ **Establish external and internal environment.** • **Identify both challenges and opportunities in the context of firm's objectives and visions, operating environment and key stakeholders.** • **Collect information at both operational and strategic levels. Include both internal and external risks facing the firm.** ❖ **Risk profile.** • **Develop a risk profile and link risk profile to strategic planning.** ❖ **Risk appetite and risk tolerance level.** • **Establish risk appetite. The amount or range of risks considered acceptable and justifiable.** • **Establish risk tolerance. The acceptable variance from risk appetite boundaries.** ❖ **A risk matrix and responsibility.** • **Develop a risk matrix consist of likelihood and consequence.** • **The risk matrix is used to rank risk for treating and monitoring.** ❖ **Business continuity planning** • **Some risks are beyond firm's control such as terrorist attack. Prepare contingency plans for business continuity.**
Risk Assessment	
❖ **Identify risks**	**Generate a comprehensive list of risks and opportunities.**
❖ **Analyse risks**	• **Perform risk analysis using likelihood and consequence based on risk matrix developed in establish context.** • **Perform two level of analysis. First level is on inherent risk. Risks that exist prior to any controls being implemented. Second level is on residual risks. The remaining risks after mitigation actions.**
❖ **Evaluate risks**	• **Evaluate the risks to determine which risks are to be treated and has the priority for treatment implementation.** • **High priority risks should be given more attention.**
Risk Treatment	**Determine appropriate risk treatments. Prepare risk treatment plans. Risk treatment plan is a document explaining how the treatment is chosen. The document consist of :** • **Proposed treatment actions and time frame.** • **Cost benefit analysis** • **Individual responsible to implement the plan.** • **Resources to implement the plan. Such as physical or human resources.** • **Performance indicator to evaluate the effectiveness of the plan.** • **Ongoing monitoring and reporting of the treatment plan.**
Monitor and review	**Continuous monitoring and reviewing of risks and the effectiveness of the treatment plan.**
Communications and consultation	**Communication, consultation and feedbacks must take place at all steps in the risk management process.**

Figure 8.6: Connecting the the ISO31000:2009 Risk Management Standard and RP

ISO 31000:2009 Risk Management Standard	Risk Prioritization (RP)
Establish Context	• Identify the problem and define the decision goal.
Risk Assessment	
Identify risks	• Identify the criteria to assess risks. • Organise the risks and criteria into a hierarchy. • Determine decision timeframe for risk assessment.
Analyse risks	• Perform pairwise comparison to assess and make trade-off between the risks. • Calculate the priority weight of the criteria and risks. • Check decision consistency. • Aggregate the priority weights to obtain overall priority weight of risks. • Discuss and approve the risk ranking.
Evaluate risks	Based on the risk ranking, decide which risks are to be treated or has the priority for treatment. Document the risk assessment procedure and decision.
Risk Treatment	• Identify risk treatment alternatives for the chosen risk, and criteria to evaluate the risk treatment. • Organise the alternatives and criteria in a hierarchy. • Perform pairwise comparison to assess and make trade-off between the alternatives. • Calculate priority weight of criteria and alternatives. • Check decision consistency. • Aggregate the priority weights to obtain overall priority weight of the alternatives. • Discuss and approve ranking of the alternatives. • Document the risk treatment decision making process and risk treatment decision.
Monitor and review	Monitor the decisions. Revise decision if problem environment changes or if treatment is ineffective.
Communications and consultation	Communicate decision making process to stakeholders throughout the decision making process. Consults and seek expert opinions and suggestions throughout the process.

FIGURE 8.7: Post Evaluation RP Decision Making Steps

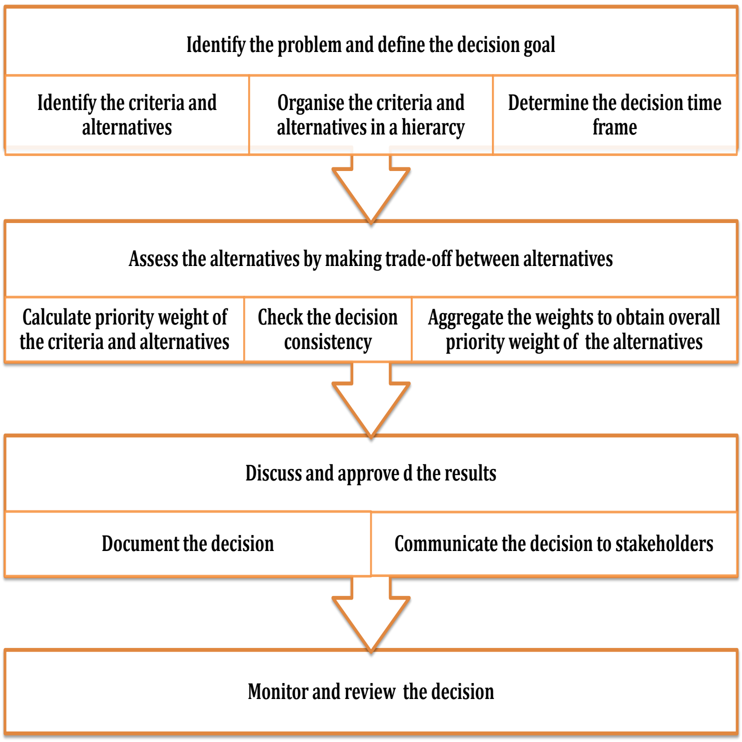
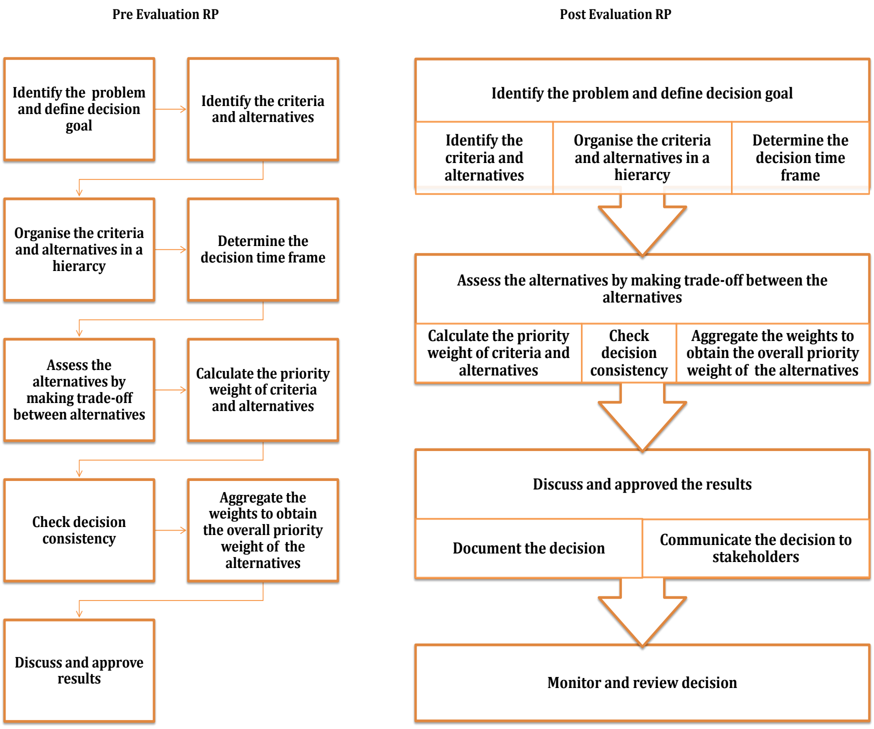


FIGURE 8.8: Post and Pre Evaluation RP Decision Making Steps



9

RP Strengths and Limitations

9.1 Introduction to Chapter 9

This chapter brings together Chapter 3, 5 and 8 into a coherent discussion on the strengths and limitations of RP. It discusses RP's strengths and limitations as a decision-making tool for risk management decision making and in addressing risk management decision-making challenges. Risk management decision making and risk management decision-making challenges were discussed in Chapter 3. The arguments to support the strengths and justify the limitations are based on the RP framework developed in Chapter 5 and the analysis of the RP evaluation feedback discussed in Chapter 8.

The goals of this chapter are outlined below:

- justify that RP can support risk management decision making and mitigate risk management decision making challenges. (Sections 9.2.1and 9.3.1)

- justify RP limitations in certain area of risk management decision making and risk management decision-making challenges. (Sections 9.2.2 and 9.3.2

9.2 Risk Management Decision Making

This section discusses RP strengths and limitations for decision making in risk management. The discussion is based on the RP framework developed in Chapter 5 and analysis of the risk managers feedbacks in Chapter 8.

9.2.1 RP Strengths

Making Trade-off

Decision making in risk management is complicated by trade-offs. Making trade-offs is difficult and time-consuming. RP uses pairwise comparisons to make trade-offs. Pairwise comparison is a systematic technique to compare alternatives or risks to decide which alternative or risk is more important. An effective way to make a focused and disciplined judgement is to take a pair of elements and compare them to a criterion without concern for the other criteria (Saaty, 1990).

Every time the risk managers decide that a risk is important, they are unconsciously comparing risks and assigning preferences to the risks. Pairwise comparisons enable them to focus their thoughts. Pairwise comparisons force the risk managers to exercise careful and deliberate judgement, and logical thinking rather than jumping to conclusions or giving emotional responses. It improves risk assessment by making explicit trade-offs between the risks.

Structuring a Complex Problem

The most important determinant of problem solution is the presentation or formulation of the problem Mitroff and Sagasti (1973). Mitroff and Featheringham (1974) introduced one of the most important errors associated with problem solving: the error of the third kind. According to Mitroff and Featheringham (1974), the error of the third kind is solving a wrong problem because of wrong problem representation. Boal and Meckler (2010) defined the error of the third kind as a vision error, which occurs when decision makers do not notice, fail to consider or fail to pay attention to the main issue. Instead, they focus their attention on subordinate or inconsequential issues, or on the effects of the main issues, instead of solving the main issues.

Structuring a problem is an integral part of RP to ensure that risk managers are solving the right problem with the right actions. Chapter 6 provides detail explaination how to struture risk management problems using RP. The starting point of RP is a well-structured problem with the following components clearly stated:

- The decision goal: The answer sought by the the risk managers.
- The set of alternatives from which the decision will be made.
- The set of criteria to evaluate the alternatives.

RP structures and simplifies complex problems. It uses hierarchies to structure the criteria and alternatives of a problem. The hierarchy links the criteria, alternatives and the decision goal. Structuring and simplifying a complex problem requires an in-depth understanding of the problem. The risk managers have to organise and sort their thinking and understanding. The hierarchy systematically structures risk managers' abstract understanding of influences, connections and interactions between criteria and alternatives, and provides a holistic view of the problem. Chapter 6 shows how the hierarchy systematically structured risks faced by an insurance companies. The risks are grouped into similar category allowing the risks managers to focus their decision on a particular risk category. It increases the risk managers confidence on their judgement and the accuracy of the risk ranking.

For a large problem with many criteria and alternatives, RP forces risk managers to probe their mind and deconstruct the problem into smaller, manageable sub-problems. Deconstructing a problem requires risk managers to exercise reductive thinking and logical analysis to break a problem into sub-problems. Each sub-problem must fit together for the problem to make sense as a whole. Using a hierarchy, a large problem is structured, organised and simplified.

