นวัตกรรมของตัวแบบการประเมินความเสี่ยงสำหรับโครงการพัฒนาผลิตภัณฑ์อาหารใหม่

นายดั้นดุสิต โปราณานนท์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
สาขาวิชาธุรกิจเทคโนโลยีและการจัดการนวัตกรรม (สหสาขาวิชา)
บัณฑิตวิทยาลัย จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2557

INNOVATION OF RISK ASSESSMENT MODEL FOR NEW FOOD PRODUCT DEVELOPMENT PROJECT

Mr. Dundusid Porananond

A Dissertation Submitted in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy Program in Technopreneurship and Innovation Management
(Interdisciplinary Program)
Graduate School
Chulalongkorn University
Academic Year 2014

Thesis Title	INNOVATION OF RISK ASSESSMENT MODEL FOR NEW FOOD PRODUCT DEVELOPMENT PROJECT
By	Mr. Dundusid Porananond
Field of Study	Technopreneurship and Innovation Management
Thesis Advisor	Associate Professor Natcha Thawesaengskulthai, Ph.D.
Thesis Co-Advisor	Associate Professor Thitivadee Chaiyawat, Ph.D.

Accepted by the Graduate School, Chulalongkorn University in Partial Fulfillment of the Requirements for the Doctoral Degree

.....Dean of the Graduate School
(Associate Professor Sunait Chutintaranond, Ph.D.)

THESIS COMMITTEE

.....Chairman
(Assistant Professor Pongpun Anuntavoranich, Ph.D.)
.....Thesis Advisor
(Associate Professor Natcha Thawesaengskulthai, Ph.D.)
.....Thesis Co-Advisor
(Associate Professor Thitivadee Chaiyawat, Ph.D.)
.....Examiner
(Associate Professor Suthas Ratanakuakangwan)
.....Examiner
(Assistant Professor Rath Pichyangkura, Ph.D.)
.....Examiner
(Assistant Professor Tippakorn Rungkasiri, Ph.D.)
.....External Examiner
(Assistant Professor Pasit Lorterapong, Ph.D.)

ดั้นดุสิต โปราณานนท์ : นวัตกรรมของตัวแบบการประเมินความเสี่ยงสำหรับโครงการพัฒนาผลิตภัณฑ์อาหารใหม่ (INNOVATION OF RISK ASSESSMENT MODEL FOR NEW FOOD PRODUCT DEVELOPMENT PROJECT) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. ดร. ณัฐชา ทวีแสงสกุลไทย, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: รศ. ดร. ฐิติวดี ชัยวัฒน์, 179 หน้า.

การพัฒนาผลิตภัณฑ์ใหม่ได้รับการยอมรับโดยทั่วไปว่ามีส่วนสำคัญในการสร้างความสามารถในการแข่งขันขององค์กรธุรกิจ และนำประโยชน์มาสู่องค์กร แต่ในขณะเดียวกัน กระบวนการพัฒนาผลิตภัณฑ์ใหม่ ก็เป็นกิจกรรมที่นำความเสี่ยงมาสู่องค์กร เช่นการตัดสินใจลงทุนในโครงการที่ล้มเหลว หรือความผิดพลาดจากใช้ทีมงานที่ขาดประสบการณ์ จุดมุ่งหมายของวิทยานิพนธ์ฉบับนี้คือการพัฒนารูปแบบในการประเมินความเสี่ยงของโครงการพัฒนาผลิตภัณฑ์ใหม่ในองค์กรธุรกิจ โดยเริ่มต้นการวิจัยด้วยการทบทวนวรรณกรรมทางวิชาการจากแหล่งความรู้สามแหล่ง คือบทความทางการศึกษาที่ตีพิมพ์ระหว่างปี พ.ศ. 2545 ถึงปี พ.ศ. 2555 องค์ความรู้เกี่ยวกับการบริหารโครงการจากเอกสารวิชาการที่ตีพิมพ์โดยหน่วยงานส่งเสริมความรู้ในด้านการบริหารโครงการ รวมถึงมาตรฐานระหว่างประเทศที่เกี่ยวเนื่องกับการบริหารความเสี่ยงในโครงการ เพื่อพัฒนาเป็นกรอบแนวความคิดพื้นฐานในการบริหารความเสี่ยง โดยตัวแบบในการประเมินความเสี่ยงประกอบด้วยกระบวนการในการค้นหาความเสี่ยง และการวิเคราะห์ความเสี่ยงเพื่อจัดลำดับความสำคัญของปัจจัยเสี่ยง การศึกษาปัจจัยความเสี่ยงของโครงการและการพัฒนาตัวแบบของการประเมินความเสี่ยงใช้การเก็บข้อมูลด้วยแบบสอบถามและการสัมภาษณ์ผู้เชี่ยวชาญจากกระบวนการพัฒนาผลิตภัณฑ์ใหม่ในอุตสาหกรรมอาหาร โดยการศึกษาได้พบปัจจัยเสี่ยงทั้งหมด 39 ปัจจัยเสี่ยง และนำไปพัฒนาเป็นโครงสร้างแจกแจงความเสี่ยงซึ่งประกอบด้วยกลุ่มปัจจัยเสี่ยง 20 กลุ่ม จากนั้นตัวแบบของการประเมินความเสี่ยงได้ถูกตรวจสอบเพื่อยืนยันความถูกต้องโดยใช้กรณีศึกษาโครงการพัฒนาผลิตภัณฑ์ใหม่ในอุตสาหกรรมอาหารในประเทศไทยจำนวน 4 โครงการ โดยความเสี่ยงสำคัญที่ได้จากกรณีศึกษาได้แก่ ปัญหาคุณภาพของวัตถุดิบ ปัญหาการกีดกันทางการค้าในกรณีส่งออก การไม่เข้าใจความต้องการของผู้บริโภค ราคาวัตถุดิบที่มีการเปลี่ยนแปลงในแต่ละฤดูกาล ปัญหาการสื่อสารระหว่างทีมพัฒนาผลิตภัณฑ์กับฝ่ายผลิต ปัญหาความรู้ของทีมงานในการบริหารโครงการ ปัญหาทรัพยากรบุคคลไม่เพียงพอ และปัญหาเรื่องการปรับสูตรของผลิตภัณฑ์เมื่อนำไปผลิตเป็นอุตสาหกรรม

หลังจากนั้นตัวแบบของการประเมินความเสี่ยงที่ได้ถูกนำไปพัฒนาต่อเป็นเครื่องมือต้นแบบในการประเมินความเสี่ยงของโครงการ ซึ่งประกอบด้วยเครื่องมือในการค้นหาความเสี่ยงของโครงการโดยใช้โครงสร้างการแจกแจงความเสี่ยง และการวิเคราะห์ความเสี่ยงโดยใช้การอนุมานแบบฟัซซีลอจิก รวมถึงมีการศึกษาและเสนอแนวทางทั่วไปในการตอบสนองหรือรับมือกับความเสี่ยง โดยเครื่องมือบริหารความเสี่ยงโครงการที่พัฒนาขึ้นมานี้สามารถนำไปพัฒนาต่อยอด และนำไปใช้ประโยชน์ในทางธุรกิจได้ตามแนวทางที่เสนอในแผนธุรกิจ เพื่อใช้ในการกำหนดแนวทาง และวิธีการดำเนินงานอย่างเป็นระบบตามขั้นตอนในการบริหารความเสี่ยงของโครงการพัฒนาผลิตภัณฑ์ในอุตสาหกรรมอาหาร โดยการทดสอบการยอมรับต้นแบบของเครื่องมือจากงานวิจัยพบว่าผู้ใช้ในโครงการพัฒนาผลิตภัณฑ์ใหม่ให้การยอมรับในอัตราร้อยละ 90.5

สาขาวิชา ธุรกิจเทคโนโลยีและการจัดการนวัตกรรม ลายมือชื่อนิสิต .....

ปีการศึกษา 2557 ลายมือชื่อ อ.ที่ปรึกษาหลัก .....

ลายมือชื่อ อ.ที่ปรึกษาร่วม .....

5387772920 : MAJOR TECHNOPRENEURSHIP AND INNOVATION MANAGEMENT
KEYWORDS: PROJECT RISK / RISK ASSESSMENT / PROJECT MANAGEMENT / NEW PRODUCT DEVELOPMENT / FOOD INDUSTRY

DUNDUSID PORANANOND: INNOVATION OF RISK ASSESSMENT MODEL FOR NEW FOOD PRODUCT DEVELOPMENT PROJECT. ADVISOR: ASSOC. PROF. NATCHA THAWESAENGSKULTHAI, Ph.D., CO-ADVISOR: ASSOC. PROF. THITIVADEE CHAIYAWAT, Ph.D., 179 pp.

New product development (NPD) is widely recognized as an important source of being a competitive advantage. It can bring considerable returns to an organization but can also be considered a risky process, such as making wrong decisions in the project selection or suffer consequences from using inexperienced project teams. This study aims to develop a risk management model to help NPD teams in managing risks with their projects. The conceptual framework is developed from three sources of publications; systematic literature review of academic research during year 2002-2012, the project management body of knowledge from a professional association and the international standards related to risk management. The model consists of risk identification and the risk analysis process to use for the prioritization of risk factors. Thirty-nine risk factors were identified during the study and the risk breakdown structure (RBS) for food NPD with twenty risk categories have been developed and used for risk identification. The model has been validated by four case studies of NPD projects in the food industry of Thailand. The major risks found in these case studies were the quality of raw materials, trade barriers for export, understanding of customer requirements, inconsistency of raw material costs, communication problems between R&D and the manufacturing team, NPD team knowledge in project management, human resource constraints and product formulation for scale-up.

Refined risk assessment models have been used to develop risk assessment tool, consisting of risk identification by RBS and a risk checklist, and risk analysis by fuzzy inference systems. Some suggestions for risk response strategies have been studied and discussed in this research. This integrated tool can be further developed and commercialized as suggested in a business plan to use by NPD teams as a roadmap and process work-flow for risk management of a NPD project in the food industry. The user acceptance test for prototype of a risk assessment tool from research showed results of a 90.5% acceptance rate by users in the NPD team.

Field of Study:	Technopreneurship and Innovation Management	Student's Signature	.....
		Advisor's Signature	.....
Academic Year:	2014	Co-Advisor's Signature	.....

ACKNOWLEDGEMENTS

My completion of this dissertation could not have been accomplished without the support of my advisor. I would like to express my greatest gratitude to Dr. Natcha Thawesaengskulthai who helped & supported me throughout my research.

I wish to express my appreciation to co-advisor, Dr. Thitivadee Chaiyawat for her valuable constructive feedback and suggestions to improve this dissertation.

I cannot express enough thanks to my committee for their continued support and encouragement. Dr. Pongpun Anuntavoranich, my committee chair; Assoc.Prof. Suthas Ratanakuakangwan; Dr. Rath Pichyangkura; Dr. Tippakorn Rungkasiri and Dr. Pasit Lorterapong. I offer my sincere appreciation for the learning opportunities provided by them.

I would like to acknowledge all those in the food industry who co-operated with the conduct of the survey, interview and case study. In order to preserve anonymity, they cannot be named. Without their help, this study could not have been carried out.

Finally, to my caring, loving and supportive family; my deepest gratitude. Your encouragement when times got rough are much appreciated and duly noted. My heartfelt thanks to all of you.

CONTENTS

Page

Page

Page

Page

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AHP	Analytic hierarchy process
AS/NZS	Australia/New Zealand Standards
BN	Bayesian network
FIS	Fuzzy inference system
FMEA	Failure mode and effect analysis
ISO	The international organization for standardization
NPD	New product development
PMBOK	Project management body of knowledge
PMI	Project management institute
RBS	Risk breakdown structure
RM	Risk management
TOC	Theory of constraints

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

New product development (NPD) is widely recognized in the business world as an important factor to leverage competitive advantages for organization. A well-defined NPD project strategy may improve NPD project outcomes and enhance market performances (Yang 2012). Industries continue to have the need for a better new product management process (Cooper 1990). Researchers and managers in industry aim to improve NPD and find better systems that simultaneously provide quality, variety of products, speed of response and customization capability to serve customer requirements (Cooper and Kleinschmidt 1993, Cooper 1994).

New product development, especially for projects that involve high technology and break-through product development concepts, seem to perceive higher risks, even if it brings considerable returns to an organization and NPD teams (Keizer and Halman 2007). Moreover, worldwide competition, diverse and rapidly changing technologies, including demanding customer expectations, have made the development process of product innovation more complex and increasing uncertain of possible outcomes (Keizer, Vos, and Halman 2005). Empirical research indicates that the success rate of new product development projects are very low compared to other types of projects (Griffin 1997). The study by Stevens and Burley (2003) indicated that only 60% of NPD projects are success and can be passed from the fuzzy front end stage to commercialization, even a systematic NPD process like the Stage-Gate system are employed. Therefore, identifying and managing risks in product innovation have become increasingly important issues.

By the literature review on research streams on the NPD process in the last few decades, many studies have been focused on determinants of new product success and failure (Keizer, Vos, and Halman 2005). This stream of research about new product success and failure identified various groups of important factors related to managerial issues in NPD such as factors related to product performance,

factors related to market and marketing issues, factors related to an organization& synergy and factors related to project management.

As one important success factor; industry requires more research on NPD which focuses on project management and risk management which seems to be more complex and have different issues, compared to other types of projects. Some researchers try to study the differences in each type of project (Pinto and Covin 1989). Several studies also try to point out the unique characteristics and particular requirements of project management in NPD process (Karagozoglu and Brown 1993, Milosevic and Patanakul 2005, Thal Jr, Badiru, and Sawhney 2007, Pons 2008).

Some characteristics of the NPD project which are related to project management issues, can be illustrated as following.

- Conventional project management requires a complete initial definition of the project scope and outcomes which can be the problem in the case of the NPD project.
- NPD projects usually involve the creation, evaluation, and/or refinement of ideas, product or service while project management in other types of projects are more focused on planning with certain activities with a clear process step.
- Project management in NPD projects are less routine, more innovative and less predictable than other types of projects.
- Technological uncertainty is closely related to the degree that the NPD project uses new technologies versus mature technologies.
- NPD projects often involve greater overt risks throughout their development process such as unclear user requirements, lack of support from management, uncertain resource requirements, technical problems and the lack of experienced project team members.
- Team personnel in NPD projects typically have lower project management experience and are characterized by the unique requirements of a product and processes, people with different skills and expertise may be specially recruited or assigned for a different NPD team.

Another difference in the characteristics of risk in each type of a project, can be seen in the study by De Meyer, Loch, and Pich (2002) which discussed the uncertainty in a project. The paper has proposed uncertainty in profiles comprising of four uncertainty types and the ways to manage them as 1) variation; 2) foreseen uncertainty; 3) unforeseen uncertainty; and 4) chaos. Variation, foreseen and unforeseen uncertainties, can be usually seen on all types of the project and can be handle by traditional project management methods and tools. However, the last type of uncertainty called "Chaos" which refers to uncertainty where the basic structure of the project plan is uncertain, such as development technology or project development path are unclear. This type of uncertainty often causes the project ending up with final results that are completely different from the project's original intent. This finding emphasizes the importance of risk management in technology and product development areas and leads to the study of research gaps in project management and risk management for NPD in their research.

Project management concepts are widely used in many industries for different types of projects from construction, information technology (IT), manufacturing, marketing and military, including new product development (NPD). The increasing acceptance and more implementation of project management in several industries, indicated that the application of appropriate knowledge, processes, skills, tools, and techniques can have a significant impact on a project's success (PMI 2013). However, the importance and benefits of risk management in some types of projects, such as NPD, seem to get lower attention. A systematic risk management process is not usually included in the NPD activity by organization.

In specific, to benefit with risk management in projects, according to the studies in this field (Chapman and Ward 2004, Aloini, Dulmin, and Mininno 2012), risk management can lead to a range of benefits for projects and organizational such as:

- Provide guidance for decision making about alternative options in projects;
- Increased confidence in a project's success and outcome;
- Reduced unexpected events that caused project delays or went over budget;

- Better estimation and planning by reduced deviation from a project's objective
- Reduced duplication of effort by systematic risk management systems and
- Raise team awareness
- Use as the alternative way to support the introduction of complex systems (Aloini, Dulmin, and Mininno 2012)

The benefits of project management and risk management are widely accepted by researchers. But, in contrast, the acceptance of a formal risk management process in industry is still in question. The recent study in 2013, indicated that the PM method suffered from low adoption and individual acceptance rates. The study by Ahlemann et al. (2013) showed that there is a lack of universal applicability as well as a lack of consideration of the usage environment (contextual factors) and antecedents of a successful application of PM methods that may be the reason for low acceptance rates of the PM method in industry.

One approach to make risk management process understandable and applicable by the project team members is the use of a software application for risk management. There are several such software in the market have been developed for risk management, especially for IT and the construction market which are the main users of project management. But fewer numbers of software have been developed specifically for NPD type projects and a review of commercially available off-the-shelf risk management tools by Zhou (2003) identified that these tools generally lack a systematic "risk roadmap" required to identify, capture, and visualize the causal relationship of risk factors and their accumulated and inherited impacts in product development projects.

More recent study with problems in risk planning by Zwikael and Ahn (2011) identified problems of existing tools that are "complicate" for users. Moreover, when the size and complexity of projects increased, the effort required for effective risk planning exponentially rises, making those tools difficult to use.

The study about risk management tool development for the NPD projects by Kayis et al. (2007), also indicates the gap in commercial-off-the-shelf software that

lacked capabilities to support project risk identification, analysis and mitigation of risks during life cycle of the project, because those types of software are mainly designed for risk analysis and assessment. These findings can be used for the direction of new risk management tool development in this research.

Finally, research gaps in risk management for NPD can be summarized as following:

- There is a need for research and development of better and more user-friendly risk management tools for NPD projects for industrial users.
- The tools should provide roadmaps and focus on risk identification processes which are the difficult part of risk management for the NPD team, but also have the capability to support project teams in all process steps in risk management.
- The tools should provide universal applicability and comply to current project management and risk management standards. But also include consideration of contextual factors in each NPD project.

1.2 RESEARCH AIM AND OBJECTIVES

This research aims to develop the risk assessment model to use as the project management and decision support tool for product innovation development projects. The new risk assessment model will help organization and enterprises to select the best strategy and project environment (development team, technologies, materials, suppliers, etc.) for new product development projects, to shorten the lead time to market and increasing the chance of success.

Research objectives

1) To explore the risk management process for new product development (NPD) projects.
2) To study risk management practices of NPD projects in food companies in Thailand.
3) To explore common risk factors in NPD projects for the food industry.
4) To develop risk assessment model for NPD Projects.
5) To validate & refine risk assessment model.
6) To develop tool for risk assessment in NPD projects.

Technology : Information technology and MATLAB® software for fuzzy inference system

Innovation : 1) Risk Breakdown Structure for common risks in NPD project
2) New approach of using integrated tool for systematic risk management
3) Fuzzy risk analysis by 3 inputs (Impact, Likelihood and Priority Weight)

Management : Project management and Risk management methodology

1.3 SCOPE OF THE RESEARCH

1) Food industry in this research focus on medium and large size companies in Thailand.
2) Scope of NPD in this research focuses on the development process after the feasibility study and idea selection, until ready for mass production.
3) The research focuses on project risks that effect objectives of the NPD project and to some extent, product risks from the design phase. However, the risks from business activities after a product launch are not considered in this research.

1.4 EXPECTED OUTCOME

From research objectives, the expected outcome of the research will be as following:

1) Common risk factors for NPD projects which can be used as guidelines for risk identification.
2) Risk assessment model for NPD in the food industry which will be developed from a generalized model for NPD and common risk factors of NPD in all industries, but also include context specific risk factors for the food industry in Thailand.
3) Risk assessment tools that can be used by a member of the NPD team. This tool will be the roadmap for all process steps in risk management and can be used by a user with different experience and knowledge in Project Management and Risk Management.

1.5 BENEFITS OF THE RESEARCH

Contribution to theory

1) Advance study of success factor in food NPD by project risk management (Suwannaporn and Speece 2000, Suwannaporn and Speece 2010)
2) Test application Risk Management theory from International Standard and PM Body of Knowledge (ISO 2003, 2009, PMI 2013)

3) Test application of Fuzzy set theory as risk degree determination (Choi and Ahn 2010)

Contribution to practice

1) Enable effective systematic risk management process for food companies.
2) Support decision making for NPD project investment and portfolio management
3) Help NPD team to identify, analyze and control project risks, results in reducing NPD project lead-time and increasing success rate of NPD.

Originality and value of research

1) Risk assessment model for NPD in food industry.
2) Risk breakdown structure (RBS) and checklist of common risk factors for the NPD project in the food industry.
3) Fuzzy risk analysis method for NPD using Impact, Likelihood and Importance weight of risk categories.

1.6 TERMS AND DEFINITIONS

Risk : effect of uncertainty on objectives (Objectives can have different aspects (such as financial, health and safety, and environmental goals) and can apply at different levels (such as strategic, organization-wide, project, product and process).

(ISO Guide 73:2009, Risk management — Vocabulary)

Project Risk : An uncertain event or condition that, if it occurs, has a positive or negative effect on a project's objectives. (PMI PMBOK version 5th, 2013)

Risk Management : coordinated activities to direct and control an organization with regard to risk (ISO Guide 73:2009, definition 2.1)

Risk Assessment : overall process of risk identification, risk analysis and risk evaluation (ISO Guide 73:2009, definition 3.4.1)

Risk Identification : process of finding, recognizing and describing risks (ISO Guide 73:2009, definition 3.5.1)

Risk source : element which alone or in combination has the intrinsic potential to give rise to risk (A risk source can be tangible or intangible) (ISO Guide 73:2009, definition 3.5.1.2)

Risk criteria : terms of reference against which the significance of a risk is evaluated (Risk criteria are based on organizational objectives, and external and internal context; Risk criteria can be derived from standards, laws, policies and other requirements. (ISO Guide 73:2009, definition 3.3.1.3)

1.7 RESEARCH LIMITATION

From literature review some research about risk management focused on empirical study of risk management in specific industries such as oil & gas industry, transportation industry, automotive industry, consumer product, food and medical products. However, the approaches of risk management process in those researches are almost the same, except some industry specific risk factors that can be difference in each project and each industry.

Then the study in this research will cover general project risk management for product development process in all industries which can be applied and used by specific industries with project specific parameters adjust, and adding industry specific risk factors in risk identification phase. However, the validation process for risk management model and risk management tool was validated by case studies of food companies in Thailand only.

The contribution of this research is focus on development of methodology and tool for risk assessment. The risk factors identified from risk assessment process and risk index as the output from analysis tool were the examples of data used for model validation only.

CHAPTER 2

LITERATURE REVIEW

2.1 BACKGROUND OF RISK MANAGEMENT FOR NPD

This research focuses on overlap areas of three main research fields. The literature review covered new product development, project management and risk management areas. The study started from a review of a new product development process in this research. This was followed up by a review of the risk management process in project management and risk management standards and the last part covered a review of risk factors and risk categories. This information was used for the development of a risk assessment model in the later phase of the research.

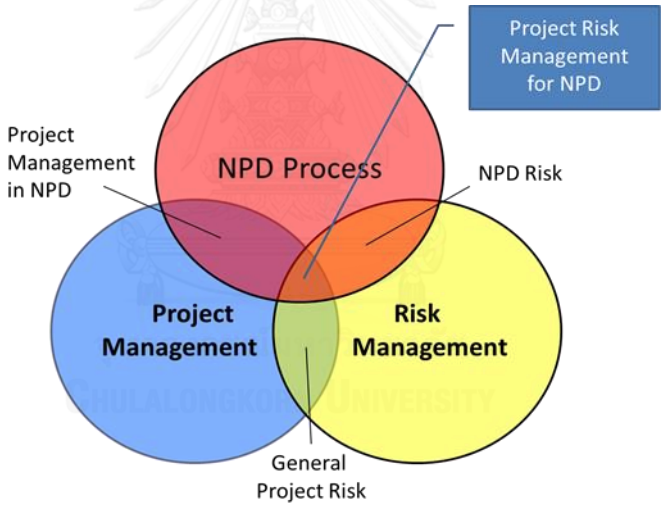


Figure 2.1 Scope and focus of the study

2.1.1 New product development process

It is widely accepted by academic research and industry, that new products or services are one of the main factors for a sustainable success of any company (Marxt and Hacklin 2005). The study by Cooper and Kleinschmidt (2007) indicated that there are three factors that really drive new product performance. The first factor is high-quality of new product processes used by organization by the NPD

team. The second factor is to clearly define a new product strategy for the business unit and the last factor is an adequate resource for new product development projects which are strongly related to the project management.

The new product development process has a long development history including the classic and well-known process called "stage-gate" systems which have been widely adopted and generally had a strong and positive impact on firms (Cooper 1994). The first generation of this process was developed by NASA in the 1960s as NASA's PPP (phased project planning) which was also called the "Phase Review Process". The new product process in that time was engineering driven which focused and applied strictly to the physical design and development activities of a new product and was designed to deal solely with technical risks by not taking business risks into consideration.

The second-generation stage-gate process consists of identifiable and discrete stages preceded by a review point or "gate" but this generation of stage-gate is very much a cross functional process that involves activities from many different functions in the organization or corporation. The sales and marketing function, include the manufacturing team that is now becoming integral parts of the product development process. The results of implementing this second-generation, or stage-gate approach, appear to have been positive. One study by Cooper and Kleinschmidt (1991) showed positive results from leading firms, including 3M, IBM, Nortern Telelcom and others.

The Third-Generation stage-gate was proposed by Cooper (1994). This generation stage-gate process intended to overcome some problems in the second-generation stage-gate such as long project lead times from waiting at each gate review and limit the overlap of activities in each stage. So the third generation has 4 fundamentals.

1) Fluidity: adaptable with overlapping and fluid stages for better speed.
2) Fuzzy gates: with conditional Go decision.
3) Focused: prioritization method for entire portfolio of projects.
4) Flexible: allow each project to have its own routing through the process..

Another well-known product development process was developed by Ulrich and Eppinger (2008). This NPD process is called "The generic product development process" This process consists of 6 process steps for planning, concept development, followed by system-level design, detail design, testing & refinement and production ramp-up.

Table 2.1 Review of new product development processes

NPD Process	NPD phase	Focus	Authors/Year
Phased review process	Consist of 5phases: 1) Preliminary analysis, 2) Definition, 3) Design, 4) Development, and 5) Operations	Engineering driven and applied strictly to physical design and development process by did not consider the market factor in new product development	NASA, 1960s
2nd Generation Stage-Gate	5 Phase: 1) Preliminary assessment, 2) Business case, 3) Development, 4) Testing & Validation 5) Full Production& Market Launch	More cross-functional process, involves activities from many different department. Marketing and manufacturing become integral parts of process	Cooper, 1990
3rd Generation Stage-Gate	5 Phase same as 2nd generation but allow overlapping between phase	Focus on reduce lead time for development by parallel or concurrent processing	Cooper, 1994
New Concept Development	5 Phase : 1) Opportunity identification, 2) Opportunity analysis, 3) Idea Genesis, 4) Idea selection, and 5) Concept & technology development)	Focus on new concept development process for input to design and development phase	Koen et al., 2001
Typical development phases	3 Phase for : 1) Concept development, 2) Product design and 3) Pilot production/testing	Focus on design and development function and not include manufacturing and launch phase	Schroeder, R. G., 2003
Front-end process model	1)Environmental screening 2) Idea generation 3) Concept Project and business planning	Focus in early phase of innovation process	Husig, Kohn, and Poskela, 2005

Food Product Development Process	9 process steps for 1) Strategic evaluation, 2) Market Assessment, 3) Evaluation of company fit, 4)Product definition, 5)Prototype development, 6) Market testing, 7)Scale-up and trial production, 8) Product refinement and 9) Final product production and launch	Model illustrates the FDA's role in new product development of food products which FDA administration involved after product definition and product refinement phases	Glueck-Chaloupka et al., 2005
Process of Innovation in Heath care	8 process steps for 1) Idea generation, 2) Opportunity/problem recognition, 3) Idea evaluation, 4) Development, 5) First use, 6) commercialization, 7) diffusion and 8) Local adaptation	Focus on innovation development for both of new product and process in health care	Varkey et al., 2008
Generic development process	6 Phase process, consists of: 1) Planning, 2) Concept Development, 3) System-level design, 4) Detail design, 5) Testing & refinement and 6) Production ramp-up	Defined development process and also identifies the key activities and responsibilities of different functions in organization	Ulrich and Eppinger, 2008
NPD process for High-Tech Enterprise	5 Phase, consist of: 1) Product concept 2) Feasibility 3) Development 4) Validation 5) Commercialization	Focus on NPD on High-Tech Innovation Life Cycle	Aleixo and Tenera, 2009

From the comparison of several NPD processes in Table 2.1, the development trend of the NPD process started from a narrow focus on engineering or technical area, then expanded the scope to involve other functions in organization. Especially, increase the use of inputs for customer and market requirement from marketing team for development target of product. Most NPD process were developed as generic process that can be applied to use in different industries, but some process models have been developed specifically for particular industries such as process of innovation for health care by Varkey, Horne, and Bennet (2008) which included additional steps for diffusion and local adaptation after

commercialization, or NPD process for high-tech enterprise purposed by Aleixo and Tenera (2009).