Managing Uncertainty

Knight (1921) differentiated risk and uncertainty. Risk is an event with known probability of an outcome. For example, betting on a flip of a fair coin, a roll of a balanced die or a spin of a roulette wheel. Uncertainty is an event with unknown probability of an outcome. For example, making overseas investment, pursuing an experimental medical treatment or launching a new product. According to Wu et al. (2004), risks have objective probabilities and uncertainty has subjective probabilities. For uncertainties, a decision maker needs to estimate or infer the probabilities. For example, a situation in which the probability of an event to occur is 100 percent. If the event is impossible to occur, the probability is zero. If it is certain to occur, the probability is one and if the event is uncertain, the probability is judged between zero and one.

Uncertainty or the unknown probability of an outcome results from a lack of complete knowledge, information or understanding concerning the situation and possible consequences (Merna and Al-Thani, 2005). Therefore, uncertainty is a state of mind, characterise by doubt, due to lack of knowledge about what will happen or not happen in the future. As stated by Bernstein (1996, p 133), *we can say something is uncertain when our information is correct and an event fails to happen, or when our information is incorrect and an event does happen*

Uncertainties can be categorised into aleatory and epistemic. Epistemic uncertainty is uncertainty due to lack of knowledge, and aleatory uncertainty is uncertainty due to inherent variability in the physical world Yoe (2012). In principle, epistemic uncertainty is reducible and aleatory uncertainty is irreducible. Epistemic uncertainty could arise from incomplete theory or understanding of a system, modelling limitations or limited data. Aleatory uncertainty arises because of natural, unpredictable variations in the performance of the system under study.

Saaty (1987b) defined two types of uncertainties: (i) uncertain about the occurrence of events; and (ii) uncertainty about the range of judgements to express preference. RP defines the first uncertainty as aleatory and beyond risk managers' control. The second uncertainty is epistemic, in which the uncertainty is reducible by the amount of information available and risk managers' understanding of a problem.

Merna and Al-Thani (2005, pg. 13) identified the factors relating to epistemic uncertainties:

- lack of clarity in structuring a problem.
- inability to identify alternative solutions to a problem.
- the amount and quality of available information.
- futuristic nature of decision making.
- objectives to be satisfied within decision making.
- level of confidence of the post-decision stage of implementation.
- the amount of time available to make decisions.
- personal qualities of the decision makers.

According to Aven and Zio (2011), presenting accurate and relevant information and knowledge of a problem to the decision makers could reduce uncertainties. A clear, informed picture of the problem enables decision makers to confidently reason and deliberate the decision. A decision making process often starts with limited or no information. A lack of information, or zero information, increases uncertainties in the problem. Gathering sufficient relevant and reliable information reduces the uncertainties (Citroen, 2011). Citroen (2011) stated that to obtain the right answers to reduce uncertainties, decision makers need to ask the right questions and be responsive to still missing important information. Another way to reduce epistemic uncertainty is to examine divergences in the opinions of experts and be attentive to the potential effects of experts' disagreements on the results (Pat-Cornell and Dillon, 2006). Knowing the cause of divergence in the opinion of the experts are valuable to reduce epistemic uncertainties. As stated by Sunstein and Hastie (2015), decision makers usually focus on information that everybody in the decision making group already knew, and neglect the critical unshared information. The failure to identify and obtain missing critical information leads to failure of the decision.

RP reduces epistemic uncertainties in two ways:

- It reduces epistemic uncertainty by ensuring that the relevant information and knowledge of a problem are collected and structured in a hierarchy. The hierarchy presents a complete picture of the problem and reduces the possibility that important information is overlooked. The hierarchy increased transparency of the problem. Therefore, facilitates discussion and debate on the problem and improves the risk managers understanding of the problem before making judgements.

- It reveals epistemic uncertainties by enabling comparisons of the ranking of alternatives of different risk assessors. Comparing the rankings enables the risk managers to evaluate different risk opinions and attitudes among risk assessors. A ranking that is far apart from other rankings-particularly from a knowledgeable person or an expert-may require further investigation and communication. The expert may have critical information that other decision making group members are unaware of.

Visualising and Communicating a Problem

RP uses hierarchies to visualise and communicate risk management problems. A hierarchy is not just a diagram. It has the following purposes:

- It organises the problem in a simple framework that is easy to follow and analyse.

- It is easier to share and communicate a problem. A hierarchy presents a holistic view of the problem by displaying the criteria and alternatives of the problem. A hierarchy provides a structure to collaborate different views of a problem. Therefore, other people, units or departments can see their involvement or contribution to the problem.

- It is a quick way to engage people in a problem. The risk managers usually assign members of the decision group to perform specific tasks or communicate certain components of the problem without providing the whole picture, thereby creating a limited or myopic view of the problem. A hierarchy provides everyone in the decision-making group with a shared vision of the problem. The hierarchy synchronises the group's vision and understanding of the problem to deliver better decisions.

- It improves the understanding of a problem. A hierarchy shows linkages between elements in the problem, and between the elements and the decision goal. It enables people who are involved in the decision-making process to constructively criticise the reasoning and organisation of the problem, and to improve their understanding of the problem.

- A hierarchy makes a problem transparent. It presents the alternatives and the criteria to evaluate the alternatives. Therefore, it shows the trade-offs that risk assessors have to make when choosing one alternative over another. It also enables risk assessors, decision makers and stakeholders to see whether the risk manager or person developing the hierarchy is structuring the problem bias to their agenda.

RP is not the only decision-making tool promoting problem visualisation using hierarchies. Previous efforts to structure risks using hierarchy were by (Haimes et al., 2002, Hampton, 2009, Hillson, 2002, 2007, Olson and Wu, 2010). Eppler and Aeschimann (2009) stated that visualisation support risk-related communication. However, visualisation in risk management is limited to VaR diagram, risk matrix and risk dashboard. Another type of risk visualisation is risk cluster (Hampton, 2009). Hampton (2009) used risk cluster to show important risks, relationship or interaction between the risks and person responsible for the risks. Risk cluster group similar risks and sub-risks. Therefore, risk managers could see the interaction between risks. Hahn et al. (2007) stated that interactive risk visualisation is better at communicating risk to decision makers compared to text or prints. Roam (2008) promoted visual thinking through solving problems using pictures. According to Roam (2008), any problem can be made clearer using pictures. Pictures can represent complex concepts and summarise vast sets of information so they are easy to see and understand. A picture can clarify thoughts and ideas, and the same picture can be used to clarify thoughts and ideas to other people, inviting comments and inspired discussions.

Measuring Intangibles

RP corrects the perception that certain things are immeasurable. The word intangible is used widely to represent immeasurable things. Decision making in risk management requires better knowledge of intangibles. For example:

- Should the firm proceed with a certain project?
- What are the risks of launching a new product?
- What are major threats to the company?
- Should the firm invest in a foreign country?
- Should the firm outsource production?
- What could be the impact of new regulation to business?

These examples are some major decisions that risk managers must make. Assuming that the problem is immeasurable, the risk managers may make decisions based on only the tangible factors of the problem. This results in ill-informed decisions and increases the chance of decision error. RP enables the risk managers to use subjective judgement to measure the intangible elements of a problem. For example RP can be use to prioritise operational risks. One of the main problem in operational risk is lack of data. Using RP, the risk managers can consider all factors either tangible or intangible and all risks either quantitative or qualitative to be structured in a hierarchy to be prioritised.

Simple and Easy to Use

The objective of using RP is to improve the ability of risk managers to make timely and better-quality decisions. Complicated tools produce results that the risk managers prefer, but the tools require considerable time to understand and utilise. RP is a simple and easy-to-use decision-making tool. The simple aspects of RP are: (i) RP does not rely on extensive data or inputs; (ii) RP uses simple calculations to derive the results; and (iii) RP uses the hierarchy to visualise all relevant factors to problem; and (iv) RP does not require a complicated market, economy or probability assumptions or estimation.

Gigerenzer (2014) stated that whether a problem requires a simple or complex method depends on three features. First, the more uncertainty, the simpler the decision-making method, and the less uncertainty, the more complex the method. For example, the stock market is highly uncertain. A simple method is better for portfolio selection. Second, problems with many alternatives require a simple method. Problems with fewer alternatives should use a complex method. Third, problems with many historical data should use a complex method. Problems with limited or no data should use a simple method. Gigerenzer (2014) discussed the bias-variance dilemma-a mathematical theory on why and when simple is better. Bias is the difference between prediction and true outcome. Bias is a decision-making error and, in an uncertain world, bias is unavoidable. Another type of error is variance. Variance is the variability of a prediction around its mean. For the complex method, as more data are used, more factors need to be estimated. Therefore, there are more errors due to variance. The simple method does not use any data. Therefore, it does not have any variance. However, if the dataset is large (e.g., 500 years), the variance is reduced significantly, and using complex method is more beneficial.

Rebonato (2007) stated that complex techniques have the following limitations: (i) model builders may not be aware of the weaknesses or assumptions of the model; and (ii) decision makers may not fully understand how the model works. Simple decision-making methods have been criticised as producing unreliable results, being exposed to judgement biases and only representing part of the real problem. However, studies have shown that simple methods, rules and checklist can produce the answers sought by the decision makers (Aikman et al., 2014, Gawande, 2009, Gigerenzer, 2014, Neth et al., 2014, Rebonato, 2007). The simple methods have been applied to many domains, ranging from financial problems to medical and hospitals.

For example, Aikman et al. (2014) conducted a study with the Bank of England to model banks' capital requirement and predict individual bank failure during the global financial crisis. The study demonstrated that: (i) simple methods dominate complex methods for calculating banks capital requirement; (ii) simple methods are useful for problems with limited data or the underlying risks are characterised by fat-tail distributions; (iii) simple indicators outperformed complex metrics in predicting bank failure during the global financial crisis; and (iv) when combining information from different indicators, the simple method 'fast and frugal' decision tree performs comparably to the regression technique. However, the advantage of the simple method is that it is easier to communicate the process to the stakeholders.

Transparent and Traceable Decisions

RP is a transparent decision making process. RP requires factors relevant to a problem to be displayed in a hierarchy. The pairwise comparison explicitly elicits risk managers' judgement. To systematically review or retrace a decision, requires a transparent and properly structured decision making process. According to Finkelstein et al. (2009), two factors contribute to decision flaw: an individual or group making the judgement error, and failure of the decision process. A bad decision starts with an influential person or a few persons in the group making a judgement error. However, if a transparent and systematic decision process is in place, the decision process could prevent the error. Displaying the facts and factors of the problem enables other members to debate and challenge the decision. A systematic decision process enables group members to identify parts of the process requiring further investigation or analysis.

Rational Decisions

Grunig and Kuhn (2005) stated that the success or failure of a decision is not the correct yardstick for a decision. Instead, people must distinguish between a rational versus a successful decision. Rational decisions normally produce successful decisions. However, to assume that, with rationality, every decision can overcome any uncertainties and produce a successful result is a false understanding of rationality. According to Grunig and Kuhn (2005) a rational decision process exhibits the following characteristics:

- The decision process is goal oriented.
- The deliberation used in the decision process is based on relevant information. The information is evaluated as objectively as possible.

- The decision process follows a systematic, structured procedure of action and uses clear methodical rules. The process is comprehensible to non-participants or people outside the decision process.

RP defines rationality as (Saaty, 1994):

- Focus on the goal of the problem.
- Know enough about the problem to develop a thorough structure of relations and influence.
- Have enough knowledge and experience to assess the priority of influence and dominance among the relations in the structure.
- Have access to knowledge and experience of others to assess the priority of influence and dominance among the relations in the structure.
- Allow for differences in opinion with the ability to develop the best compromise.

RP's systematic decision-making process guides the risk managers to make rational decision. The risk managers acknowledged they cannot fully control the outcome of a decision. However, a systematic decision-making process will likely produce a successful decision. Using RP increases the risk managers confidence on the risk ranking and enables them to convince others such as top management of the decision. Kahneman (2011) stated that people will strive to make better decisions when they expect their decisions to be judged by how they were made not by how they turn out. For RP, the rationality of the decision depends on the process of making the decision, and not on the outcome of the decision.