This study focused on the context of the food industry which some researcher's referred to as an area of lower tech industry due to innovations in the area were incremental innovation (Suwannaporn and Speece 2010). Study by Francis (2006) and Winger and Wall (2006) showed only 2 percent of new food products can probably be considered as high-innovation or radical innovation products. This characteristic of innovation in the food industry raised the question for researchers as whether we need specific a NPD process for this group of products.

The review of the NPD process found some studies that focused specifically in the food industry. The study by Glueck-Chaloupka, Capella, and Coggins (2005) discussed the NPD process for a food product using the NPD model that focused on the role of FDA's regulation in the food product development. However, this study used the same principle for general product development. Another study by Francis (2006) tried to find appropriate a NPD process for fast moving consumer products by matching a Stage model process with the three case studies of development processes in three food manufacturing companies in the UK and found that the same general principle for generic NPD process can be applied to this industry. However, some NPD process models in the past also fail to recognize some important steps in the food industry such as the packaging development process.

The objective of this research is not to mainly focus on the development of the NPD process for the food industry, but the understanding of works that have been done in this area which can be used as a conceptual background for the development of risk management models in later phases. The generic NPD process which was developed by Ulrich and Eppinger (2008) has been used as the starting point for the NPD process step before further empirical studies of the NPD in the food industry in Thailand.

2.1.2 Project risk management

Risk management is the one of critical process in nine knowledge areas of project management as descript by Project Management Institute in Project management body of knowledge - PMBOK, 5th edition (PMI 2013)

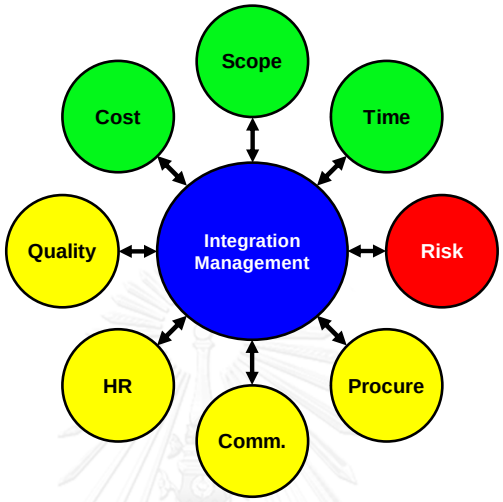


Figure 2.2 Project management knowledge areas

The definition of risk as defined by PMI in PMBOK(PMI 2013). The risk is an uncertain event or condition that, if it occurs, has an effect on at least one project objective. In the same way, Risk management standard ISO31000 (ISO 2009) which use the same approach as AS/NZS 4360 (Australia 2004) also define risk as the chance that something happening that will have an impact on an objective. Traditionally risk was perceived as negative events but some standards such as ISO31000 suggest that the risk could have either negative or positive impact.

From past study by Jafari et al. (2011). There are four well-known approaches to Risk Management : 1) Project risk analysis and management (PRAM) (APM 2004), 2) Management of risk-MOR (OCG, 2002); 3) Standard AS/NZS4360 (Standards Australia/Standards New Zealand, 2004); and 4) PMBOK (PMI 2013). There is no significant difference between them include the new version of Practice Standard for project risk management (PMI 2009) and Risk Management standard ISO31000(ISO 2009) which announced in the same year and also use the similar approach and

process step in risk management. This lead to conclusion that process step for risk management from ISO31000 can be used as the framework for risk assessment in project without any problem or conflict with others standard and traditional practice of project management in industry.

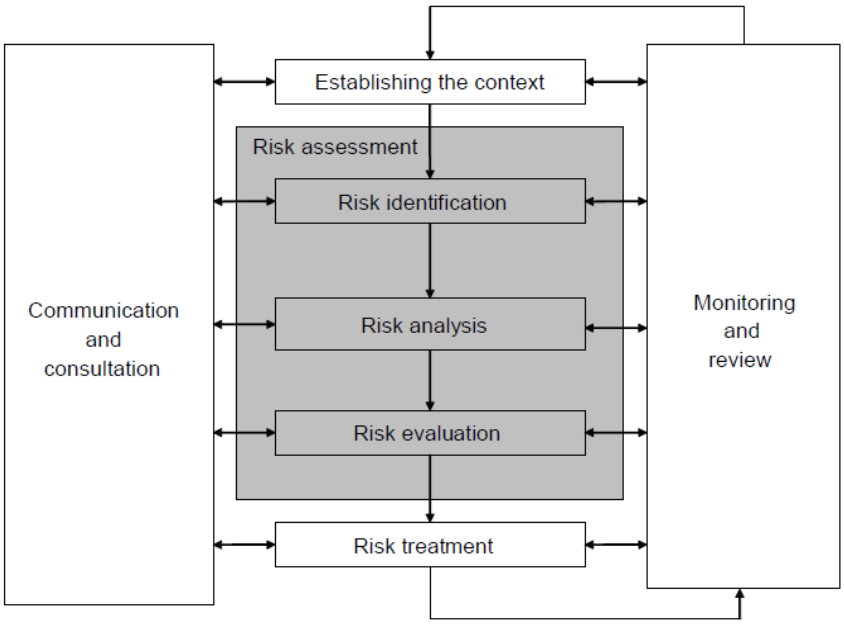


Figure 2.3 Risk management process in ISO31000

2.1.3 Risk management standard

2.1.3.1 ISO 31000:2009 Risk management standard (Principles and guidelines)

The International Organization for Standardization (ISO) released the first international risk management standard in November 2009. This standard called ISO 31000:2009 Risk Management – Principles and Guidelines (ISO 31000). The purpose of this standard is to provide organizations with principles and generic guidelines on risk management.

The standard consists of 5 parts as following

1) Scope : explain scope and intention of use for this standard
2) Term and Definition : explain the definition of key term
3) Principles: define principle that an organization should be comply at all levels

4) Framework: provide management frame work for risk management as foundation and arrangements that will embed through organization

5) Process: comprises the activities in risk management process

The components of risk management process are as following

1) Communication and consultation: The standard recommends that communication and consultation with project stakeholders should continue take place during all stages of the risk management process. This activity and exchange of information should be truthful, relevant, accurate and understandable but also taking into consideration for confidential and personal integrity issues.

2) Establishing the context: Divided to 2 parts for external and internal context. The external context includes external factors such as social and cultural, political, legal, regulatory, financial, economic, technological, natural and competitive environment. The internal context include internal factor such as organizational structure, roles and accountabilities, capabilities, resources and knowledge.

3) Risk assessment: consist of three process step for risk identification, risk analysis and risk evaluation.

4) Risk treatment: suggests risk treatment option that can be consider such as avoiding, removing risk source, changing the likelihood or changing the consequences

5) Monitoring and review: suggests monitoring and review activities to be planned as part of the risk management process with clearly responsibilities define.

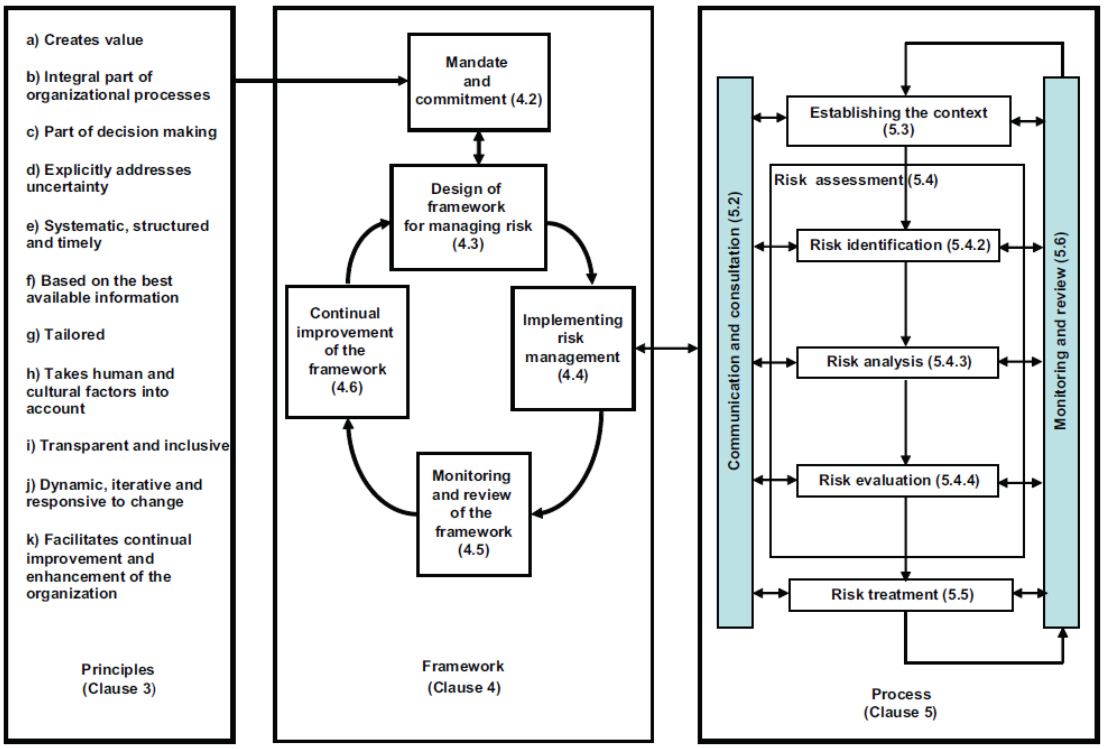


Figure 2.4 Risk management principles, framework and process

2.1.3.2 ISO/IEC31010:2009 Risk management standard (Risk assessment Techniques)

The standard consists of three major parts for risk assessment concepts, risk assessment process and selection of risk assessment technique.

1) Risk assessment concepts: provides the purpose and benefits of this standard. Benefits of performing risk assessment include:

- Understand the risk and its potential impact to project objectives;
- Identify the important contributors to risks and weak links in systems and organizations;
- Provide information for decision making;
- Assist in selection of treatment options;
- Compare of risks in alternative systems, technologies or approaches;
- Communicate risks and uncertainties;
- Assist and establish priorities;

This part of document also explains the risk management framework and process as defined in ISO31000

2) Risk assessment process: Risk assessment is the overall process of risk identification, risk analysis and risk evaluation.

2.1) Risk identification: is a process to identify sources of risk, cause of risk, areas of impacts, and their potential consequences.

Risk identification methods may include:

- Evidence based methods such as using check-lists and reviews of historical data;
- Systematic team approaches and systematic process to identify risks
- Inductive reasoning techniques such as HAZOP.

2.2) Risk analysis: This process involves developing an understanding of the risk and provides an input to risk evaluation Risk analysis can also help in decision making where choices involve different types and levels of risk.

Risk analysis in this standard includes activities in several dimensions such as controls assessment, consequence analysis, probability estimation or likelihood analysis and uncertainties and sensitivities analysis.

2.3) Risk evaluation: involves comparing the level of risk found during the analysis process to determine the need for treatment and the priority for treatment implementation.

3) Selection of risk assessment technique:

The techniques for risk assessment can be selected based on factors such as the objectives of the study, type and range of risks being analyzed, the availability of information and data, the degree of expertise in team member, human and other resources needed and regulatory and contractual requirements.

2.1.3.3 ISO 21500:2012 Guidance on project management

This ISO standard intend to provide the guidance on the concepts and processes for overall project management which also include risk management as one of 10 subject groups consist of integration, stakeholder, scope, resource, time, cost , risk , quality, procurement and communication. The subject group are similar to nine knowledge areas in PMBOK (PMI 2009) except “Stakeholder” has been added for additional subject groups in this ISO standard.

The part of risk subject group in this standard consist of four process groups

1) Identify risks: explain the purpose of this process to determine potential risk events and risk characteristics. This process should involve multiple functions, such as executive management, project sponsor, project manager, project team member, project customer and risk management expert.
2) Assess risk: explain the purpose to measure and prioritize the risk from identify risk step, The activity include estimating the probability of occurrence, estimating corresponding consequence on objective and prioritizing risk by other factors such as timeframe and stakeholder' risk tolerance
3) Treat risk: The process to develop options of action to enhance opportunities and reduce treats to the project objective. The option for risk treatment may include mitigate risk, deflect risk and contingency plans. The output from this process will include risk responses and change request in project.
4) Control risks: the purpose of this step is minimize disruption to the project by determining whether the risk responses are execute and how risk response have effect on project. The output of this process may include the change requests and corrective actions.

2.1.3.4 ISO10006:2003 Guidelines for quality management in projects

This standard intends to provide guidance on the application of quality management in projects. The standard defines quality systems in projects that include project characteristics, organizations, process and phases in projects, project management processes.

ISO10006 defines project management process in to seven process groupings for Inter dependency-related, scope-related, time-related, cost-related, communication-related, risk-related and purchasing-related processes.

Risk-related processed grouping consist of four processes as following:

1) Risk identification which should be performed at the beginning of the project, at progress evaluation and when signification are made
2) Risk assessment is the process to analyze and evaluate risks to project process and project output.