Group Decision Making

RP supports group decision making. RP can be used for two types of group decision making: reconciling individual group judgement and making decisions based on a superior person in a group. The first type eliminates the conformity effect by enabling members of the group to answer the pairwise comparison questions separately. RP aggregates the individual priority weights to obtain the overall priory weight of the group. The second type eliminates conflict between group members and superior people in the group. Group member rate the power of influence of the superior members. The final decision is based on the member with the highest power of influence.

9.2.2 RP Limitations

Number of Level in a Hierarchy.

The hierarchy is an essential part of RP. However, the challenge is how big the hierarchy should be to represent a complete problem. A large hierarchy with many levels captures the whole problem and results in many pairwise comparison judgements. A small hierarchy does not capture the whole problem, has fewer pairwise comparisons and is easier to evaluate.

A hierarchy organises the relevant information of the problem in an easy-to-follow and analyse framework. A hierarchy structures risk managers' thoughts. The risk managers can add or delete any level as necessary. However, a hierarchy with many levels eliminates the simplicity of the problem, but produces a truer version of the problem. To determine how many levels to include in the hierarchy, risk managers need to make trade-offs between simplicity or a true picture of a problem.

Validating the Hierarchy

RP does not have a specific measurement to validate the hierarchy. The structure of the hierarchy depends on the risk managers' interpretation of the problem. Therefore, different risk managers may have different way to structure a problem in a hierarchy.

However, the risk managers can check whether a hierarchy is correct. The hierarchy levels indicate relationships between elements of one level and those of the level immediately below. The relationship percolates down from the highest to the lowest level of the hierarchy. The risk managers can check the hierarchy by comparing the elements at the lower level against the elements at the next higher level.

Validating the Result

RP does not have a specific measure for result significance. According to Saaty (2009), in decision-making, significance is interpreted subjectively at the beginning of the process through judgement. In science, significance is derived at the end after numbers are input into formulas. Science derives results using a number objectively and interprets significance subjectively. The significance of the results is interpreted on how well they serve the decision objective.

For RP, significance is interpreted subjectively at the beginning of the decision-making process, during the pairwise comparison judgement. A consistent pairwise comparison judgement obtained from a valid hierarchy produces objective priority weights. The priority weights are unique for a particular problem, with particular elements and alternatives. Therefore, changing the elements or alternatives could change the weight of the alternatives.

9.3 Risk Management Decision Making Challenges

This section discusses RP strengths and limitations in terms of risk management decision making challenges discussed in Chapter 3.

9.3.1 RP Strengths

Broad Framing

RP uses broad framing to structure choices. The following discusses RP broad framing:

- Combined evaluation: In RP, choices of the alternatives are combined and simultaneously displayed to risk managers. For example, a problem to prioritise four type of risks: A, B, C and D, is presented as combination of choice, AB, AC, AD, BC, BD and CD. To evaluate the risks in pair requires careful and deliberate thinking. Therefore, forces risk managers to use the System 2 thinking. Framing choices in pairs enable risk managers to see the possibility of an unimportant risk could be an important risk in combination. As stated by Kahneman (2011), comparative judgement involves the thinking of System 2 and more likely to be stable than single evaluation. Single evaluation is more likely to be guided by emotional responses of System 1.

- Displaying all alternatives: RP requires alternatives of the problem to be displayed. In the hierarchy, the alternatives are displayed at the bottom level. Displaying the alternatives reduces the decision making bias of overestimating the importance of one particular alternative. Studies have shown that under conditions of uncertainty, decision makers have a tendency to let their likes and dislikes determine their preferences or only consider a narrow set of possibilities to base their judgement. Therefore, the judgement biases under risk management decision making are risk managers only considering a favourite alternative, looking for evidence to support the alternative and being less mindful of the existence of other alternatives. Displaying the alternatives forces risk managers to explore other alternatives and evaluate how the alternatives affect decision goal.

Consistent Decision

For situations where comparisons and/or rankings are important, being consistent is more important than being right (Koller, 2000). Inconsistent decision are overcome by segregating options into similar categories (Kahneman, 2011). Consider the following three questions: (i) which do you like more, apple or peaches? (ii) which do you like more, steak or stew? (iii) which do you like more, apples or steak? The first two questions belong to the same category. The category of comparison is the same. In contrast, statement three is comparing choices of different categories, creating unstable answer. Apple is not a natural substitute for steak. Context of comparison is important to eliminate judgement bias and inconsistent decision. Kahneman (2011) stated that judgement and preferences are coherent for options of the same category, but potentially incoherent if the options belong to a different category.

RP applies the principle of homogeneity. To ensure consistency in the pairwise comparisons, elements to be compared must be of the same order of magnitude Saaty (2000). For incomparable elements, RP cluster the elements into a homogeneous group.

Then, the elements are compared within the group and across groups.

Further, to ensure consistent judgement across decision makers the alternatives are compared for a criterion. The criterion is a referent to judge the alternatives. Without a referent, decision makers tend to judge the alternatives based on standard, norm or own perception (Kahneman, 2011). For example, to determine how tall a person is, the answer depends on the referent or criterion. A person whose height is 5 feet is judged very tall for a six-year-old and very short for a 16-year-old. Age is the referent or criterion to judge the height of the person. Without a referent, decision makers will judge the person's height based on any norm or standard familiar to them.

RP requires that the alternatives are judged in terms of specific criteria. Therefore, the risk assessors are evaluating the alternatives using the same standard instead of using their own perceptions and norms. Risk managers need to use criteria that can meaningfully judge the alternatives and ensure that the risk assessors have the same understanding of the criteria.

Standardised Problems Framing

RP standardises the framing of problems. Therefore, prevents risk managers from manipulating the representation of a problem to obtain output bias to their agenda. Studies have shown different ways of framing a problem effect rational judgement. RP provides a standardised method to frame a problem and elicit judgement. It uses the hierarchy to display the criteria and alternatives. The hierarchy can be used to all problems faced by an organisation. It is a standardised and transparent framework to structure the problems. Therefore, everybody will have the same understanding of the problems. The hierarchy makes the problems transparent. Risk managers, decision makers and stakeholders can directly see factors relevant to the problem and the trade-offs they have to make. RP standardised judgement elicitation. It uses the pairwise comparison to make trade-offs to determine the importance of the alternatives.

Using Both System 1 and 2 Thinking

RP harnesses the strengths of both thinking systems, and minimal judgement biases arise from the weaknesses of the systems. Learning automatically and continuously is the operation of System 1, which is efficient in making associations between events. However, risk managers can learn more about a problem by using System 2 to reflect on decisions and different events. RP forces risk managers to mobilise System 2 to make conscious reflection and learning, and to double-check the intuitive thinking of System 1. By making the process a habit, risk managers can detect cognitive errors and judgement biases.

RP requires risk managers to use both rational and creative thinking. Risk managers identify available alternatives through creative and expansive thinking, and use logical and reductive thinking to choose or prioritise the alternatives. The process forces risk managers to use both System 1 and System 2 thinking. Risk managers use System 1 to make associations between criteria and alternatives, and System 2 to evaluate the associations logically.

In ambiguous situations, System 1 exhibit cognitive biases. It ignores the fact that there is missing relevant information and makes decisions based on available, limited and irrelevant information. RP forces risk managers to use System 2 thinking in ambiguous situations. System 2 thinking is in charge of doubting and unbelieving. RP forces the risk managers to ask, 'What do I need to know before I form a decision?'. To answer the questions requires risk managers to collect relevant information of the problem before making judgements.

Reduce Judgement Bias

The following explains how RP reduces judgement bias.

- A balanced view of a problem: Often risk managers have prior beliefs about a problem and alternatives to the problem. The beliefs could come from witnessing a risk event, experiencing a risk event, risk attitude, preference, knowledge or educational background. RP requires risk managers to collect sufficient relevant information of a problem and structure the problem in a hierarchy. The structuring process forces risk managers to identify alternatives that otherwise could be overlooked, or to discover unexpected links between elements of the problem. Structuring the problem also forces risk managers to filter the information. Only relevant information is structured in the hierarchy. Gathering and structuring the information enables risk managers to modify their belief or view of the problem. Previous and new information are now combined to create a balanced view of the problem..

- Using both intuitive and analytic judgement: Risk in the modern world is perceived and acted upon in two ways: feelings and analysis (Slovic and Peters, 2006). Risk as feelings refer to instinct and intuitive judgement, while risk as analysis uses logic, reasons and scientific deliberation According to Slovic and Peters (2006), evaluating risk as feelings can be influenced by emotions. For example, fear increase risk estimates and anger weakened the estimate.

  RP uses both intuitive and analytic judgement. The following explains how RP uses both intuition and analytic to make judgements. The pairwise comparison requires risk managers to determine the dominance and intensity of an alternative over another. Dominance asks which of the two alternatives has the property or meets the criterion more and intensity asked how much more. Saaty (2010b) stated that dominance stands for importance established through experience, present perceived preference or likelihood projected in the future. In RP, dominance asks risk managers to use their feelings represented by knowledge and experience to judge the importance of the alternatives, and intensity quantifies the feelings. RP uses quantitative method to analyse the judgements on intensity and calculate the priority weight. Decision making using RP is divided into two parts. The first part is using feelings or intuition to make judgements on the importance of the alternatives. The second part is using quantitative analysis to rank the alternatives.

- Consistency checks: RP uses CR to measure coherence. The CR is a monitoring mechanism for capturing randomly assigned judgements. Therefore, it forces risks managers to make careful and deliberate judgements.

9.3.2 RP Limitation

Relying on Experts Intuition and Judgement

RP requires risk assessors to use their subjective judgement to determine the importance of the alternatives. The risks assessors use their knowledge, skills and experience to make the judgements. To produce a valid and accurate ranking, the risk assessors have to be experts in the area.

According to Kahneman (2011), intuition is information stored in a person's memory and the information provides the answer to a problem. However, the confidence the experts have in their intuitions is not a reliable guide to the validity of the decision. Kahneman (2011) stated that whether to rely on experts' intuition depends on the type of environments in which the experts acquire their skills. The experts could be learning their skills from a regular and predictable environment. For example, physicians, nurses, athletes and fire fighters face complex problems but in an orderly situation. Experts in this environment have opportunities to learn the regularities through prolonged practice. They are able to recognise a situation and generate quick and accurate predictions and decisions. In an unpredictable environment (e.g., stock brokers and political scientists), the experts work in a zero validity environment or unpredictable environment. They do not have opportunities to learn the regularities due to the unpredictability of the environment. Therefore, their intuitions are invalid.

In RP, logic, feelings, emotions, intuition and experience are all required to make rational decisions. The risk assessors need to use their experience and intuition to structure a problem. They need to exercise logical thinking to identify the linkages between the decision goal, criteria and alternatives. They need to use feelings and emotions to evaluate the alternatives. However, RP provides a deliberate and conscious technique to make judgements using feelings and emotions. The pairwise comparisons force the risk assessors to be explicit about their preference, and to be explicit requires them to perform careful and logical thinking. RP requires judgements to be made by experts, and for judgement biases to be mitigated through pairwise comparisons.

9.4 Summary

This chapter discussed RP's strengths and limitations in terms of risk management decision making and risk management decision-making challenges. The strengths show that RP can improve risk managers' ability to make judgements and minimise judgement biases. However, as with any decision-making tool, risk managers must use RP with judgements that appreciate and compensate for the limitations of RP in particular settings.

10

Contribution, Limitation and Future Direction

10.1 Introduction to Chapter 10

This chapter summarises the thesis contributions to the theory and practice of risk management, decision making and the AHP. The chapter concludes by discussing limitations of the thesis and the need for further research in the area.

The goals of this chapter are outlined below:

- briefly describe how the thesis achieved the research aim and objectives, and how it answered the research questions. (Section 10.2)

- describe the contribution of the thesis to risk management, decision making and the AHP. (Sections 10.3 and 10.4)

- justify the limitations of the research. (Section 10.5)
- propose directions for future research. (Section 10.6)

10.2 Research Questions, Aims and Objectives Revisited

Chapter 1 discussed the research questions and aims. The main question was: Does RP have something to offer, or is it relevant to risk management? RP is the decision-making tool developed in this thesis for risk management. The tool exploits the AHP, which is a multi-criteria decision-making tool developed for complex problems.

The research question was deconstructed into the following sub-questions:

- How or when is RP useful for risk management?
- How or when is RP not useful for risk management?
- How is RP used for risk management?
- What do risk managers require to use RP effectively?

The research questions were derived from the primary aim of the thesis-that is, to explore whether RP has something to offer and whether it is relevant to the practice of decision making in risk management. To support the aim, the main aim of the thesis was stated as follows:

- To explore situations in which RP is useful as a decision-making tool for risk management, and how it is useful.
- To explore situations in which RP is not useful as a decision-making tool for risk management, and how it is not useful.
- To investigate how RP can be used for decision making in risk management.
- To investigate how risk managers can use RP effectively.

To answer these questions, the thesis applied RP to risk management problems. Chapter 5 explained RP, and Chapter 6 demonstrated RP applications to risk management problems. Chapter 6 demonstrated that the RP framework developed in

Chapter 5 is able to structure complex risk management problems. Chapter 7 investigated whether RP is relevant to the practice of decision making in risk management. Chapter 7 introduced RP to the practical setting of risk management. The risk management problems structured using RP were presented to risk managers. The risk managers evaluated the practical usability of RP. Chapter 7 also discussed the evaluation process and reported the feedback obtained from the risk managers on RP usability. Chapter 8 discussed the analysis and responses made to the feedback. Chapter 9 discussed the strengths and limitations of RP for risk management decision making and risk management decision-making challenges. Chapter 2 discussed the main results and the conclusion.

10.3 Contribution to Knowledge

This thesis contributes to the knowledge of how to apply AHP to risk management. The thesis demonstrated the application of the AHP concept, theory and framework to risk management problems. Chapter 4 discussed the AHP application to different types of complex problems. This thesis brought the AHP into a new area of application: risk management.

For risk management, the contribution of this thesis was in developing a risk management decision-making framework exploiting the AHP and applying the framework to risk management problems. The framework enables risk managers to structure and simplify complex risk management problems and improve their understanding of the problems. As stated by Grunig and Kuhn (2005), complex problems are ill-structured problems. Therefore, the first step to confront the problems is to design the problems into an organised and understood structure.

For decision making, the thesis contributes to existing knowledge by identifying and demonstrating how the RP's concepts, frameworks and analytic steps can improve risk management decision making and addresses challenges to make decisions under conditions of uncertainty or risk.

The thesis contributed to examining and clarifying two disciplines: risk management and decision making in risk management. The contribution to the areas is identifying the differences between risk management and risk management decision making. The thesis makes an explicit distinction between risk management and risk management decision making. Risk management is managing uncertainties. Risk management decision making is decision making under uncertainties. The processes require different tools. To manage uncertainties, risk managers need risk management standards or processes. To make decisions under uncertainties, risk managers need a decision-making tool. The tool developed in this thesis is for risk management decision making.

Risk management problems are unstructured, with multiple conflicting factors influencing solutions to the problems, the outcome of the decisions is uncertain and has a significant effect on the firm, and the outcome of the decision affects several stakeholders across the firm. To face the complexities and ambiguities of risk management problems, risk managers cannot rely only on intuition or common sense. Risk managers need a decision-making tool able to address the complexity and uncertainties. The perspective led the thesis to connect risk management decision making and decision theory. Decision theory is about decision-making behaviours and judgement biases under uncertainties. However, not all judgement biases are relevant to risk management decision making. This thesis contributed in identifying the judgement biases influencing risk managers to make decisions under uncertainties and risks.

This thesis contributed to combining risk management, decision-making behaviour under uncertainties and prescriptive decision theory. Risk management needs a prescriptive decision model to improve decision making, minimise judgement biases and confront complexities. Prescriptive decision theory is about the methods a decision maker should use to improve decisions. To address complexities risk management needs a multi-criteria decision-making tool. AHP is a multi-criteria decision-making tool that structures and simplifies complex problems. The thesis contributed to demonstrating how the AHP is a suitable tool for risk management decision making.

The thesis contributes to knowledge on humans' ability to make judgements. The tool developed in this thesis does not aim to replace the human brain; rather, it aims to extend its reach and amplify its power. The thesis explains the application of the two human thinking systems for decision making in risk management, System 1 and 2. The two human thinking systems are known in psychology and decision behaviour studies. The tool requires risk managers to use both rational and creative thinking, harnessing both System 1 and 2 thinking systems. Good decision-making demands identification of available alternatives through creative and expansive thinking, the work of System 1. The alternatives are chosen or prioritise through logical and deliberate thinking, the work of System 2. System 1 makes association between criteria and alternatives, and System 2 logically evaluates the associations.

10.4 Contribution to Practice

The contribution of the thesis to practice is developing RP, which is a decision-making tool for risk management. RP enables risk managers to address complex risk management problems systematically. First, RP structures and simplifies the problems. Second, RP provides a systematic and logical decision-making process. A systematic and logical decision-making process produces reliable, objective and defensible decisions.

This thesis has the potential be a change agent to the practice of decision making in risk management. The thesis can be viewed as the first to explore how to apply the AHP to risk management, and it can serve as a valuable document for the risk management community.

The thesis brings light to the human element that is often under-appreciated and under-served in the automatic and technology space of decision making. The common practice is to automate the decisions governing business operations. However, the reality is that many operational and business decisions require human components. The view of this thesis is that the human components should be amplified with processes to refine and bolster it. The decision-making tool developed in this thesis amplifies risk managers' ability to make judgements, while minimising the judgement biases.

The contribution of the thesis to practice is to bring attention to risk managers that developing a good decision-making process is as important as developing a good risk management process. Firms routinely look for ways to improve their risk management process to ensure that they are effectively managing their risks and achieving their business objectives. However, an important component of risk management is making decisions. Therefore, firms need to ensure the quality of their risk judgements and decisions. They should also routinely look for ways to improve the decision-making process. A good decision-making process is essential for firms to implement risk management effectively.

10.5 Research Limitations

One of the limitations of this thesis was the assumption of independence between levels of a hierarchy and elements within the same level of the hierarchy. In the risk world, risks interact and correlate. In RP, the process of evaluation is linear. The upper level determined the importance of the lower level. The criteria determined the importance of the alternative. However, the focus of the thesis is at the major advantage of RP, which is structuring and simplifying complex problems. The main reason the thesis developed RP is to structure and simplifies complex risk management problems.

The thesis investigates how and when RP is useful and not useful to risk management. To find the answers, risk managers were recruited to evaluate RP's practical usability. As risk management experts, the risk managers provided quality and valid feedback on RP. The evaluation feedback was obtained from members of MARIM. The thesis identified the participants as experts in the field of risk management. However, the MARIM members were a limited subset of a large group of risk managers. With these concerns in mind, any attempt to generalise the findings need to be verified carefully. Further, the findings relied on participants' knowledge and experience of risk management as practice in Malaysia. Choosing a focus group and country facilitated the data collection, but limited the generalisation of the findings.

10.6 Future Research

This thesis forms the basis for investigating decision making in risk management. However, RP still needs many improvements. This thesis provides a number of opportunities for future research:

- To improve the current RP framework to include risk interconnectivity: An advanced AHP, called the ANP (Saaty, 2010b), can be used to capture the interaction and dependence of higher-level elements with lower elements. In the ANP, the evaluation flows in a loop defined in a network instead of a linear relationship in a hierarchy. The criteria determine the importance of the alternatives, and the importance of the alternatives become feedback to determine the importance of the criteria.

- To include sensitivity analysis: The sensitivity analysis will measure how changes in the priority weights of the criteria affect the alternatives.

- To apply RP to a variety of risk management problems: This thesis focuses on risk management problems faced by insurance companies. The future development of RP should work with risk managers on using RP to solve other risk management problems.

- To apply RP using case studies: For the thesis, risk managers evaluated RP on prepared risk management problems. Future research should work with risk managers to apply RP to risk management using case studies.

- A spreadsheet decision support tool was developed to assist risk managers to learn and evaluate RP. The support tool could be extended and made more user-friendly. The alternatives and criteria could be entered into a database or a profile, and risk managers could select the particular alternatives and criteria for a risk management problem from the database. This feature would enable risk managers to easily choose and structure the alternatives and criteria relevant to a risk management problem.

10.7 Final Remark

The aim of this thesis was to contribute to the practice and knowledge of decision making in risk management. The thesis developed a systematic process to structure and simplify complex risk management problems. Undertaking the research presented an opportunity to learn and critically reflect on decision making and risk management, and on a new way of examining problems and seeking solutions. Complex problems do not necessarily need complex solutions. Rather, complex problems need to be disentangled and simplified before determining solutions.

A
Appendix

A.1 Email Invitation to Potential Participants

Invitation to Participate in a Research Project.

Dear Sir/Madam,
Project title: Risk Management Decision Making: The Analytic Hierarchy Process Approach.
Investigators: Rabihah Md. Sum (PhD Student) (Email:rabihah.md-sum@mq.edu.au)
Professor Piet De Jong (Research Supervisor) (Email: piet.dejong@mq.edu.au)

You are invited to a research project conducted by Macquarie University, Sydney. I am a doctoral candidate in the Department of Applied Finance and Actuarial Studies, Faculty of Business and Economics.

What is the project about?
My project is to test the usability of a decision making tool for risk management. The tool exploits a multi-criteria decision making technique the Analytic Hierarchy Process. The tool is called Risk Prioritization (RP). RP is designed to structure the complexity of risk management problems and assist risk managers to make clear and objective decisions. Information about RP is given in the attached brochure. The brochure provides information on what is RP, what RP does and the benefits of RP. RP is in its final stage of development which is testing the tool to see how it work practically to structure and solve risk management issues.

Why have you been approached?
You are chosen because of your experience in risk management makes you an excellent candidate to evaluate RP. Your feedback is valuable in improving RP for it to be applied practically.

If I agree to participate, what will I require to do?
If you agree, please email me at *rabihah.md-sum@mq.edu.au* or *rabihahmdsum@gmail.com*. We can arrange a suitable time to conduct the testing session. The session will take about 60 minutes to complete.

To take part in this project you will require:
(i) a basic computer skills
(ii) an access to a computer (I will provide a laptop if you do not have access to a computer).

The RP is in an excel spread sheet. It can be saved in your computer or available in the laptop. During the session you are required to use RP on prepared risk management problems and give your feedbacks on how RP assist in solving the issues. Open-ended questions will be given to you at the beginning of the session. You can use the questions to guide your thoughts. You can choose to either give written or oral feedbacks. I am seeking your expert comments on whether RP is a useful and practical tool to structure and solve risk management decision making problems. In the session I will be requesting you think out loud. The session will be audio taped to create an accurate database of information. You have the right to request that taping cease at any point during the interview.