3) Risk treatment is the process to identify solutions to eliminate, mitigate, transfer, share or accept risks
4) Risk Control is the process to monitor and control risk throughout the project, reports on project risk monitoring and control should be part of progress evaluations in projects

Table 2.2 Internationals standard related to risk management

Standard	Relation to Project Management	Risk Management Process
ISO 31000 :2009 Risk management	Included but not specific to project risks	Defines risk management process as 1) Communication and consultation 2) Establishing the context 3) Risk assessment 4) Risk treatment 5) Monitoring and review
ISO/IEC 31010:2009 Risk assessment Techniques	Included but not specific to project risks	Defines Risk assessment process as 1) Risk identification 2) Risk analysis 3) Risk evaluation
ISO 21500 :2012 Guidance on project management	Defines project management to 10 subject groups for 1) integration, 2) stakeholder, 3) scope, 4)resource, 5)time, 6) cost , 7) risk , 8) quality, 9) procurement and 10) communication.	Defines risk subject group into 4 processes 1) Identify risks 2) Assess risk 3) Treat risk 4) Control risks
ISO10006 :2003 Guidelines for quality management in projects	Defines project management to 7 process grouping for 1) Inter dependency-related processes, 2) scope-related processes, 3) time-related processes, 4) cost-related processes, 5) communication-related processes,6) risk-related processes and 7) purchasing-related processes	Defines risk-related processes group as 4 processes 1) Risk identification 2) Risk assessment 3) Risk treatment 4) Risk Control

From comparison of four International Standards related to risk management we can see the similar approach of risk management in project which also align with best practice and approach to project risk management that recommend in PMBOK (PMI 2009)

2.1.4 Risk management research

From systematic literature review methodology as descript in Chapter 3. The 182 papers related to project risk management were selected from four databases during January 2002 - October 2012. We can conclude our finding about risk management in four topics (1) Research Stream; (2) Distribution by Regions; (3) Risk study by Industry Segment and (4) Focus area of risk research

Research Stream

There are 4 main research streams of papers about project risk as following

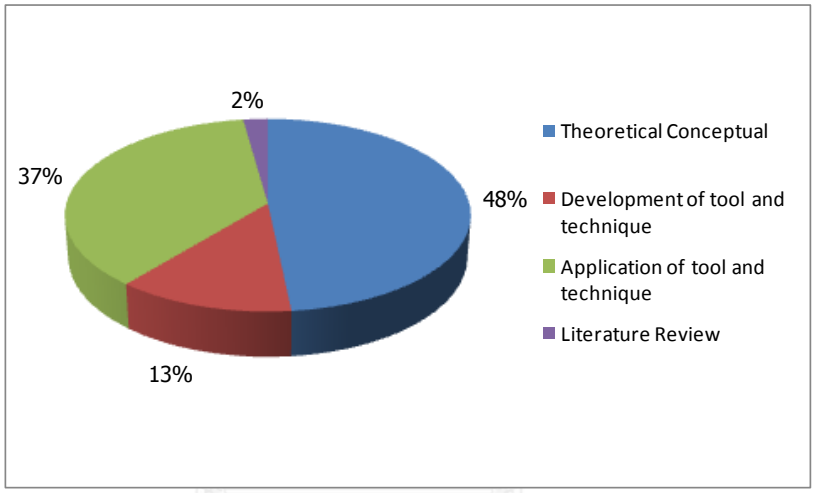


Figure 2.5 The ratio of articles by research stream

1) **Theoretical Conceptual** – paper propose new framework/methodology or hypothesis about factors relate to project risk management
2) **Development of tools and technique** – paper purpose new tool or technique for risk management, risk identification and risk evaluation, several papers also prove validation of tools by survey or case study data.
3) **Application of tools and technique** – papers propose the uses of existing tools to in risk management application or use the existing tools to solve some problem in risk management process
4) **Literature Review** – papers focus on past literature review in specific topics related to risk management such as OHS risk management (Badri, Nadeau, and Gbodossou 2012) or A systematic literature review about software

development from supplier's perspective (Savolainen, Ahonen, and Richardson 2012) or two group of different view point about risk management in research (Zhang and Chu 2011)

Distribution by Regions

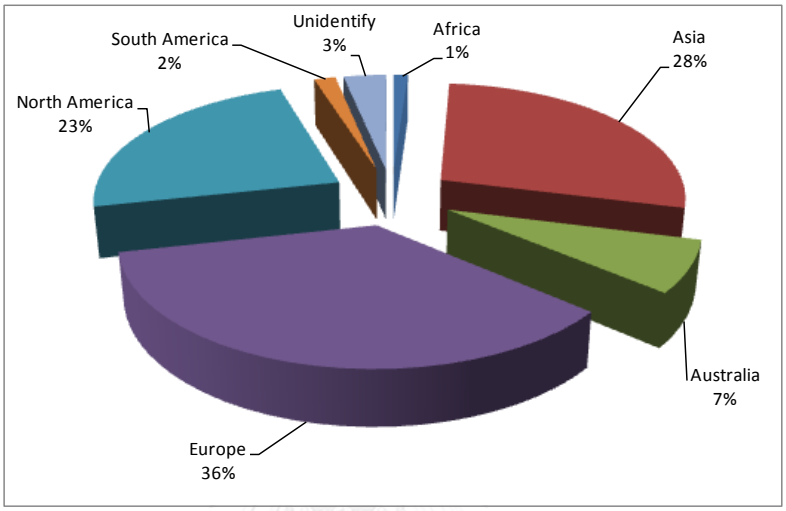


Figure 2.6 Distribution of articles by regions

Risk Study by Industry Segment

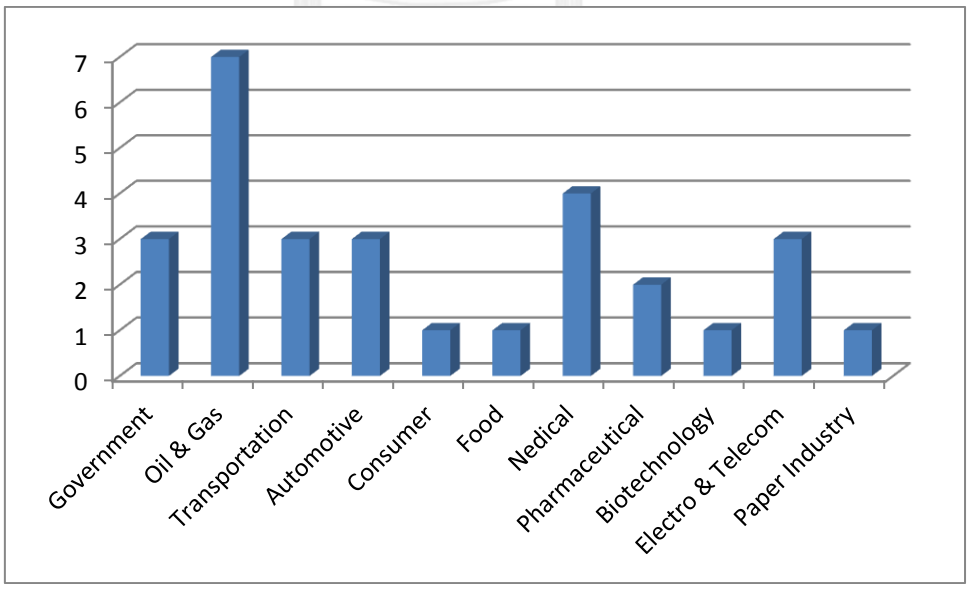


Figure 2.7 Number of articles by industry segment

Majority of the study about project risk management do not specify for market segment. However, some papers use the case study or survey data from specific group of industry.

Table 2.3 Risk researches by industry segments

Industry Segment	Reference Research
Government	Elkington and Smallman,2002; Liou et al.,2012; Procca,2008
Oil & Gas	Abrahamsen & Aven,2011; Chapman & Ward,2004; Krueger & Smith,2003; Mojtahedi et al.,2010; Nguyen et al.,2007; Nielsen,2006; Salah Eldin,2009
Transportation	Diraby & Gill,2006; Marie & Vidal,2011; Zou & Li,2010
Automotive	Ainscough et al.,2003; Patterson & Neailey,2002; Soderlund,2002
Consumer	Mike Palmer,2002
Food	Rodgers,2011
Medical	Johal et al.,2008; Millson & Wilemon ,2008; van der Peijl J et al.,2012; Sicotte et al.,2006
Pharmaceutical	Garrison,2010; Katsanis & Pitta,2006
Biotechnology	Vanderbyl & Kobelak,2008
Electro & Telecom	Kosaroglu,2009; Turgut & Baykoc,2007; Soderlund,2002
Paper Industry	Suomala & Jokioinen,2003

Focus area of risk research

Risk management process consists of several process steps and related to several knowledge areas in project management (PMBOK, 2008). Majority of papers study overall process of project risk management, while some of the study focus on

specific area of risk. The reference papers by focus area of risk study can be found in table below.

Table 2.4 Risk researches by focused areas

Focus Area	Reference Research
Communication related risk	Reed & Knight,2010
Cost Risk	Nguyen et al.,2010; Kujawski & Angelis,2010; Mojtahedi et al.,2010
Design Risk	van der Peijl J et al.,2012
Financial Risk	Davis,2002; Rouse and Houghton,2002; Mukherjee et al.,2003; Rebiasz,2007; Johal et al.,2008; Fan et al,2008; Cioffi & Khamooshi,2009; ILOIU & CSIMINGA,2009; Bukvic et al.,2009; Kulk et al.,2009; Liou et al.,2012
OHS Risk	Krueger & Smith,2003; Zeng et al.,2010; Mojtahedi et al.,2010; Garrison,2010; Rodgers,2011; Badri et al,2012
Planning Risk	Mike Palmer,2002; Alexander,2002; DeMarco & Lister,2003; Salomo et al.,2007
Product Safety Risk	Katsanis & Pitta,2006
Schedule Risk	Mike Palmer,2002; Alexander,2002; DeMarco & Lister,2003; Turgut & Baykoc,2007; Schatteman et al.,2008; Nguyen et al.,2010; Podean,2010; Mojtahedi et al.,2010; Sharma & Suri,2011; Vanhoucke,2012; Trietsch & Baker,2012; Overall Project Risk

2.1.5 Risk management process in research

Project Risk management model in research papers that we have reviewed can be separated in two types for 1) high level conceptual model; and 2) detail flowchart diagram of method or system used for risk management.

The high level conceptual models explain overall approach, process step and relation of each step of risk management in each context or application. This type of conceptual framework may include influent factors or input-output in to the process

Example for this type of framework can be seen in paper about Aligning building information model tools and construction management methods by

Hartmann et al. (2012). The second type of framework that we found in the literature review will have more details and specific information present in flowchart format to explain the details step for method or system that they used for risk management such as fuzzy assessment model by Nieto-Morote and Ruz-Vila (2011) or risk management model for build-operate-transfer projects by Dey and Ogunlana (2004)

However, we do not see much difference in process step or approach to risk management and most of these conceptual frame works will align with process step from well-known project management standard and guideline. (Kutsch and Hall 2010)

Table 2.5 Review of risk management models in researches

Risk Management Model	Description	Authors/Year
Project risk management model	9 steps of risk management for define, focus, identify, structure, ownership, estimate, evaluate, plan and manage	Chapman and Ward, 1997
Risk model for construction	5 Basic steps of Project Risk Management. Identify risks, Analyze risks, Prioritize and map risks, Resolve risks and monitor risks.	Smith and Merritt, 2002
Risk management model by TOC	Initial project planning, Identify project risk, Quantify and rank risks, Develop response plan, Subordinate response, Reduce and/or avoid risk and identify additional risk	Steyn, 2002
Risk management model for build-operate-transfer projects	5 steps for Risk identification, risk classification, risk analysis, risk attitude and risk response (or risk allocation).	Dey and Ogunlana, 2004
Fuzzy assessment model	4-phase process for risk management: 1) Risks identification 2) Risk assessment 3) Risk response 4) Risk monitoring and reviewing With fuzzy risk assessment methods	Nieto-Morote and Ruz-Vila, 2011
RISKMAN Model	1)Determine the goal of the risk management effort 2)Identify possible risks 3)Prioritize most important risks 4)Determine possible risk control measures	Hartmann et al. (2012)

2.1.6 Risk factors

Risk factors are the focus areas of several research papers. For example, Cervone (2006) discussed common risk factors which consisted of some internal factors from top management support, and external factors from failure to gain user

comments, misunderstanding of requirements, lack of user involvement and problems in management customer expectations. However for different studies, especially studies in different the types of projects and different market segments, the risk factor seem to be varied and could be considered in many different aspects. For example, studies about development of risk management tools called IRMAS (Kayis et al. 2007) mentioned about risks in more detailed levels than risk categories as other studies. They have identified 589 risk items or risk factors in their work. Then, this study considered the risks in high levels as risk dimension or a risk category and also breakdown in to lower levels as risk factors to develop checklist used for list identification.

The summary of risk dimension from literature review can be seen in table 2.6. We divided the study related to risk dimension into 4 groups for 1) NPD project; 2) IT project; 3) construction project; and 4) Non-specific type of project group.

From the data, we can see some patterns of risk dimension in each project type. The NPD project seemed to be focused on the risk related to different functions in an internal organization due to the NPD project interdisciplinary process with several functions in an organization, each function caused the individual risk which lead to project risks in big picture. For the construction project, the risk dimension seem to be more focused on additional risk factors from outside such as procurement, contract, environment and safety compared to NPD.

For IT projects, the process involves both the internal function in an organization and some outsource activities or contract. So we can clearly see the distribution of risk dimensions across different types of risks factors. This pattern can be used as a focus in future research for each type of projects. The risk factors in research are summarized by a type of project in Table 2.6.

Table 2.6 Summary of risk factors in research

		NPD							IT				Construction					General	
	Risk Factors	Kayis et al., 2007	Tang et al., 2011	Keizer & Halman,2007	Sicotte et al., 2006	Chin et al.,2009	Mu etal., 2009	Park, 2010	Kumar Day, 2010	Liu et al.,2010	Han & Huang, 2007	Hu et al.,2012	Zou & Li, 2010	Nielsen, 2006	Zeng et al.,2010	Diraby & Gill,2006	Lee et al.,2009	Chia,2006	McConnell, 1996
1	Schedule risk	•																	
2	Technical Risk	•		•	•		•	•	•	•				•			•	•	
3	External Risk	•		•															
4	Organizational Risk	•		•			•	•		•	•								
5	Communication Risk	•																	
6	Location Risk	•																	
7	Resource Risk	•			•					•	•							•	
8	Financial Risk	•							•				•	•		•	•		
9	Quality Risk														•				
10	Customer/User Risk		•	•						•	•	•						•	
11	Product Positioning Risk			•															
12	Manufacturing Technology			•															
13	Intellectual Property Risk			•															
14	SC and Sourcing Risk			•		•		•											
15	Competitors Risk			•															
16	Commercial Viability Risk			•	•														
17	Screening and Appraisal			•															
18	Product Reliability Risk					•													
19	Production Risk					•													
20	Planning Risk									•	•		•						
21	Contractual Risk												•						
22	Design Risk					•							•						
23	Geological Risk												•						
24	Construction Risk												•			•			
25	Market Risk						•	•	•	•						•			
26	Economical Risk								•					•		•	•		
27	Environmental Risk								•					•	•	•			
28	Safety Risk														•				
29	Social Risk								•					•			•		
30	Political Risk				•				•					•		•	•		
31	Natural Risk																•		
32	Legal Risk												•				•		
33	Dependencies																		•
34	Requirement									•	•	•							•
35	Management				•												•	•	•
36	Lack of Knowledge																		•
37	Deliverly/Operaton Risk							•						•		•			
38	Procurement/Contract Risk											•		•				•	
39	Project Complexity Risk										•								
	Average number = 5.7	8	1	11	5	4	3	5	7	7	6	3	7	8	3	7	8	5	4

The definitions of 39 risk factors from systematics literature review are illustrated in Table 2.7.