What are my rights as a participant?
Your feedback will remain confidential. All information will be analysed in general without references to specific individuals. You can withdraw from participation at any stage without prejudice and have any unprocessed data withdrawn and destroyed, provided it can be reliably identified. No participant personal information will be provided as part of any publication. Participant Information and Consent Form is attached in this email.

Whom should I contact if I have any questions?
If you have any questions about any aspect of the project, please contact me at *rabihah.md-sum@mq.edu.au/rabihahmdsum@gmail.com* or my supervisor Prof. Piet De Jong at *piet.dejong@mq.edu.au.* For questions regarding the ethical conduct of the session, please contact MQ Human Research Ethics Committee at ethics@mq.edu.au.

What are the benefits associated with participation?
I recognize your time is valuable and thank you in advance for your generous participation in this project. You expert opinions can contribute to the development of risk management research, particularly in decision making involving uncertainties, risky and complicated issues.

Your perspective, expertise, and experience are important. The project session is a great opportunity to share your expertise, and identify successful practices and ongoing challenges in risk management decision making.

Your contribution to this project is greatly appreciated. I hope to hear from you soon.

Yours Sincerely,
Rabihah Md. Sum
PhD Candidate
Department of Applied Finance and Actuarial Studies
Faculty of Business and Economics
Macquarie University, Sydney
Australia.
Email: rabihah.md-sum@mq.edu.au
rabihahmdsum@gmail.com
Tel: +61 4 1047 4428 (Australia)
Tel: +60 10 280 5024 (Malaysia)

A.2 Participant Information and Consent Form

Department of Applied Finance and Actuarial Studies
FACULTY OF BUSINESS AND ECONOMICS
MACQUARIE UNIVERSITY NSW 2109 AUSTRALIA

Professor Piet De Jong (Research Supervisor)
Phone: +61 (0)2 9850 8576
Email: piet.dejong@mq.edu.au

TO WHOM IT MAY CONCERN
Participant Information and Consent Form

Name of Project: Risk Management Decision Making: The Analytic Hierarchy Process Approach.
Research Supervisor: Professor Piet De Jong
PhD Student: Rabihah Md. Sum (Email:rabihah.md-sum@mq.edu.au., Phone: +61 4 1047 4428)

You are invited to participate in a study investigating how Risk Prioritization (RP) can assist in solving complex risk management problem. The purpose of the study is to find out how a risk management decision making tool (called Risk Prioritization) developed based on the Analytic Hierarchy Process assist risk managers in making risk management decisions. The Risk Prioritization decision making tool is designed to structure and simplify complex risk management problems. Your feedback will be used to evaluate whether Risk Prioritization is practically useful in structuring and solving risk management problems. It is anticipated that by participating in the survey will promote developing your understanding of risk management decision making and the ability to make better decisions.

This study is conducted to meet the requirements of PhD in Applied Finance and Actuarial Studies under the supervision of Professor Piet De Jong (Tel: +61 2 9850 8576, Email: piet.dejong@mq.edu.au) of the Department of Applied Finance and Actuarial Studies.

If you decide to participate, the session will take about 60 minutes. You will be asked to (i) use the Risk Prioritization (RP) tool to one of the prepared risk management problems. (ii) The study aims to obtain expert opinion on the useability of RP. Open-ended questions will be given to you at the beginning of the session. The questions act as a guide to give your feedbacks on RP. You are encouraged to think out loud and focus on describing your experience using the RP. You can also give any feedbacks not within the given questions about RP. You are encouraged to reflect on your expertise, skills and experience while using the RP. The session will be audio recorded to ensure accurate information database. You have the right to stop the audio recording at any point during the session. If you do not wish to think out loud and prefer writing your feedbacks, you can write your feedbacks on the open-ended questions given to you at the beginning of the session.

Any information or personal details gathered in the course of the study are confidential. No individual will be identified in any publication of the results. Only my supervisor and I will have access to the data. A summary of the results of the data can be made available to you on request by emailing rabihah.md-sum@mq.edu.au.

Participation in this study is entirely voluntary: you are not obliged to participate and if you decide to participate, you are free to withdraw at any time without having to give a reason and without consequence.

I, have read (or, where appropriate, have had read to me) and understand the information above and any questions I have asked have been answered to my satisfaction. I agree to participate in this research, knowing that I can withdraw from further participation in the research at any time without consequence. I have been given a copy of this form to keep.

Participant's Name:____
(Block letters)

Participant's Signature: _________________ Date:________________

Investigator's Name: RABIHAH MD.SUM
(Block letters)

Investigator's Signature: _____________ __ Date:________________

The ethical aspects of this study have been approved by the Macquarie University Human Research Ethics Committee. If you have any complaints or reservations about any ethical aspect of your participation in this research, you may contact the Committee through the Director, Research Ethics (Telephone +61 (2) 9850 7854; Email: ethics@mq.edu.au). Any complaint you make will be treated in confidence and investigated, and you will be informed of the outcome.

(INVESTIGATOR'S [OR PARTICIPANT'S] COPY)

A.3 RP Evaluation Questions

The following are questions about the structure and usability of Risk Prioritization (RP) in structuring and solving risk management problems. Your honest feedbacks help improve RP for future use.

RP uses hierarchy to structure the problem. The hierarchy represent the problem in a multilevel structure. The first level is the goal followed by factors and sub-factors. Hierarchy shows the linkage between the factors and sub-factors.
The hierarchy helps better understand the problem. Yes/No. If No, why
The hierarchy makes the problem more structured and organised? Yes/No. If No, why?
Disagreement can be constructively managed by presenting the information in a hierarchy? Yes/No. If No, why?
Can overlook and missing information easily detected? Yes/No. If No, why?
Communication about the problem is more focused by referring to the hierarchy? Yes/No. If No, why?
Building the hierarchy promote creative thinking in developing, structuring and organizing risk management problem? Yes/No. If No, why?

The paired comparison asks you to compare two risks. You judge which risk is more or less importance and the intensity of importance. Paired comparison assist you in making trade-offs between two risks. And the decision consistency measures whether your judgement is consistent or not.
The pairwise comparison instruction is easy to follow. Yes/No. If No, how would you improve the instruction?
The paired comparison is a natural way to make trade-offs between two risks. Yes/No. If No, why?
The scale (1, 3, 5, 7 and 9) is easily understood? Yes/No. If no, why?
The decision consistency assists you in making better judgement? Yes/No. If No, why?

RP consists of problem statement, decision making steps, a hierarchy, pairwise comparison and results.
RP is easy to use. Yes/No. If No, why?
The stepsrs are easy to follow. Yes/No. If No, why?
Rate the usefulness of each component:

Components	Useful	Not useful
Problem statement		
Decision making steps		
Hierarchy		
Pairwise Comparison Analysis		
The Results		

Are there any components that are particularly useful or well designed? Yes/No If yes, which one and why?
What components you would like to see in future versions?
How would you structure the new version with the new components?

Implementation barriers/challenges
Would you use RP for risk management decision making? Yes/No. If No, why?
Do you foresee any challenges in implementing RP in your company? Yes/No.
Are there any other risk management problems you would like RP to solve?
Are the results produces by RP useful?
Any other results you would like to see?

Demographic questions
Name of job position:
How many years of experience in your current position?
How many years of experience in risk management?
Highest education. (Please write complete qualification, for example MSc in Risk Management and Insurance.)

A.4 Ethics Approval Letter

MACQUARIE UNIVERSITY

RABIHAH MD. SUM <rabihah.md-sum@students.mq.edu.au>

Approved - 5201400295

1 message

Mrs Yanru Ouyang <yanru.ouyang@mq.edu.au> Thu, Apr 24, 2014 at 9:56 AM
To: Prof Piet de Jong <piet.dejong@mq.edu.au>
Cc: "Miss Rabihah Md. Sum" <rabihah.md-sum@students.mq.edu.au>

Dear Prof de Jong,

Re: 'Risk Management Decision Making: The Analytic Hierarchy Process Approach.'

Reference No.: 5201400295

Thank you for your recent correspondence. Your response has addressed the issues raised by the Faculty of Business & Economics Human Research Ethics Sub Committee. Approval of the above application is granted, effective "24/04/2014". This email constitutes ethical approval only.

This research meets the requirements of the National Statement on Ethical Conduct in Human Research (2007). The National Statement is available at the following web site:

http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/e72.pdf.

The following personnel are authorised to conduct this research:

Miss Rabihah Md. Sum
Prof Piet de Jong

NB. STUDENTS: IT IS YOUR RESPONSIBILITY TO KEEP A COPY OF THIS APPROVAL EMAIL TO SUBMIT WITH YOUR THESIS.

Please note the following standard requirements of approval:

1. The approval of this project is conditional upon your continuing compliance with the National Statement on Ethical Conduct in Human Research (2007).

2. Approval will be for a period of five (5) years subject to the provision of annual reports.

Progress Report 1 Due: 24th April 2015
Progress Report 2 Due: 24th April 2016
Progress Report 3 Due: 24th April 2017
Progress Report 4 Due: 24th April 2018
Final Report Due: 24th April 2019

NB. If you complete the work earlier than you had planned you must submit a Final Report as soon as the work is completed. If the project has been discontinued or not commenced for any reason, you are also required to submit a Final Report for the project.

Progress reports and Final Reports are available at the following website:

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/forms

3. If the project has run for more than five (5) years you cannot renew

approval for the project. You will need to complete and submit a Final Report and submit a new application for the project. (The five year limit on renewal of approvals allows the Committee to fully re-review research in an environment where legislation, guidelines and requirements are continually changing, for example, new child protection and privacy laws).

4. All amendments to the project must be reviewed and approved by the Committee before implementation. Please complete and submit a Request for Amendment Form available at the following website:

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/forms

5. Please notify the Committee immediately in the event of any adverse effects on participants or of any unforeseen events that affect the continued ethical acceptability of the project.

6. At all times you are responsible for the ethical conduct of your research in accordance with the guidelines established by the University. This information is available at the following websites:

http://www.mq.edu.au/policy/
http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/policy

If you will be applying for or have applied for internal or external funding for the above project it is your responsibility to provide the Macquarie University's Research Grants Management Assistant with a copy of this email as soon as possible. Internal and External funding agencies will not be informed that you have approval for your project and funds will not be released until the Research Grants Management Assistant has received a copy of this email.

If you need to provide a hard copy letter of approval to an external organisation as evidence that you have approval, please do not hesitate to contact the FBE Ethics Committee Secretariat, via fbe-ethics@mq.edu.au or 9850 4826.

Please retain a copy of this email as this is your official notification of ethics approval.