Table 2.7 Definition of common risk factors from literature review

No	Risk Factors	Definitions
1	*Commercial Viability Risk*	Risk related to long-term market potential, reliability of volume estimates, including realistic sales perspective.
2	*Communication Risk*	Risk related to the ability to effectively convey ideas and information within the company and externally to suppliers and customers, may concern language barriers, cultural differences and communication channels.
3	*Competitors Risk*	Risk related to competition in market, ability to enabling creation of potential barriers for competitors.
4	*Construction Risk*	Risk related to construction activities in project. May relate to safety, health and environment issue in construction.
5	*Contractual Risk*	Risk related to agreement and contract such as legislation change, contract dispute, contract negotiation, contractual progress payment.
6	*Customer/User Risk*	Risk related to the understanding of user needs and ensuring the new product meets target consumers' needs.
7	*Delivery/Operation Risk*	Risk related to delivering and operating the project as conceived. This involves issues or concerns associated with actual engineering, procurement, construction execution, and operation of the project, including nontraditional approaches such as a public owner's use of design-build contracts.(Nielsen 2006)
8	*Dependencies Risk*	Risk related to dependencies within project such as inter-component dependencies within software, intergroup dependencies across functions, the availability of people to perform task functions at the needed time.
9	*Design Risk*	Risk related to uncertainty that cause product specifications cannot be fulfilled within the expected schedule, including design problem such as inadequate design specification and documentation, design mistakes, design variations and issue relate to product standards.
10	*Economical Risk*	Risk related to ability to overcome the economic impact in project, involves issues or concerns associated with the macroeconomic impact of the project to the community and region within which it is to be located.

11	*Environmental Risk*	Risk related to the environmental problems, concerns, and activities confronting the project during the project execution and the project operation.
12	*External Risk*	Risk related to any issues with regards to any parties outside of the organization.
13	*Financial Risk*	Risk related to monetary receipts and expenditure, including currency exchange rates, inflation, budget and costs. Sometime refer to ability to overcome the financial risk of the project through to final completion and operation.
14	*Geological Risk*	Risk related to unclear geological conditions, complex and adverse geological conditions and geological barriers.
15	*Intellectual Property Risk*	Risk related to knowledge of relevant patent issues, patent-sharing potential, availability of required external licenses and dependency on third-party development.
16	*Lack of Knowledge Risk*	Risk from poor understanding of methods, tools, and techniques cause by inadequate training, inadequate application domain experience or project members who are not subject matter experts.
17	*Legal Risk*	Risk from changing in rules and regulations relate to product or project specification
18	*Location Risk*	Risk related to the physical distance/barrier between two respective parties, including their geographic location, proximity to each other, location selection, number of sites.
19	*Management Risk*	Risk related to poor project management or unclear project ownership and decision making processes, unrealistic commitments which lead to unrealistic expectations.
20	*Manufacturing Technology Risk*	Risk related to technological issues for manufacturing, may include quality and safety requirements of production system.
21	*Market Risk*	Risk from changing in market condition such as competitive situation, power of supplier and users, product substitution.
22	*Natural Risk*	Risk of natural disaster such as Typhoon, flood, earthquake and other uncontrollable events happen.
23	*Organizational Risk*	Risk related to the management or administration personnel of the business, defined by the organizational structure, ownership, stakeholders, leadership and the organization's culture.
24	*Planning Risk*	Risk related to process to establish scope of project and define the course of actions to execute the project.

25	*Political Risk*	Risk related to local, state, and national political opposition and code and regulatory impediments. Including issues or concerns associated with the local, regional, and national political and regulatory situation confronting the project.
26	*Procurement/Contract Risk*	Risk associated with the procurement of, or contracting for, the execution and operation of the project.
27	*Product Positioning Risk*	Risk related to project portfolio and ensuring product format meets functional requirements.
28	*Product Reliability Risk*	Risk related to ability to maintain stable production process and an expected product performance in its service lifetime.
29	*Production Risk*	Risk related to uncertainties that cause production requirements cannot be met within the expected schedule.
30	*Project Complexity Risk*	Risk of project involving the use of new technology, high level of technical complexity, use of technology that has not been used in prior projects.
31	*Quality Risk*	Risk related to quality requirement of products.
32	*Requirement Risk*	Risk related to understanding and agreement on project requirement, including prioritization and change management process in project.
33	*Resource Risk*	Risk related to the available capabilities to supplies or support project, including materials, labor, equipment and facility specific issues.
34	*Safety Risk*	Risk of accidents and dangerous events on OHS.
35	*Schedule Risk*	Risk related to plan of procedures, task in project, sequence of operations, milestones.
36	*Screening and Appraisal Risk*	Risk related to evaluation and screening of alternative options in project.
37	*Social Risk*	Risk related to social and cultural impacts of the project to the community and region within which it is to be located.
38	*Supply Chain and Sourcing Risk*	Risk related to supply chain network, supplier's readiness, quality of supply, contract arrangements and contingency option.
39	*Technical Risk*	Risk related to the ability to overcome the technological issues or concerns of the project, technological know-how, innovation and technical support.

2.1.7 Risk Categories

From 39 risk factors found in literature review we can classify these risks and combine to risk categories by source of risk in NPD to 20 risk categories as following.

Table 2.8 Common risk factors for NPD projects

No	NPD phase	Risk Categories	Description
1	Planning	Schedule risk	Risk relate to project scheduling and time estimation
2		Organization structure	Structure of NPD team and support
3		Project communication	Report and information sharing
4		Economic risk	Economic and financial status
5	Concept Development	Technical complexity	Level of technical complexity
6		Location selection	Plant location and materials source
7		Resource planning	Resources and facilities to support NPD activities
8		Team knowledge	NPD team experience and knowledge
9	System-Level design	Design risk	Design concept and uses of VOC
10		Manufacturing technology	Risk from manufacturing technology selection
11	Detail design	Intellectual properties	Limitation from patents and license
12		Sourcing and materials planning	Risk from materials availability and continuous supply
13	Testing & Refinement	Customer requirement	Requirement understanding and testing procedure
14	Production Ramp-up	Manufacturing capability	Availability and sustainability of manufacturing capacity
15		Logistics & Transportation	Selection of logistic network and transportation mode
16		Procurement and contract	Risk from outsourcing activities and contract
17	All phase	Social risk	Risk relate to community, social responsibility and environment
18		Political risk	Political situation affect to project
19		Natural risk	Natural disasters and climate change
20		Compliance risk	Law, regulation and regulatory issues

The literature review has been further conducted for 20 risk categories found in this phase of research.

1. **Schedule risk** is group of risk factors related to project scheduling and time estimation. Schedule risk was mentioned in the study by Kayis et al. (2007) as the risks related to planning of procedures for a specific project with reference to a sequence of operations, task dependencies, lead times. Schedule risk and project tracking are importance and have direct effect to key performance of the project (Vanhoucke 2011). There are many project risk factors included in this group such as the study by Luu et al. (2009) identify 16 factors in this group in construction project. Other study by Sharma and Suri (2011) also studied schedule risk in software project.
2. **Organization structure** is the project risk category related to structure of project team and other resource in organization that support project. It includes organizational risk (Kayis et al. 2007, Keizer and Halman 2007, Mu, Peng, and MacLachlan 2009, Park 2010, Liu et al. 2010, Han and Huang 2007) and management risk (Sicotte et al. 2006, Lee, Park, and Shin 2009) from Literature Review. One study in this area conduct by Bannerman (2009) Study Risk Implications of Project Organization Structures in Software industry by developing risk profiles of four common structures (functional, project, matrix and adhocracy forms) and validates them against data from a public sector study. Another study by Ekinsmyth (2002) study risk about Project Organization in Magazine Publishing.
3. **Project communication**; Risks in this group relate to report and information sharing in project. This group included Communication Risk (Kayis et al. 2007) and Project Complexity Risk (Han and Huang 2007) from literature review. There are several researches in this area. Reed and Knight (2010) have studied communication risk between traditional project teams when team members physically remote. Even the finding from research show that the virtual team

projects exhibited more risk due to insufficient knowledge transfer in project team which results from ineffective communication. Burman and Sandberg (2014) study how does project communication impact risk management and goal achievement in public place branding projects. The results conclude that project success factors are based on the projects goals and that project communication of goals. It is what interlinks the success factors and thus enables public place branding projects to achieve its goals.

4. **Economic risk**; risk in this group relate to economic situation or financial status of organization that have effect on project objective. This group of risk refer as Financial Risk (Kayis et al. 2007, Dey 2010, Zou and Li 2010, Nielsen 2006, El-Diraby and Gill 2006, Lee, Park, and Shin 2009), Commercial Viability Risk (Keizer and Halman 2007, Sicotte et al. 2006) Market Risk (Mu, Peng, and MacLachlan 2009, Park 2010, Dey 2010, Liu et al. 2010, El-Diraby and Gill 2006) and Economical Risk (Dey 2010, Nielsen 2006, El-Diraby and Gill 2006, Lee, Park, and Shin 2009) in literature review. Florescu (2012) also studies the analysis of economic risk in investment project and defined the main forms of economic risk as the operational risk (OR) and the financial risk (FR).
5. **Technical complexity**: This group of risks cause by high level of technical complexity in project. In others research they may refer as Technical risk (Kayis et al. 2007, Keizer and Halman 2007, Sicotte et al. 2006, Mu, Peng, and MacLachlan 2009, Park 2010, Dey 2010, Liu et al. 2010) To understand the level of risk in this group researchers propose different methods to define project complexity such as using the Analytic Hierarchy Process. (Vidal, Marle, and Bocquet 2011). Bosch-Rekveldt et al. (2011) proposed framework for characterizing project complexity in large engineering projects and presented 40 elements from literature review used to define project complexity which lead to development of TOE (Technical, Organizational, and Environmental) framework. Tatikonda and

Rosenthal (2000) characterize product development projects in terms of their technology novelty and project complexity levels. These methods can be used as starting point to determine project complexity which will be related to level of risk in this area.

6. **Location selection**: The decision of organization for plant location and materials source may have direct effect to project risks. Kayis et al. (2007) defines location risk as the physical distance/barrier between two respective parties including their geographic location, proximity to each other, number of project sites and their size. Tivig et al. (2008) study Regional Demographic Location Risk in Europe which cause by demographic change (population ageing). Their work included risk in labor supply, human capital, labor productivity and R&D. Some researcher use advance method such as Monte Carlo Simulation as a methodology to help determine candidate locations and then conduct a financial risk analysis to determine the ideal location of a new facility (Ridlehoover 2004).
7. **Resource planning**: This is the group of risk factor relate to resources and facilities that have been allocated to support NPD activities. This group of risk has been mention as resource risk in literature review (Sicotte et al. 2006, Kayis et al. 2007, Han and Huang 2007, Liu et al. 2010) . However, the scope also included risk management strategies as a part of integrated resource planning (Andrews 1995).
8. **Team knowledge**: This is the risk category that causes by lack of team experience and knowledge in project team. There are several researches in this area such as Suh et al. (2010) published the paper about testing the relationships between the constructs of experiential knowledge, creativity, and performance in the context of international marketing projects. Wang and Tian (2012) study tacit knowledge management for three levels in project team: member level, team

level and corporation level. Kettunen (2003) study about software project team Knowledge in modern large new product development (NPD) organizations.

9. **Design risk**: This is major group of risk that very important for project success especially for NPD project. It relates to design concept, understanding and uses of VOC. This group of risk is mentioned with different name in literature review such as Product Positioning Risk, Competitors Risk, Screening and Appraisal Risk (Keizer and Halman 2007) Product Reliability Risk (Chin et al. 2009) Contractual Risk (Nielsen 2006, Zou and Li 2010) Design Risk (Chin et al. 2009, Zou and Li 2010) Dependencies Risk. There are interesting research about risk in this group for specific industry such as construction and space industry (Reeves et al. 2012).
10. **Manufacturing technology**: This group of risk consist of Manufacturing Technology Risk (Keizer and Halman 2007), Production Risk (Chin et al. 2009) and Construction Risk (El-Diraby and Gill 2006, Zou and Li 2010) from literature review. Hottenstein and Dean (1992) study managing risk in advanced manufacturing technology. Technology risk arises from the failure to choose, design, and implement a manufacturing technology consistent with a company's basis of competitive advantage. Technology risk is high when current manufacturing processes are complex and not under control. Risk is also high when the new technology represents a major departure from existing conditions and is not well-understood. New technology is also risky if it affects several processes and/or functions because it then requires integration.
11. **Intellectual properties**: Risks related to use and protection of intellectual properties in project. The focus will be on product specification and manufacturing technology (Keizer and Halman 2007). Some researcher sets up an intellectual property risk evaluation index system of virtual R&D team (Ting 2010). The method using rough set theory is applied to evaluate intellectual property risk evaluation in virtual R&D team. Other study by Zhang, Zhang, and Zhang

(2010) analyzes the influence of Knowledge management capability to intellectual property risk.

12. **Sourcing and materials planning**: This group of risk relate to materials availability and continuous supply of raw materials to supply chain. It includes SC and Sourcing Risk (Keizer and Halman 2007, Chin et al. 2009, Park 2010) and Planning Risk (Han and Huang 2007, Liu et al. 2010, Zou and Li 2010) from literature review. For the research in this area, Christopher et al. (2011) try to understand how managers assess global sourcing risks across the entire supply chain and what actions they take to mitigate those risks. The study revealed that most companies do not have a structured supply chain risk management and mitigation system. (Sharp 2007) studied the risk of sourcing decision in e-commerce business. The paper proposed model identifies four types of risk relate to sourcing decision: financial legal risk, reputational risk and competitive risk.
13. **Customer requirement**: This group of risks relates to understanding of customer requirement, include product and market testing to ensure customer requirement. In Literature review this categories of risk are mention as Customer/User Risk (Han and Huang 2007, Keizer and Halman 2007, Liu et al. 2010, Tang et al. 2011, Hu et al. 2012) and Requirement Risk (Han and Huang 2007, Liu et al. 2010, Hu et al. 2012). There are several research in this area focus on application of Quality Function Deployment (QFD) to convert customer requirement to product specification. (Junwu, dongtao, and zhenqiang 2012, Li, Chin, and Luo 2012, Zhou et al. 2013).
14. **Manufacturing capability**: Related to ability of manufacturing process and availability of manufacturing capacity. This include Manufacturing Technology Risk (Keizer and Halman 2007), Production Risk (Chin et al. 2009) and Construction Risk (El-Diraby and Gill 2006, Zou and Li 2010) from literature review. This area got

high attention from researcher in manufacturing field. Since 1992, Rodriguez (1992) study developments in process capability analysis. Follow by Spiring et al. (2003) summarized research works relate to process capability during 1990-2002. Several papers in later year focus on process capability index while (Pan and Lee 2009) using process incapability index instead. And results show that our new process incapability index can be used in the evaluation of manufacturing risk.