Yours sincerely,

Parmod Chand
Chair, Faculty of Business and Economics Ethics Sub-Committee
Faculty of Business and Economics
Level 7, E4A Building
Macquarie University
NSW 2109 Australia
T: +61 2 9850 4826
F: +61 2 9850 6140
www.businessandeconomics.mq.edu.au/

List of Acronyms

ANC	Average of Normalized Column
AHP	Analytic Hierarchy Process
ALM	Asset Liability Mismatch
ANP	Analytic Network Process
BSC	Balance Scorecard
BOCR	Benefit Opportunity Cost Risk
CI	Consistency Index
CR	Consistency Ratio
DEA	Data Envelopment Analysis
ELECTRE	Elimination Et Choix Traduisant la Realite
GPW	Group Priority Weight
LLSM	Log Least Square Method
MARIM	Malaysian Association of Risk and Insurance Management
MAUT	Multi Attribute Utility Theory
MADM	Multi Attribute Decision Making

MAVT Multi Attribute Value Theory

MCDM Multi Criteria Decision Making

MHDIS Multi-Group Hierarchical Discrimination

MODM Multi Objective Decision Making

NGM Normalization of the Geometric Means

NRA Normalization of Row Averaged

PEST Political Economic Social and Technological

PROMETHEE Preference Ranking Organization Method of Enrichment Evaluations

QFD Quality Function Deployment

RBS Risk Breakdown Structure

RCI Random Consistency Index

RMG Risk Management Group

RP Risk Prioritisation

SWOT Strengths Weaknesses Opportunities and Threats

TOPSIS Technique for Order of Preference by Similarity to Ideal Solution

UTA Utilities Additives

UTADIS Utilities Additives Discriminantes

VaR Value at Risk

WYSIATI What You See Is All There Is

References

Aabo, T., J. Fraser, and B. J. Simkins (2005). The rise and evolution of chief risk officer: Enterprise risk management at hydro one. *Journal of Applied Corporate Finance 17*(3), 62–75. 8

Acharyya, M. (2009). The influence of enterprise risk management on insurer stock market performance: An event analysis. *Enterprise Risk Management Symposium. April 29-May 1, Chicago IL.* 8

Acharyya, M. and J. Johnson (2006). Investigating the development of erm in the insurance industry: An empirical study of four major european insurers. *The Geneva Papers on Risk and Insuranc: Issues and Practice*, 55–80. 8

Aikman, D., M. Galesic, G. Gigerenzer, S. Kapadia, K. Katsikopoulos, A. Kothiyal, E. Murphy, and T. Neumann (2014). Taking uncertainty seriously: Simplicity versus complexity in financial regulation. *Bank of England Financial Stability Paper* (28). 241

Alexander, J. M. and T. L. Saaty (1977). Stability analysis of the forward-backward process: Northern Ireland case study. *Behavioral Science 22*(6), 375–382. 117

Alhakimi, A. and P. Slovic (1994). A psychological study of the inverse relationship between perceived risk and perceived benefit. *Risk Analysis 14*(6), 1085–1096. 58

Armstrong, M. (2006). *A Handbook Of Management Techniques: A Comprehensive*

Guide To Achieving Managerial Excellence And Improved Decision Making. Kogan-Page, London. 79, 80

Asch, S. E. (1956). Studies of independence and conformity: A minority of one against a unanimous majority. *Psychological Monographs: General and Applied 70*(9), 1–70. 59, 60

Aven, T. and E. Zio (2011). Some consideration on the treatments of uncertainties in risk assessment for practical decision making. *Realiability Engineering and System Safety* (96), 64–74. 50, 237

Baker, D., D. Bridges, R. Hunter, G. Johnson, J. Krupa, J. Murphy, and K. Sorenson (2001). *Guide Book to Decision Making Methods*. Developed for the Department of Energy, United States of America. WSRC-IM-2002-00002. Downloaded from http://www.everyspec.com. 143

Bargh, J. A., M. Chen, and L. Burrows (1996). Automaticity of social behavior: Direct effects of trait construct and stereotype activation on action. *Journal Of Personality And Social Psychology 71*(2), 230. 69

Baron, J. (2012). The points of normative models in judgement and decision making. *Frontiers in Psychology 3*, 1–3. 84

Barton, T. L., W. G. Shenkir, and P. L. Walker (2002). *Making Enterprise Risk Management Pay Off: How Leading Companies Implement Risk Management*. Financial Times Prentice Hall, Upper Saddle River New Jersey. 42, 75, 78

Beasley, M., D. Pagach, and R. Warr (2008). Information conveyed in hiring announcements of senior executives overseeing enterprise-wide risk management processes. *Journal of Accounting, Auditing and Finance 23*(3), 311–332. 7

Beasley, M. S., R. Clune, and D. R. Hermanson (2005a). Enterprise risk management: An empirical analysis of factors associated with the extent of implementation. *Journal of Accounting and Public Policy* (24), 521–531. 7

Beasley, M. S., R. Clune, and D. R. Hermanson (2005b). Erm: A status report. *Internal Auditor 62*(1), 67–72. 8

Bell, D. E., H. Raiffa, and A. Tversky (1988). *Descriptive, Normative and Prescriptive Interactions in Decision Making*, Chapter 1, pp. 1–9. Cambridge University Press. 9

Bernoulli, D. (1954). Exposition of a new theory on the measurement of risk (english translation. original work published 1738). *Econometrica: Journal of the Econometric Society 22(1)*, 23–36. 9, 84

Bernstein, P. L. (1996). *Against The Gods: The Remarkable Story of Risk*. John Wiley & Sons, Inc. 236

BIS (2004). International convergenge of capital measurement and capital standards: A revised framework. Technical report, Bank for International Settlements, Switzerland. 209

Boal, K. and M. Meckler (2010). Decision errors of the 4th, 5th, and 6th kind. In P. C. Nutt and D. C. Wilson (Eds.), *Handbook of Decision Making*, Chapter 12, pp. 327–348. John Wiley & Son, Inc., West Sussex. 235

Bondt, W. F. D. (1993). Betting on trends: Intuitive forecasts of financial risk and return. *International Journal of forecasting 9*(3), 355–371. 55

Borge, D. (2001). *The Book of Risk*. John Wiley & Sons Inc, New York. 3, 4, 5, 9, 20, 47

Brugha, C. M. (1998). Structuring and weighting criteria in multi criteria decision making. *Proceedings of the 13th International Conference on Multiple Criteria Decision Making, Stewart, T. J. and Van den Honert, R.C. (eds.)*, 229–242. 211

Bushan, N. and K. Rai (2004). The Analytic Hierarchy Process. In R. Roy (Ed.), *Strategic Decision Making: Applying the Analytic Hierarchy Process*, Chapter 2, pp. 11–21. Springer-Verlag London. 99

CAS (2003). Overview of enterprise risk management. Technical report, Technical Report- Enterprise Risk Management Committee Casualty Actuarial Society. 42, 44

Chabris, C. and D. Simons (2010). *The Invisible Gorilla And Other Ways Our Mind Could Deceive Us*. Crown Publishers, New York. 68

Chapman, R. J. (2006). *Simple Tools and Techniques for Enterprise Risk Management*. West Sussex England: John Wiley & Sons. 40, 42, 43, 44, 74, 75, 210

Charette, R. N. (1997). The risks with risk identification. Technical report, ITABHI Corporation. 48

Chatterjee, S. and T. B. Heath (1996). Conflict and loss aversion in multiattribute choice: The effects of trade-off size and reference dependence on decision difficulty. *Organizational Behavior and Human Decision Processes 67*(2), 144–155. 21

Citroen, C. L. (2011). The role of information in strategic decision-making. *International Journal of Information Management* (31), 493–501. 237

Clarke, A. and R. Dawson (1999). *Evaluation Research*. SAGE Publications Ltd., London. 184, 185

Colquitt, L., R. E. Hoyt, and R. B. Lee (1999). Integrated risk management and the role of the risk manager. *Risk Management and Insurance Review 2*, 43–61. 7

COSO (2004). Enterprise risk management integrated framework. Technical report, Committee of Sponsoring Organization of the Treadway Commision (COSO). 46

Cox, L. A. (2008). What is wrong with risk matrices? *Risk Analysis 28*(2), 497–512. 73

Crawford, G. (1987). The geometric mean procedure for estimating the scale of a judgement matrix. *Mathematical Modelling 9*(3), 327–334. 149

Crawford, G. and C. Williams (1985). A note on the analysis of subjective judgment matrices. *Journal of Mathematical Psychology 29*(4), 387–405. 149

Damodaran, A. (2007). *Strategic Risk Taking: A Framework For Risk Management*. Prentice Hall, Upper Saddle River New Jersey. 75, 76, 77, 78

Desender, K. A. (2007). On the determinants of Enterprise Risk Management implementation. *Available at Social Science Research Network (SSRN) http://ssrn.com/abstract=1025982.*. 7

Douglas Clinton, S. A. W. and J. M. Hassel (2002). Implementing the Balanced Scorecard using the Analytic Hierarchy Process. *Management Accounting Quarterly 3*(3), 1–11. 126

Doumpos, M. and C. Zopounidis (2002). *Multicriteria Decision Aid Classification Methods*. Kluwer Academic Publisher, Dordrecht. 86

Duckert, G. H. (2011). *Practical Enterprise Risk Management A Business Process Approach*. John Wiley & Sons, Hoboken New Jersey. 23, 74

Emblemsvag, J. and L. E. Kjolstad (2006). Qualitative risk analysis: Some problems and remedies. *Management Decision 44*(3), 395–408. 73

Embrechts, P., R. Frey, and A. McNeil (2005). Quantitative risk management: Concept, techniques and tools. *Princeton Series in Finance, Princeton 10*. 75

Epley, N. and T. Gilovich (2006). The anchoring-and-adjustment heuristic why the adjustments are insufficient. *Psychological science 17*(4), 311–318. 57

Eppler, M. J. and M. Aeschimann (2009). A systematic framework for risk visualization in risk management and communication. *Risk Management 11*(2), 67–89. 239

Erb, H. P., A. Bioy, and D. J. Hilton (2002). Choice preferences without inferences: Subconscious priming of risk attitudes. *Journal of Behavioral Decision Making 15*, 251–262. 70

Eshlagy, A. T. and M. Homayanfar (2011). Multi criteria decision making methodologies and applications: A literature review from 1999 to 2009. *Research Journal of International Studies 21*, 86–137. 11

Finch, H. and J. Lewis (2003). Focus group. In J. Ritche and J. Lewis (Eds.), *Qualitative Research Practice: A Guide For Social Science Students And Researchers*, Chapter 7. SAGE Publication, London. 191

Finkelstein, S., J. Whitehead, and A. Campbell (2009). Think again: Why good leaders make bad decisions. *Business Strategy Review*, 62–66. 5, 242

Flage, R., T. Aven, E. Zio, and P. Baraldi (2014). Concerns, challenges, and directions of development for the issue of representing uncertainty in risk assessment. *Risk Analysis 34*(7), 1196–1207. 50

Florig, K., G. Morgan, K. M. Morgan, K. E. Jenni, B. Fischhoff, P. S. Fischbeck, and M. L. DeKay (2002). A deliberative method for ranking risks (i): Overview and test bed development. *Risk Analysis 21*(5), 913–913. 50

Forman, E. and M. Selley (2002). *Decision By Objectives: How To Convince Others That You Are Right*. World Scientific Publishing Co. Pte. Ltd. Singapore. 99, 211

Forman, E. H. and S. I. Gass (2001). The Analytic Hierarchy Process: An Exposition. *Operations Research*, 469–486. 99, 127, 128

Fox, C. R. (1999). Strength of evidence, judged probability, and choice under uncertainty. *Cognitive Psychology 38*, 167–189. 62

Fraser, J. and B. J. Simkins (2010). *Enterprise Risk Management: Today's Leading Research & Best Practices For Tomorrow's Executives*. John Wiley & Sons, Hoboken New Jersey. 77

Fraser, J. R., K. Schoening-Thiessen, and B. J. Simkins (2008). Who reads what most often? A survey of enterprise risk management literature read by risk executives. *Journal of Applied Finance Spring/Summer 2008*, 73–91. 223

Gates, S., J. Nicolas, and P. Walker (2009). Perceived value of enterprise risk management. *University of Virginia Working Paper*. 8

Gawande, A. (2009). *The Checklist Manifesto: How to Get Things Right.* Metropolitan Books, New York. 241

Gigerenzer, G. (2014). *Risk Savvy: How To Make Good Decisons.* Penguin Book, London England. 3, 24, 54, 240, 241