15. **Logistic & Transportation**: related to selection of logistic network and transportation mode, including Delivery/Operation Risk (El-Diraby and Gill 2006, Nielsen 2006, Park 2010) that is identified in literature. Another study by Wright and Datskovska (2012) proposed recommendations for managing the vulnerabilities in logistics and transportation risk management. The report identified a number of recent supply chain and transport concerns that have increased organizations' risk Information/communication disruptions Infrastructure failure, Reliance on oil and Legislation and regulation
16. **Procurement and contract**; include risk from outsourcing activities and contract. (Nielsen 2006, Hu et al. 2012). Some study in this area Study the need for procurement risk management and suggest for clear allocation of responsibility for procurement risk management to responsible persons (Murray 2013). Shi et al. (2011) proposed model using multi-stage stochastic programming. The model attempts to minimize the risk exposure of procurement decisions measured as conditional value-at-risk. The replenishment decisions are made at various stages along a time horizon, with replenishment quantities being determined by simultaneously considering the stochastic demand and the price volatility of the spot market. Osipova and Eriksson (2011) study procurement risk management which affect by procurement options in construction project by consider project delivery method, form of payment, and use of collaboration or partnering.

17. **Social risk**: Risk relate to Environmental (El-Diraby and Gill 2006, Nielsen 2006, Dey 2010, Zeng, Tam, and Tam 2010) and Social Risk (Nielsen 2006, Lee, Park, and Shin 2009, Dey 2010). The Environmental Protection Agency (EPA) recently published guidelines for cost benefit analysis of environmental regulation (U.S. EPA 2000) examples of the kinds of costs that result from regulation are Real-Resource Compliance Costs, Social Welfare Losses and Transitional Social Costs (Firm closings, Unemployment, Resource shifts to other markets)
18. **Political risk**: risk related to political situation affect to project. (El-Diraby and Gill 2006, Nielsen 2006, Sicotte et al. 2006, Lee, Park, and Shin 2009, Dey 2010). One paper investigates the relationship between political instability and per capita GDP growth in a sample of 113 countries for the period 1950 through 1982. (Alesina et al. 1996). Some researcher also found that in countries and time periods with a high propensity of government collapse, growth is significantly lower than otherwise (Sigelman and Simpson 1977).
19. **Natural risk**: This group of risk consist of Geological Risk (Zou and Li 2010) and Natural Risk (Lee, Park, and Shin 2009). Study by (Nelson 2013) about natural disasters show that Bangkok is included in group of cities most vulnerable to the effects of climate-related natural disasters and rising sea levels.
20. **Compliance risk**: Risk relates to law and regulations (Lee, Park, and Shin 2009, Zou and Li 2010). For NPD project in food the compliance is the major issue which related to food safety. Branquinho, Ferreira, and Cardarelli-Leite (2010) survey of compliance with labeling legislation in food. Study by Hirschauer, Bavorová, and Martino (2012) analyze the multiplicity of behavioral factors influencing producers' motivation to break the food safety norms intentionally and proposed an analytical framework for a behavioral analysis of non-compliance in food safety. Bamberger (2009) study automation of compliance or

technology systems and computational analytics for risk management that measure and predict corporate risk levels and 'force" decisions accordingly.

2.2 RISK MANAGEMENT TOOLS

2.2.1 Risk management tools in research

By the review of the academic literature published during 2002 and 2012. Tools have been used in two major areas in the risk management process for risk identification steps and risk analysis steps. The level of complexity of tools start from basic tools such as risk breakdown structures by common risk category and risk matrix, until more complex tools using probability and mathematic models for risk analysis are used.

Popular tools which have been used are the Failure Mode and Effect Analysis (FMEA) Analytic Hierarchy Process(AHP), Bayesian network (BN), Fuzzy set, Expected utility theory and Monte Carlo Simulation with few paper used less popular tools such as Bubble Diagrams (Abrahamsen and Aven 2011), Control Charts (Hamza 2009) and Theory of constraints (TOC) (Steyn 2002).

FMEA which is simple but a powerful tool which does not require high levels of user skill, has been use in several papers (Carbone and Tippett 2004, Segismundo and Miguel 2008, Zhang and Chu 2011). One example by Zhang, Zhang, and Zhang (2010) successfully used FMEA specifically for Safety, Environmental and Quality Risks.

Another example of tools with a wide use in risk management application is Analytic Hierarchy Process (AHP). An example of a study used AHP by Dey (2010) which demonstrated the development of integrated framework for managing project risks. The study combined AHP and a traditional risk map approach to manage project risks in different levels from a project's work package, down to activity levels.

Another approach of the risk management study by Chin et al. (2009) considered project risks as the network and used the Bayesian network approach to facilitate the evaluation of NPD projects by determining the project execution risk. In this study, four major groups of risks are identified as nodes in a network. Four nodes

consisted of research and development risk, supply risk, production risk and product reliability risk. This group of risks is further incorporated into a Bayesian network to facilitate quantitative risk analysis for the NPD project.

In summary, risk management tools that used in risk research can be separate in the group of traditional project management tools such as risk breakdown structure, risk matrix and more advanced tools which focus on risk analysis and probability calculation. Most of the advanced risk analysis tools using complex calculations which can be difficult for the user in the NPD project who are not an expert in Project Management or Risk management.

The summary of tools and methodology used for the risk management process in research from our literature review can be seen in Table 2.9.

Table 2.9 Tools and methodologies used in risk research

Tools and Methodology for risk assessment	**Reference Papers**
Analytic Hierarchy Process (AHP)	Badri et al,2012; Dey,2002; Jaskowski & Biruk,2011; Kayis et al,2006; Kayis et al,2007; Kumar Dey,2010;Nieto-Morote & Ruz-Vila,2011
Bayesian network (BN)	Al-Rousan et al.,2009; Chang Lee et al.,2009; Chin et al.,2009; Feng & Yu, 2004; Hu et al.,2012
FMEA	Carbone & Tippett,2004; Segismundo & Augusto,2008; Zeng et al.,2010; Zhang & Chu,2011
Fuzzy set	Abdelgawad et al.,2010; Choi & Ahn,2010; Tüysüz & Kahraman,2006; Zeng & Smith,2007; Ismail et al.,2008; Zou & Li,2010; Wei & Chang,2011
Expected utility theory	Kutsch & Hall,2005; Miles,2004
Game theory	ZHAO & JIANG,2009
Theory of constraints	Steyn,2002
Monte Carlo Simulation	Liou et al.,2012; Sharma & Suri,2011; Turgut & Baykoc,2007; Vanhoucke,2012
Bubble Diagrams	Abrahamsen & Aven,2011
Control Charts	Salah Eldin,2009

Financial Model	Bukvic et al.,2009; Fan et al,2008; Flage & Aven,2009; Johal et al.,2008; Pan & Chen,2006 Rebiasz,2007; Rouse and Houghton,2002
PMI PMBOK	Benta et al.,2011; Chapman,2006; Chia,2006; Globerson & Zwikael,2002; Kwak & Ibbs,2002; Jafari et al.,2011; Fenollera et al.,2011; Pana & Simionescu,2011; Nielsen,2006; Wickboldt et al.,2011
Other RM standard	Chapman,2006; Elkington and Smallman,2002; Rodgers,2011; van der Peijl J et al.,2012; Wickboldt et al., 2011

2.2.2 Comparison of risk analysis tools

Table 2.10 Comparison of analysis tools

Analysis Tools	Characteristics	Application	Benefit/Limitation
Failure mode and effects analysis (FMEA)	Use RPN number calculate from Occurrence, impact and control or risks	Assessment for failure of process, system or design	Benefit: Good for initial assessment. Limitation: Cannot be used with complex decision. Qualitative analysis only. (ISO31010,2009)
Analytic Hierarchy process (AHP)	Hierarchy structure Based on paired comparison Priorities of factors and criteria	Multi-criteria decision making	Benefit: Straight forward approach. Easy to implement. Limitation: Strict hierarchy. Elements in same level are independent of each other.
Analytic Network Process (ANP)	Structured of clusters, nodes and links as network 3 Super-matrices, Unweighted Super matrix, Weighted Supermatix and Limit Supermatrix	Multi-criteria decision making with dependence and feedback	Benefit: Can handle dependencies between elements. Can express relationship of each element through relative weight. Limitation: Cannot quantify influences among elements.

Bayesian Network (BNs)	Bayesian probability Directed acyclic graph (DAG) Nodes and arcs Condition probability table	Decision under uncertainty and limit information.	Benefit: Causal probabilistic models Can handle dependencies and quantify influence among elements. Limitation: Medium breadth & depth of analysis and medium validity of outcome (Peniwati, 2007)
Fuzzy Inference System (FIS)	Use Fuzzy Set theory to create inference system by expert knowledge	Decision under uncertainty and subjective judgments	Benefit : Developed specifically to deal with uncertainties that are not statistical in nature (Zadeh 1965) Efficient tool for applications where no sharp boundaries or problem definition (Markowski, Mannan, and Bigoszewska 2009) Limitation: Limited to static problem and cannot effectively cope with dynamic properties such as the time-series data. (Vairappan et al. 2009)

For a selection of risk assessment tools for this research, we required both qualitative and quantitative analysis results for the total risk index which can be used for decision support. As summarized in table 2.10, AHP can be used as a decision support tool for multi-criteria decision making, however AHP lacks the capability to handle dependencies of the element in the same level (Jharkharia and Shankar 2007). While ANP can overcome this problem and address relations of an element in network and allow measurement of the interdependency among the factors (Yüksel and Dagdeviren 2007). However, ANP can express relationships through relative weight but still could not quantify an influence among an element which BNs seem to have more advantage at this point (Chin et al. 2009), In addition, even AHP and ANP can provide high accurate results and high validity of outcomes, but in a situation where we have to deal with uncertainty or a dynamic environment like the NPD project. It will be difficult for ANP to update results due to changes of information and elements in networks and will impact all pair-wise comparison scores in the Supermatrix. Also, in a situation where we have in-complete data and a

decision must be based on judgments or knowledge/believes of the experts such as in the case of project risk assessment, Fuzzy Inference System, seem to be effective tools for the NPD team due to it inputs that can be expressed in a linguistic way. Also, it can have different relative importance of each input (by fuzzy rule) while provide more meaningful output than FMEA or Risk Matrix with similar levels for ease of use.

2.2.3 Fuzzy set theory and fuzzy inference

Fuzzy set theory

Fuzzy Set Theory (FST) was formalized by Prof. Lofti Zadeh at the University of California in 1965 (Zadeh 1965) to solve fuzzy phenomenon problems existing in the real world, such as uncertain, imprecise, unspecific, and fuzzy situations. This theory has an advantage over the traditional set theory when measuring the ambiguity of concepts that are associated with human beings' subjective judgments (Liu et al. 2012). The significance of fuzzy variables is that they facilitate gradual transition between states and consequently, possess a natural capability to express and deal with observation and measurement uncertainties (Taylor, 2008).

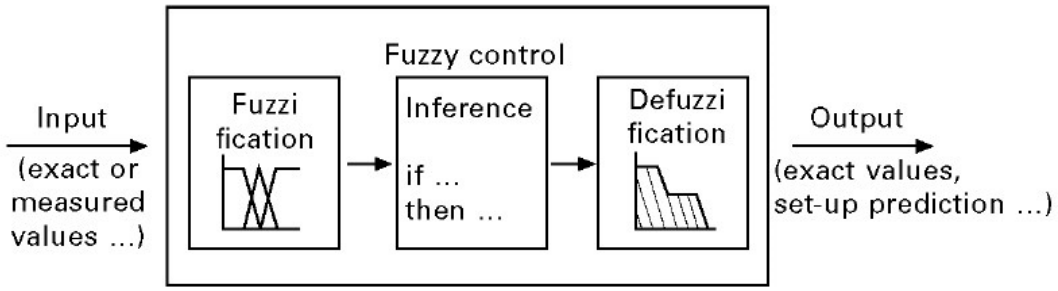


Figure 2.8 Principle of a fuzzy logic controller. (Veit, 2012)

. In the classic theory of sets, very precise bounds separate the elements that belong to a certain set from the elements outside the set. Element x's membership in set A is described in the classic theory of sets by the membership function $\mu_A(x)$, as follows:

$$\mu_A(x) = \begin{cases} 1, \text{if and only if } x \text{ is member of A} \\ 0, \text{if and only if } \boldsymbol{x} \text{ is not member of A} \end{cases}$$

In fuzzy sets an object can belong to a set partially. The degree of membership is defined through a generalized characteristic function called membership function:

$$\mu_A(x): U \longrightarrow [1, 0]$$

where U is called the universe, and A is a fuzzy subset of U. The values of the membership function are real numbers in the interval [0,l] , where 0 means that the object is not a member of the set and 1 means that it belongs entirely. Each value of the function is called a membership degree. According to Seising (2007), the membership function of fuzzy set can take any value from the closed interval [0, 1]. Fuzzy set A is defined as the set of ordered pairs A = [x, $\mu_A(x)$], where $\mu_A(x)$ is the grade of membership of element x in set A. The greater $\mu_A(x)$, the greater the truth of the statement that element x belongs to set A.

If fuzzy sets A and B defined over set X. Fuzzy sets A and B are equal (A = B) if and only if $\mu_A(x) = \mu_B(x)$ for all elements of set X. Fuzzy set A is a subset of fuzzy set B if and only if $\mu_A(x) \leq \mu_B(x)$ for all elements x of set X. In other words, A $\subset$ B if, for every x, the grade of membership in fuzzy set A is less than or equal to the grade of membership in fuzzy set B. The intersection of fuzzy sets A and B is denoted by A $\cap$ B and is defined as the largest fuzzy set contained in both fuzzy sets A and B. The intersection corresponds to the operation "and." Membership function $\mu_{A \cap B}(x)$ of the intersection A $\cap$ B is defined as follows:

$$\mu_{A \cap B}(x) = \min \left\{ \mu_A(x), \mu_B(x) \right\}$$

The union of fuzzy sets A and B is denoted by A $\cup$ B and is defined as the smallest fuzzy set that contains both fuzzy set A and fuzzy set B. The membership function $\mu_{A \cup B}(x)$ of the union A $\cup$ B of fuzzy sets A and B is defined as follows:

$$\mu_{A \cup B}(x) = \max \left\{ \mu_A(x), \mu_B(x) \right\}$$

Membership Function

There are various types of membership function in fuzzy logic. Membership functions contain the membership values of elements in fuzzy set. Membership values can lie between 0 and 1. The graphs of the functions may have very different shapes and may have some specific properties (e.g. continuity). Whether a particular shape is suitable or not can be determined only in the application context (Klir and Yuan, 1995). In many practical instances, fuzzy sets can be represented explicitly by

families of parameterized functions, the most common being Triangular functions and Trapezoidal function.

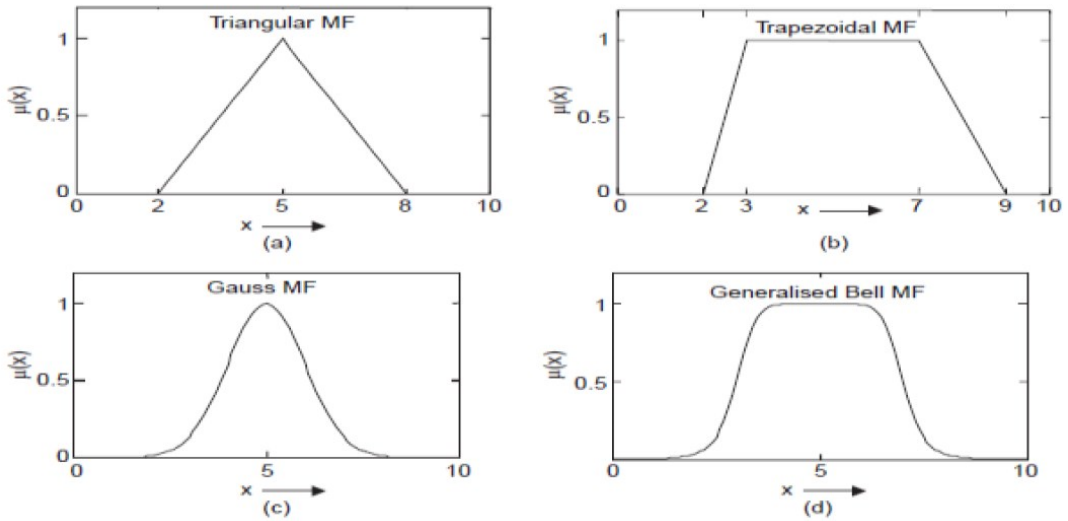


Figure 2.9 Fuzzy logic membership functions (Nassa and Yadav 2012)

A positive trapezoidal fuzzy number A can be denoted as (a1, a2, a3, a4). The membership function A is defined as:

$$\mu_{\tilde{A}}(x) = \begin{cases} 0, & x < a_1, \\ \frac{x-a_1}{a_2-a_1}, & a_1 \leqslant x \leqslant a_2, \\ 1, & a_2 \leqslant x \leqslant a_3, \\ \frac{x-a_4}{a_3-a_4}, & a_3 \leqslant x \leqslant a_4, \\ 0, & x > a_4. \end{cases}$$

where [a2, a3] is called a mode interval of A, and a1 and a4 are called lower and upper limits of A, respectively.

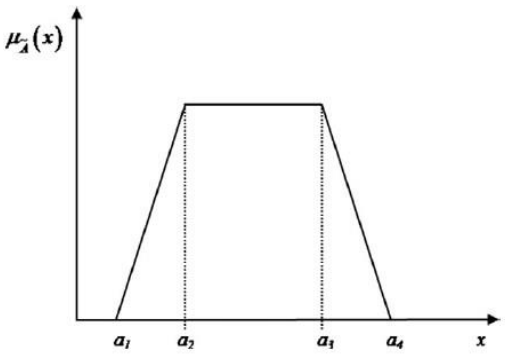


Figure 2.10 Trapezoidal membership functions

Give any two positive trapezoidal fuzzy numbers A = (a1; a2; a3; a4) , B = (b1; b2; b3; b4) and a positive real number r, the algebraic operations of the trapezoidal fuzzy numbers can be displayed as follows:

$$\widetilde{A} \oplus \widetilde{B} = [a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4],$$

$$\widetilde{A} \ominus \widetilde{B} = [a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1],$$

$$\widetilde{A} \otimes \widetilde{B} \cong [a_1 b_1, a_2 b_2, a_3 b_3, a_4 b_4],$$

$$\widetilde{A} \otimes r \cong [a_1 r, a_2 r, a_3 r, a_4 r].$$

The operations of $\vee$ (max) and $\wedge$ (min) are defined as follow:

$$\widetilde{A} \vee \widetilde{B} \cong [a_1 \vee b_1, a_2 \vee b_2, a_3 \vee b_3, a_4 \vee b_4],$$

$$\widetilde{A} \wedge \widetilde{B} \cong [a_1 \wedge b_1, a_2 \wedge b_2, a_3 \wedge b_3, a_4 \wedge b_4].$$

Fuzzy Rule

According to basic definition of fuzzy set theory by Teodorovič and Vukadinovič (1998). The basic elements of each fuzzy logic system are rules. Fuzzy rules can conveniently represent the knowledge of experienced operators used in control. The rules can be also formulated by using the observed decisions (input/output numerical data) of the operator. Fuzzy rule (fuzzy implication) takes the following form:

If x is A, then y is B

Where A and B represent linguistic values quantified by fuzzy sets defined over universes of discourse X and Y. The first part of the rule “x is A” is the premise or the condition preceding the second part of the rule “y is B” which constitutes the consequence or conclusion.

Let us consider a set of fuzzy rules containing three input variables x_1, x_2, and x_3 and one output variable y.

Rule 1: If x_1 is P_{11} and x_2 is P_{12} and x_3 is P_{13}, then y is Q_1,

or

Rule 2: If x_1 is P_{21} and x_2 is P_{22} and x_3 is P_{23}, then y is Q_2,

or

Rule k: If x_1 is P_{k1} and x_2 is P_{k2} and x_3 is P_{k3}, then y is Q_k.

The given rules are interrelated by the conjunction or. Such a set of rules is called a disjunctive system of rules and assumes the satisfaction of at least one rule. It is assumed that membership functions of fuzzy sets P_{k1} and P_{k3} (k = 1, 2, ..., K) are of a triangular shape, whereas membership functions of fuzzy sets P_{k2} and Q_k (k = 1, 2, ..., K) are of a trapezoidal shape.

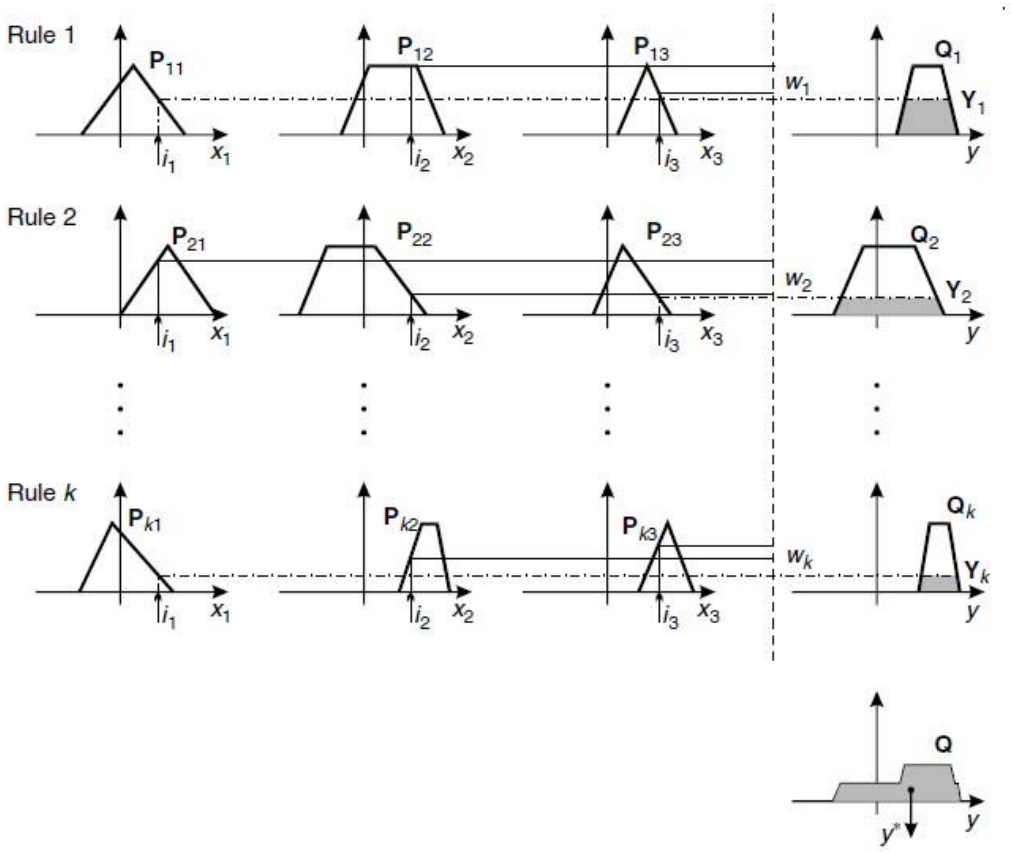


Figure 2.11 Graphical interpretation of a disjunctive system of rules (Taylor, 2008)

Let the values i1, i2, and i3, respectively, taken by input variables x1, x2, and x3, be known. In the considered case, the values i1, i2, and i3 are crisp. Figure 3.13 also represents the membership function of output Q. This membership function takes the following form:

$$\mu_Q(y) = \max_k \left\{ \min \left[\mu_{P_{k1}}(i_1), \mu_{P_{k2}}(i_2), \mu_{P_{k3}}(i_3) \right] \right\}, \quad k = 1, 2, \ldots, K$$

Whereas fuzzy set Q representing the output is actually a fuzzy union of all the rule contributions Y_1, Y_2, ..., Y_k, that is:

$$\mathbf{Q} = \mathbf{Y}_1 \text{ U } \mathbf{Y}_2 \text{ U } \ldots \text{ U } \mathbf{Y}_k$$

$$\mu_Q(y) = \max\left\{\mu_{Y_1}(y), \mu_{Y_2}(y), \ldots, \mu_{Y_k}(y)\right\}$$

The value $\mu_{P11}(i_1)$ indicates how much truth is contained in the claim that i_1 equals P_{11}. Similarly, values $\mu_{P12}(i_2)$ and $\mu_{P13}(i_3)$, respectively, indicate the truth value of the claim that i_2 equals P_{12} and i_3 equals P_{13}.

Value w_1, which is equal to

$$w_1 = \min\left\{\mu_{P_{11}}(i_1),\ \mu_{P_{12}}(i_2), \mu_{P_{13}}(i_3)\right\}$$

indicates the truth value of the claims that, simultaneously, i_1 equals P_{11}, i_2 equals P_{12} and i_3 equals P_{13}. As the conclusion contains as much truth as the premise, after calculating value w_1, the membership function of fuzzy set Q_1 should be transformed. In this way, fuzzy set Q_1 is transformed into fuzzy set Y_1. Values w_2, w_3, ..., w_k are calculated in the same manner leading to the transformation of fuzzy sets Q_2, Q_3, ..., Q_k into fuzzy sets Y_2,Y_3, ..., Y_k.

Defuzzification

An important step in fuzzy modeling and fuzzy multi-criteria decision-making is the defuzzification task which transforms a fuzzy number into a crisp value. Many different techniques for this transformation can be utilized,

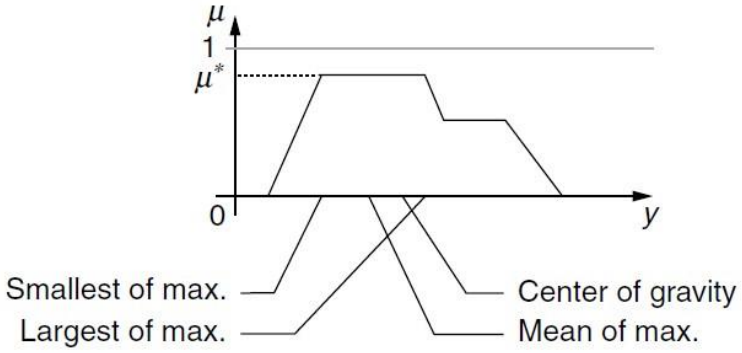


Figure 2.12 Defuzzification methods (Taylor, 2007)

The most commonly used defuzzification method is the centroid defuzzification method, also known as the center of gravity (COG) or center of area (COA) defuzzification. The centroid defuzzification method can be expressed by following relation:

$$\bar{x}_0(\tilde{A}) = \frac{\int x\mu_{\tilde{A}}(x)dx}{\int \mu_{\tilde{A}}(x)dx},$$

where $\bar{x}_0(\tilde{A})$ is the defuzzified value. For trapezoidal fuzzy number (a1, a2, a3, a4) (Liu et al. 2012)

CHAPTER 3
RESEARCH METHODOLOGY

Research methodology in this chapter consists of five parts: 1) Research design; 2) Systematic literature review method; 3) Risk management model development; 4) Validation and refinement of risk management model and 5) Risk management tool development.

3.1 RESEARCH DESIGN

Research design comprises of methodology uses in four research phases and frame work of research design.

Research Methodology

1) Literature study of PM body of knowledge and ISO standards related to risk management.
2) Systematic Literature Review for research gap, risk management process, risk factors and research tool.
3) Study risk management practice and develop risk management model by expert in-depth interview.
4) Refine risk management model and risk factors by 4 case studies of NPD in food industry.
5) Develop NPD risk management tool using software development process

Table 3.1 Research methodology and output

Research Objective	Research Process	Research Method	Output
To explore the risk management process in NPD projects	Phase I	Literature study and Systematic Literature review	Conceptual Background of risk management for NPD
To study risk management practice for NPD of food companies in Thailand.	Phase I	Questionnaire Survey and short interview	Need of industry and concept for model development
To explore risk common risk factors in NPD projects.	Phase II	Questionnaire Survey	Common risk factors in NPD
To develop risk assessment model for NPD Projects.	Phase III	In-depth Interview	Risk assessment model
To validate & refine risk assessment model	Phase IV	Case study and Action Research	Refined risk assessment model and tool conceptual
To develop risk assessment tool	Phase V	Software development process	Prototype of software tool for NPD risk assessment