Goepel, K. D. (2013). Implementing the analytic hierarchy process as a standard method for multi-criteria decision making in corporate enterprises a new AHP excel template with multiple inputs. In *Proceedings of the 12th International Symposium on the Analytic Hierarchy Process, Kuala Lumpur 23-26 June 2013.* 211, 215

Gordon, L. A., M. P. Loeb, and C. Y. Tseng (2009). Enterprise risk management and firm performance: A contingency perspective. *Journal of Accounting and Public Policy 28*(4), 301–327. 8

Grunig, R. and R. Kuhn (2005). *Sucessful Decision Making: A Systematic Approach to Complex Problems.* Springer - Verlag, Berlin Heidelberg. 2, 4, 27, 242, 255

Hafeez, K., Y. B. Zhang, and N. Malak (2002). Determining key capabilitiesof a firm using analytic hierarchy process. *International Journal of Production Economics* (76), 39–51. 126

Hahn, D., R. Shangraw, M. Keith, and D. Coursey (2007). Does visualization affect perceptions of ethically complex policy decisions: An experimental study. *Proceedings of the 40th Hawaii International Conference on System Sciences*. 239

Haimes, Y. Y., S. Kaplan, and J. H. Lambert (2002). Risk filtering, ranking and management framework using hieararchical holographic modeling. *Risk Analysis 22*, 383–397. 239

Hammond, J. S., R. L. Keeney, and H. Raiffa (1998). Even swaps: A rational method for making trade-offs. *Harvard Business Review 76*, 137–150. 20

Hampton, J. J. (2009). Visual risk cluster. In *Fundamental of Enterprise Risk Management: How Top Companies Assess Risk, Manage Exposure and Seize Opportunities.* American Academy of Management (AMACOM), New York. 48, 49, 239

Hargreaves, J. (2010). Quantitative risk assessment in ERM. In *Enterprise Risk Management: Today's Leading Research and Best Practices for Tomorrow's Executives*. John Wiley & Sons, Hoboken New Jersey. 74, 158

Harrington, S., G. Niehaus, and K. Risko (2002). Enterprise risk management: The case of united grain growers. *Journal of Applied Corporate Finance 14*(4), 71–81. 8

Hillson, D. (2002). Use of risk breakdown structure (RBS) to understand your risks. In *The Project Management Institute (PMI) Annual Seminars and Symposium, 3-10 October.*, San Antonio,Texas. 239

Hillson, D. (2007). Understanding risk exposure using multiple hierarchies. In *Project Management Institute (PMI) Global Congress EMEA Proceedings - Budapest*. 239

Hillson, D. and R. M. Webster (2005). *Understanding and Managing Risk Attitude*. Gower Publishing Limited, England. 34, 56, 57

Ho, W. (2008). Integrated Analytic Hierarchy Process and its application - a literature review. *European Journal of Operational Research 186*, 211–228. 126

Hopkin, P. (2010). *Fundamentals of Risk Management: Understanding, Evaluating and implementing Effective Risk Management*. The Institute of Risk Management. Kogan Page Publisher, London. 44

Hoyt, R. E. and A. P. Liebenberg (2003). The determinants of enterprise risk management: Evidence from the appointment of chief risk officers. *Risk Management and Insurance Review 6*(1), 37–52. 7

Hoyt, R. E. and A. P. Liebenberg (2011). The value of enterprise risk management. *Journal of Risk and Insurance 78*(4), 795–822. 7

Hsee, C. K. (1996). The evaluability hypothesis: An explanation for preference reversals between joint and separate evaluations of alternatives. *Organizational Behavior and Human Decision Processes 67*(3), 247–257. 63, 64, 65

Hsee, C. K. (2000). Attribute evaluability and its implications for joint-separate evaluation reversals and beyond. *Choices, Values And Frames, D. Kahneman & A. Tversky, Eds., Cambridge University Press, 2000. Available At SSRN: http://ssrn.com/abstract=936581*. 63

Hsee, C. K., G. F. Loewenstein, S. Blount, and M. H. Bazerman (1999). Preference reversals between joint and separate evaluations of options: A review and theoretical analysis. *Psychological Bulletin 125*(5), 576. 63

Hubbard, D. W. (2007). *How to Measure Anything: Finding the Value of Intangibles in Business*. John Wiley & Son, Inc., Hoboken New Jersey. 25

Hubbard, D. W. (2009). *The Failure of Risk Management: Why It's Broken and How To Fix It*. John Wiley & Sons, Inc., Hoboken, New Jersey. 34

IAA (2009). Note on enterprise risk management for capital and solvency purposes in the insurance industry. Technical report, Technical Report - International Actuarial Association, Ontario Canada. 170

IRM (2002). A risk management standard. Technical report, The Institute of Risk Management (IRM), The Association of Insurance and Risk Managers (AIRMIC) and The National Forum for Risk Management in the Public Sector (ALARM). 46

Ishizaka, A. and A. Labib (2011). Review of the main developments in the Analytic Hierarchy Process. *Expert Systems with Applications 38*(11), 14336–14345. 11

Islam, R. (2009). Prioritizing issues of Malaysian Vision 2020: An application of the Analytic Hierarchy Process. *Proceedings of the 10th International Symposium on the Analytic Hierarchy Process, 29 July - 1st August 2009, Pittsburgh Pennsylvania.*, 1–16. 192

Iyer, S. R., D. A. Rogers, and B. J. Simkins (2010). Academic research on enterprise risk management. In *Enterprise Risk Management: Today's Leading Research and Best Practices for Tomorrow Executives*, Chapter 23, pp. 419–443. John Wiley & Sons, New Jersey. 8

Jong, P. D. (1984). A statistical approach to Saaty's scaling method for priorities. *Journal of Mathematical Psychology 28(4)*, 467–477. 149

Kahneman, D. (2011). *Thinking, Fast and Slow.* Penguin Book, London England. 5, 24, 32, 54, 55, 58, 61, 62, 65, 66, 67, 243, 245, 246, 247, 250

Kahneman, D. and A. Tversky (1972). Subjective probability: A judgment of representativeness. *Cognitive psychology 3*(3), 430–454. 55

Kahneman, D. and A. Tversky (1979). Prospect theory: An analysis of decision under risk. *Econometrica: Journal of the Econometric Society*, 263–291. 9, 60, 84

Kleffner, A., R. B. Lee, and B. MacGanon (2003). Stronger corporate governance and its implication on risk management. *Ivey Business Journal 67*(5). 7

Knight, F. H. (1921). *Risk, Uncertainty and Profit.* Houghton Mifflin, New York. 236

Koller, G. (2000). *Risk Modelling for Determining Value and Decision Making*, Chapter Chapter 3 Gathering Information Consistently in an Inconsistent World. Chapman & Hall/CRC. 246

Koller, M. (2011). *Life Insurance Risk Management Essentials.* Springer-Verlag Berlin Heidelberg. 170

Lai, V. S., B. K. Wong, and W. Cheung (2002). Group decision making in a multiple criteria environment: A case using the ahp in software selection. *European Journal of Operational Research 137*, 134–144. 127

Leung, L. C., K. Lam, and D. Cao (2005). Implementing the Balanced Scorecard using the Analytic Hierarchy Process & the Analytic Network Process. *Journal of the Operational Research Society 57*(6), 682–691. 126

Lootsma, F. A. (1999). *Multi-Criteria Decision Analysis via Ratio and Difference Judgement.* Kluwer Academic Publisher, Dordrecht. 86

Max H. Bazerman, G. F. L. and S. B. White (1992). Reversals of preference in allocation decisions: Judging an alternative versus choosing among alternatives. *Administrative Science Quarterly 37(2)*, 220–240. 60

M.Dillon, S. (1998). Descriptive decision making: Comparing theory with practice. *Proceedings of the 33rd Annual Conference of the New Zealand Operational Research Society, August 31 - September 1, Waikato University, Hamilton.*, 99–108. 84

Merkhofer, M. W. (1986). Comparative analysis of formal decision-making approaches. In *Risk Evaluation and Management*, Chapter 7, pp. 183–219. Plenum Press, New York. 83

Merna, T. and F. F. Al-Thani (2005). *Corporate Risk Management: An Organizational Perspective*. John Wiley & Sons, Ltd, West Sussex England. 76, 236, 237

Millet, I. and T. L. Saaty (2000). On the relativity of relative measures-accomodation both rank preservation and rank reversals in the AHP. *European Journal of Operational Research* (121), 205–212. 128

Mitroff, I. I. and T. R. Featheringham (1974). On systemic problem solving and the error of the third kind. *Behavioral Science 19*(6), 383–393. 234, 235

Mitroff, I. I. and F. Sagasti (1973). Epistemology as general systems theory: An approach to the design of complex decision-making experiments. *Philosophy of the Social Sciences 3*(1), 117–134. 234

Moeller, R. R. (2007). *COSO Enterprise Risk Management: Understanding the New Integrated ERM Framework*. New Jersey: John Wiley & Sons. 40, 71, 72, 73, 74

Monahan, G. (2008). *Enterprise Risk Management: A Methodology for Achieving Strategic Objectives*. John Wiley & Sons, Inc., Hoboken, New Jersey. 75

Morewedge, C. K. and D. Kahneman (2010). Associative processes in intuitive judgment. *Trends In Cognitive Sciences 14*(10), 435–440. 69

Morgan, M. G., H. K. Florig, M. L. DeKay, and P. Fischbeck (2002). Categorizing risks for risk ranking. *Risk Analysis 20*(1), 49–58. 218

Neth, H., B. Meder, A. Kothiyal, and G. Gigerenzer (2014). Homo heuristicus in the financial world: From risk management to managing uncertainty. *Journal of Risk Management in Financial Institutions 7*(2), 134–144. 241

Nichols, L. H. (2012). Intergenerational risks. Chapter 37, pp. 932–957. Springer Science+Business Media. 79, 80

Nieto, B. G., C. S. Cinca, and J. C. Cala (2011). A credit score system for socially responsible lending. *Centre Emile Bernheim (CEB) Working Paper. Universit Libre de Bruxelles - Solvay Brussels School of Economics and Management 28*(11), 1–21. 126

Nocco, B. W. and R. M. Stulz (2006). Enterprise risk management: Theory and practice. *Journal of Applied Corporate Finance 18*(4), 8–20. 8

North, D. W. (1968). A tutorial introduction to decision theory. *IEEE Transactions on Systems Science and Cybernetics 4*(3), 200–210. 83

Olson, D. L. and D. Wu (2010). *Enterprise Risk Management Models*. Springer-Verlag Berlin Heidelberg. 239

Paape, L. and R. F. Speklé (2012). The adoption and design of enterprise risk management practices: An empirical study. *European Accounting Review 21*(3), 533–564. 7

Pagach, D. and R. Warr (2008a). The characteristics of firms that hire chief risk officers. *North Carolina University Working Paper*. 7

Pagach, D. and R. Warr (2008b). The effects of enterprise risk management on firm performance. *North Carolina University Working Paper*. 8

Pagach, D. and R. Warr (2011). The characteristics of firms that hire Chief Risk Officers. *The Journal of Risk and Insurance 78*(1), 185–211. 7

Panning, W. H. (2006). Managing the invisible: Measuring risk, managing capital and maximizing value. In *Enterprise Risk Management Symposium, April 23-25 2006, Chicago IL,*. 8

Pat-Cornell, M. E. and R. L. Dillon (2006). The respective roles of risk and decision analyses in decision support. *Decision Analysis 3*(4), 220–232. 237

Patton, M. (1986). *Utilization-Focused Evaluation*. Sage, Newbury Park CA. 185, 186

Patton, M. (1997). *Utlization-Focused Evaluation: The New Century Text*. Thousand Oaks, CA. Sage. 185, 186, 187

Patton, M. Q. (2002). *Qualitative Research and Evaluation Method*. Sage Publications, Thousand Oaks, CA. 186

Protiviti (2006). Guide to enterprise risk management: Frequently asked questions. Technical report, Protiviti Independent Risk Consulting. 75

Ramrez, R. and D. Brodhead (2013). *Utilization Focused Evaluation: A Primer for Evaluators*. South Bound, Penang Malaysia. 186

Rebonato, R. (2007). *Plight of the Fortune Teller: Why We Need to Manage Financial Risk Differently*. Princeton University Press, Princeton New Jersey. 9, 27, 47, 241

Riddick, C. C. and R. V. Russell (1999). *Evaluative Research in Recreation, Park, and Sport Settings: Searching for Useful Information*. Sagamore Publishing Inc., USA. 185

Roam, D. (2008). *The Back of the Napkin: Solving Problems and Selling Ideas with Pictures*. Penguin Book, London England. 239

Rudolph, M. J. (2014). The best model doesn't win. In *Investment Fallacy*. Society of Actuaries, Schaumburg, Illinois. 3

Saaty, T. L. (1977). A scaling method for priorities in hierarchical structure. *Journal of Mathematical Psychology 15*, 234–281. 19, 81, 92, 97, 99, 134, 211

Saaty, T. L. (1987a). The Analytic Hierarchy Process: What it is and how it is used. *Mathematical Modelling 9*(3-5), 161–176. 92

Saaty, T. L. (1987b). Risk-its priority and probability: The Analytic Hierarchy Process. *Risk Analysis 7(2)*, 159–171. 25, 236

Saaty, T. L. (1990). How to make a decision: The Analytic Hierarchy Process. *European Journal of Operational Research 48(1)*(48), 9–26. 144, 234

Saaty, T. L. (1994). *Fundamentals of Decision Making and Priority Theory with The Analytic Hierarchy Process.* RWS Publications, Pittsburgh PA. 128, 243

Saaty, T. L. (1999). *Decision Making For Leaders: The Analytic Hieararchy Process For Decisions In A Complex World.* RWS Publication, Pittsburgh, PA USA. 92, 106, 116, 117, 124, 150, 220

Saaty, T. L. (2000). *Fundamentals of Decision Making and Priority Theory with the Anaytic Hierarchy Process (Analytic Hierachy Process Series Vol.6).* RWS Publications, Pittsburgh PA. 246

Saaty, T. L. (2001). *Creative Thinking, Problem Solving and Decision Making.* RWS Publication, Pittsburgh, PA USA. 115, 149

Saaty, T. L. (2008a). Decision making with the Analytical Hierarchy Process. *International Journal Services Sciences 1*(1), 83–98. 127

Saaty, T. L. (2008b). Relative measurement and its generalization in decision making: Why pairwise comparisons are central in mathematics for the measurement of intangible factors in the Analytic Hierarchy/Network process. *Revista de la Real Academia de Ciencias Exactas, Fisicas y Naturales. Serie A. Matematicas 102*(2), 251–318. 87

Saaty, T. L. (2009). An essay on how judgment and measurement are different in science and in decision making. *International Journal on Analytic Hierarchy Process 1*(1), 61–62. 245

Saaty, T. L. (2010a). Economic forecasting with tangible and intagible criteria: The analytic hierarchy process of measurement and its validation. *Economic Horizons 12*(1), 5–45. 82, 102

Saaty, T. L. (2010b). *Mathematical Principles of Decision Making: Generalization of the Analytic Network Process to Neural Firing and Synthesis.* RWS Publications, Pittsburgh PA USA. 4, 95, 109, 125, 128, 249, 259

Saaty, T. L. (2013). The modern science of multicriteria decision making and its practical applications: The AHP/ANP approach. *Operations Research 61*(5), 1101–1118. 92

Saaty, T. L., J. W. France, and K. R. Valentine (1991). Modeling the graduate business school admissions process. *Socio-Economic Planning Sciences 25*(2), 155–162. 104

Saaty, T. L. and M. Ozdemir (2003). Why the magic number seven plus or minus two. *Mathematical and Computer Modelling 38*(3), 233–244. 127, 211

Saaty, T. L. and L. G. Vargas (1982). *The Logic Of Priorities: Applications In Business, Energy, Health, And Transportation.* Kluwer-Nijhoff Boston. 97, 144, 151, 211

Saaty, T. L. and L. G. Vargas (2012a). The benefits and costs of authorizing riverboat gambling. In *Models, Methods, Concepts & Applications of the Analytic Hierarchy Process*, Chapter 20, pp. 291–301. Springer Science+Business Media New York. 111

Saaty, T. L. and L. G. Vargas (2012b). *Models, Methods, Concepts and Applications of the Analytic Hierarchy Process.* International Series in Operations Research & Management Science, Springer Science+Business Media New York. 123

Saaty, T. L. and H. J. Zoffer (2013). Principles for implementing a potential solution to the Middle East Conflict. *Notices of the American Mathematical Society 60*(10), 1300–1322. 121, 123

Sandstrom, A. (2006). *Solvency: Models, Assessment and Regulation.* Chapman & Hall/CRC, Taylor and Francis Group, Boca Raton FL. 170

Saunders, M. (2012). The use and usability of evaluation outputs: A social practice approach. *Evaluation 18*(4), 421–436. 187

Scriven, M. (1967). *Perspectives of curriculum evaluation*, Volume 1, Chapter The Methodology of Evalution, pp. 39–83. Rand McNally Chicago. 185

Shenkir, W. G. and P. L. Walker (2007). Enterprise risk management: Tools and techniques for effective implementation. *Statement of Management Accountant, Institute of Management Accountant, Montvale NJ.*, 1–31. 42, 71, 73, 217

Shortreed, J. (2010). ERM frameworks. In J. Fraser and B. J. Simkin (Eds.), *Enterprise Risk Management: Today's Leading Research and Best Practices for Tomorrow's Executives*, Chapter 7, pp. 97–123. John Wiley & Sons, Hoboken New Jersey. 44, 46, 51

Sipahi, S. and M. Timor (2010). The Analytic Hierarchy Process and Analytic Network Process: An overview of applications. *Management Decision 48*(5), 775–808. 11

Slovic, P. and E. Peters (2006). Risk perception and affect. *Current Directions in Psychological Science 15*(6), 322–325. 249

Spronk, J., R. E. Steuer, and C. Zopounidis (2005). Multicriteria Decision Aid/Analysis in Finance. In *Multiple Criteria Decision Analysis: State Of The Art Surveys*, Chapter 20, pp. 799–849. Kluwer Academic Publishers, Boston/Dordrecht/London. 125

Stanovich, K. E. and R. F. West (2000). Individual differences in reasoning: Implications for the rationality debate? *Behavioral And Brain Sciences 23*, 645–726. 66

Stroh, P. (2005, July). Enterprise risk management at united healthcare. *Strategic Finance*, 27–35. 8

Stuer, R. E. and P. Na (2003). Multiple Criteria Decision Making combined with Finance: A categorized bibliographic study. *European Journal of Operational Research 150*, 496–515. 11, 125

Stufflebeam, D. L. and A. J. Shinkle (1985). *Systematic Evaluation: A Self-Instructional Guide to Theory and Practice*. Dordrecht: Kluewer, Nijhoff. 185

Suchman, E. A. (1967). *Evaluative Research: Principles And Practice In Public Service and Social Action Programs*. Russel Sage Foundation, New York. 185

Sunstein, C. R. and R. Hastie (2015). *Wiser: Getting Beyond Group Think To Make Groups Smarter*. Harvar Business Review Press, Boston, Massachusetts. 31, 32, 237

Sweeting, P. (2011). *Financial Enterprise Risk Management (International Series on Actuarial Science)*. Cambridge University Press, New York. 145

Tarbell, D. S. and T. L. Saaty (1980). The conflict in South Africa: directed or chaotic. *Conflict Management and Peace Science 4*(2), 151–168. 118

Thaler, R. H. and C. R. Sunstein (2008). *Nudge: Improving Decisions About Health, Wealth, And Happiness*. Yale University Press, New Haven & London. 57, 60

Tierney, J. (2011). Do you suffer from decision fatigue? *The New York Times*. 21

Tonello, M. (2007). Emerging governance practices in enterprise risk management. Technical report, The Conference Board Governance Center. 43

Triantaphyllou, E. (2000). *Multi-Criteria Decision Making Methods: A Comparative Study*. Springer, New York, NY USA. 86, 150

Tversky, A. and D. Kahneman (1973). Availability: A heuristic for judging frequency and probability. *Cognitive psychology 5*(2), 207–232. 56

Tversky, A. and D. Kahneman (1974). Judgment under uncertainty: Heuristics and biases. *SCIENCE 185*(4157), 1124–1131. 24, 57

Tversky, A. and D. Kahneman (1981). The framing of decisions and the psychology of choice. *SCIENCE 211*, 30. 60, 61, 62

Tzeng, G.-H. and J.-J. Huang (2011). *Multi Attribute Decision Making: Methods and Applications*. CRC-Press, Taylor & Francis Group, Boca Raton FL. 84, 87

Vadiveloo, J. (2012). Micro risk management: Identifying small-business risk. In *Contigencies*, pp. 30–33. American Academy of Actuaries. 25

Vaiday, O. S. and S. Kumar (2006). Analytic Hierarchy Process: An overview of applications. *European Journal of Operational Research 169*, 1–29. 12

Verbano, C. and K. Venturini (2011). Development paths of risk management: Approaches, methods and fields of application. *Journal of Risk Research 14*(5), 519–550. 12

Viswanadhan, K. (2005). How to get responses for multi-criteria decisions in engineering education–an AHP based approach for selection of measuring instrument. *Financial Support*, 20. 212

Wang, J., N. Novemskyand, R. Dhar, and R. F. Baumeister (2010). Trade-offs and depletion in choice. *Journal of Marketing Research 47*(5), 910–919. 21

Weiss, C. H. (1997). How can theory-based evaluation make greater headway? *Evaluation Review 21*(4), 501–524. 185

Wittenberg, A. and G. Tett (2009). Emerging risks: Strategic decision-making in the face of uncertainty. Technical report, Financial Times and Oliver Wyman. 42

Wu, G., J. Zhang, and R. Gonzalez (2004). *Decision Under Risks*, Chapter 20, pp. 399–423. Blackwell Publishing, MA USA. 236

Yamagishi, K. (1997). When a 12.86% mortality is more dangerous than 24.14% : Implications for risk communication. *Applied Cognitive Psychology 11*, 496–506. 24, 66

Yoe, C. (2012). *Primer on Risk Analysis: Decison Making Under Uncertainty.* CRC-Press Taylor & Francis Group, Boca Raton, FL. 47, 49, 236

Yow, S. and M. Sherris (2007). Enterprise risk management, insurer pricing and capital allocation. *UNSW Actuarial Studies working paper and paper presented to* *the Bowles Symposium and Enterprise Risk Management Symposium, March 28-30 2007, Chicago IL.* 8

Zeleny, M. and J. L. Cochrane (1982). *Multiple Criteria Decision Making*, Volume 25. McGraw-Hill New York. 87

Zopounidis, C. (1999). Multicriteria decision aid in financial management. *European Journal of Operational Researc h* (119), 404–415. 10

Zopounidis, C. and M. Doumpos (2002). Multi-criteria decision aid in financial decision making: Methodologies and literature review. *Journal of Multi-Criteria Decision Analysis 11*(4-5), 167–186. 10