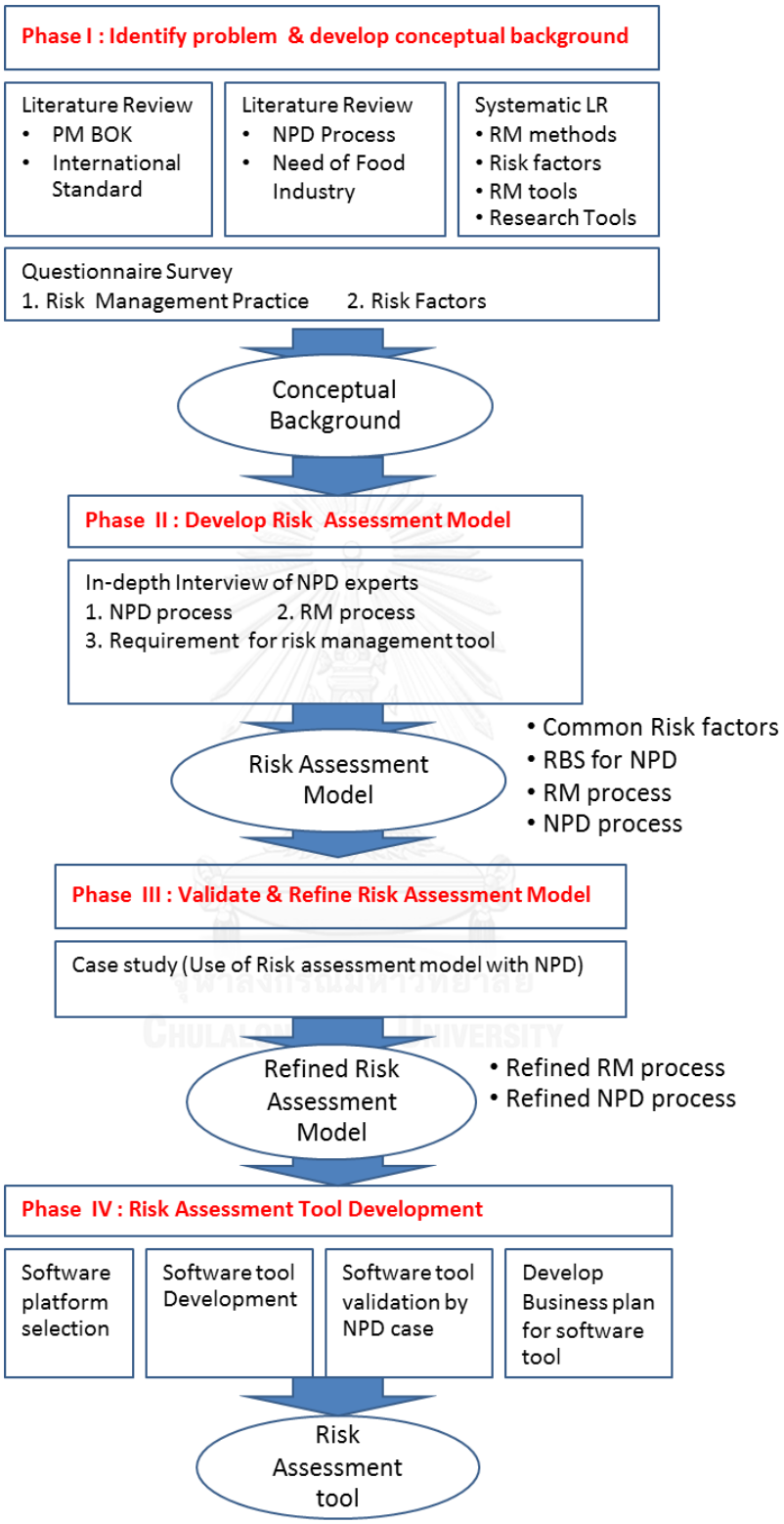


Figure 3.1 Research design framework

The overview of process step, methodology and output of each step during the process to develop list management model are illustrated in Figure 3.2.

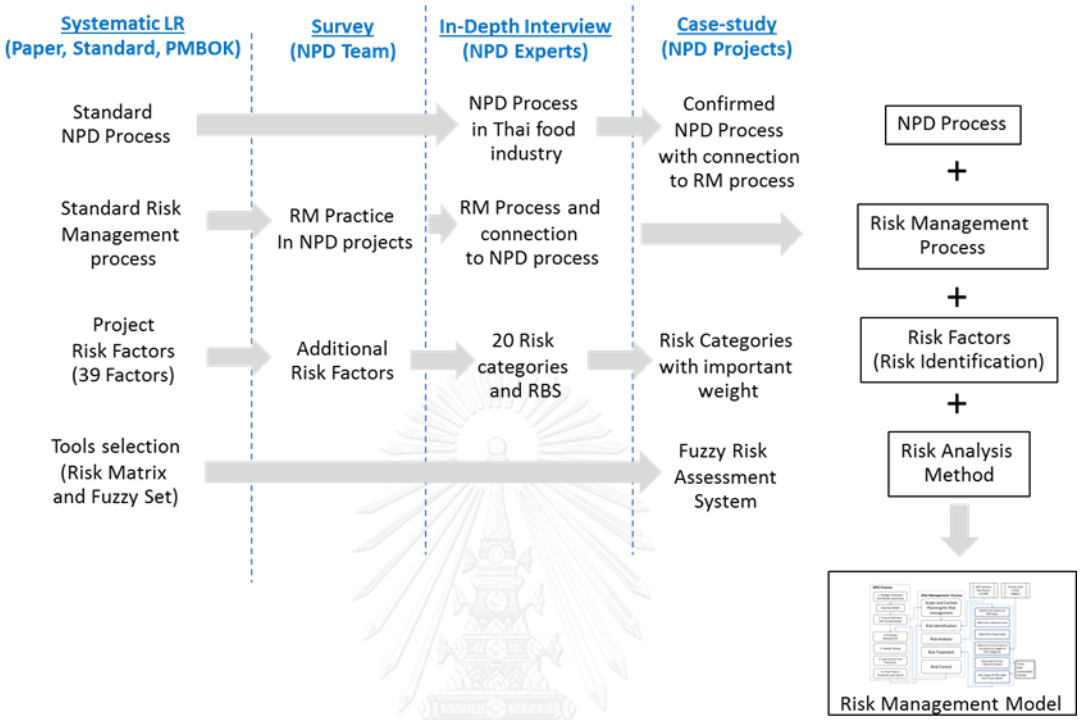


Figure 3.2 Process for development of risk assessment model

3.2 SYSTEMATIC LITERATURE REVIEW METHOD

The systematic literature review is a review of articles that clearly formulate the searching strategy and method for screening. This methodology can limit the bias by random select or non-systematic search. The review follow the 4 process step for 1) Searching; 2) Screening; 3); Data Extraction; and 4) Synthesis.

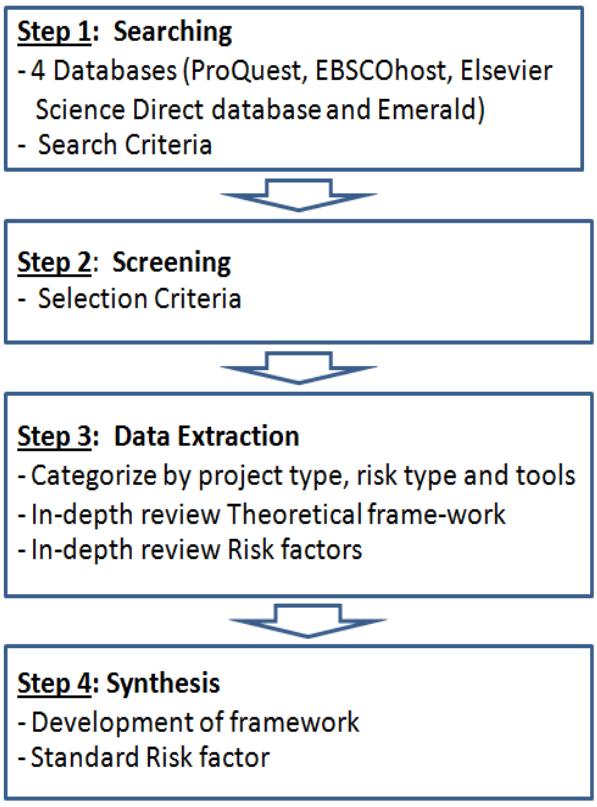


Figure 3.3 Process steps for systematic literature review

3.2.1 Database selection

For selection of document collection, we decided not to be specific on any Journal due to Risk Management and Product Development are the interdisciplinary subject which can be published in many journal of different research area. However we also assured the conclusion of main journal on Project Management such as Project Management Journal and International Journal of Project Management should be included in document collection.

We conducted initial search to see the number of paper about project management and risk management in each database that we have access by university network then selected 4 major databases that initial search found highest number of publication about risk management and project management. 4 databases are (1) ProQuest; (2) EBSCO host; (3) Elsevier Science Direct; and (4) Emerald.

1) ProQuest- included ABI/INFORM Complete (search.proquest.com);
2) EBSCOhost (web.ebscohost.com);
3) Elsevier Science Direct (www.sciencedirect.com);
4) Emerald (www.emeraldinsight.com);

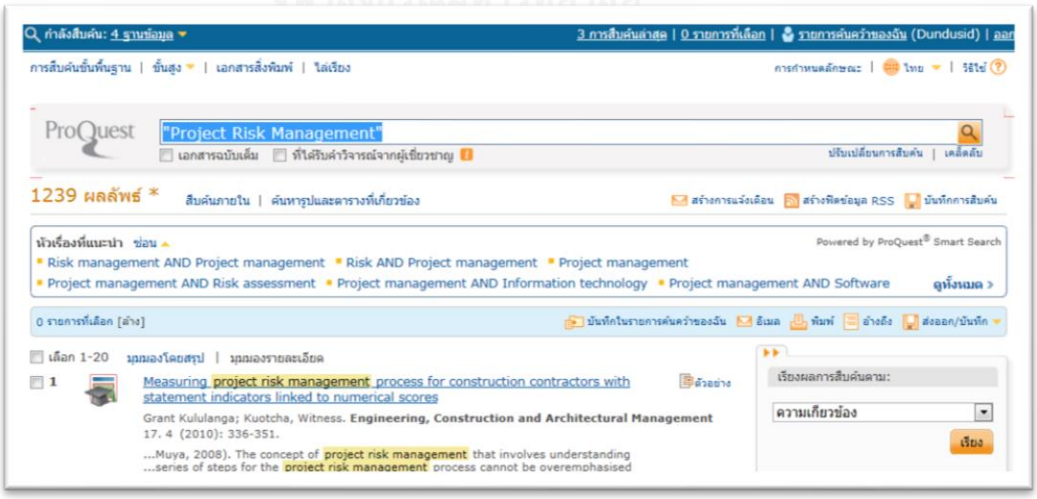


Figure 3.4 ProQuest database

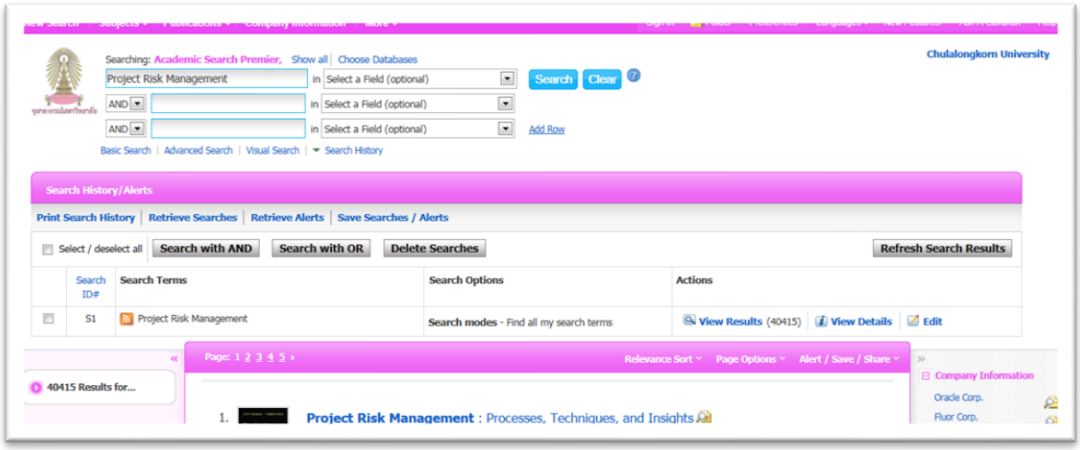


Figure 3.5 EBSCOhost database

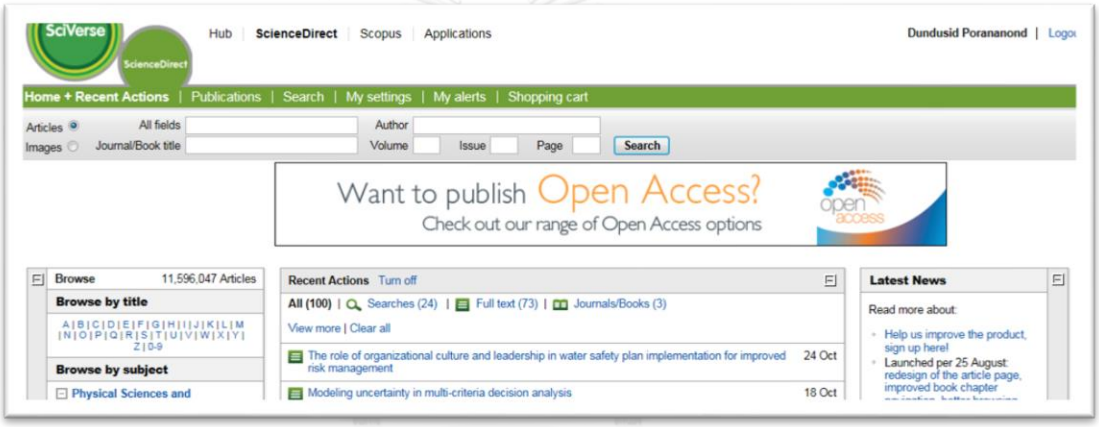


Figure 3.6 Elsevier Science Direct database

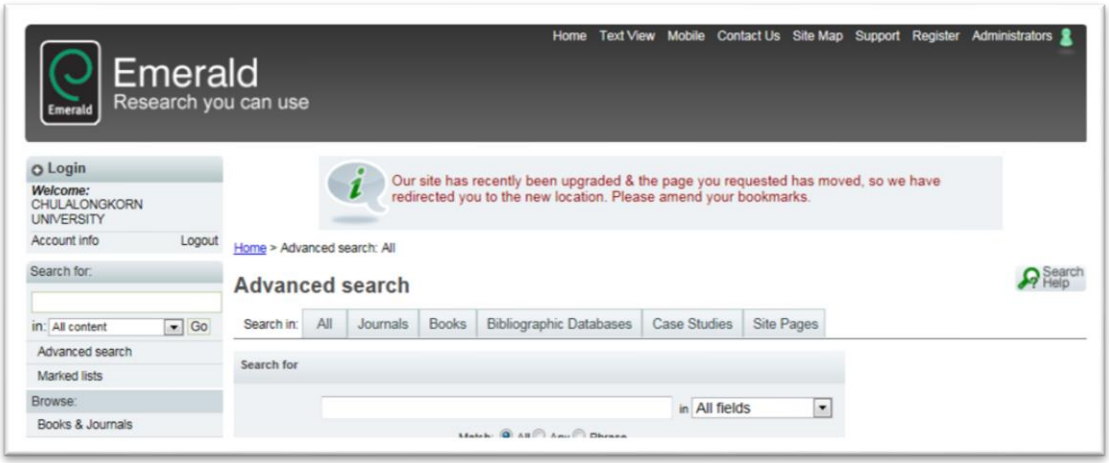


Figure 3.7 Emerald database

3.2.2 Search criteria

The search criteria for Literature Review are following.

1) Journal article with peer review only. Book chapter, non-peer review publication, technical paper and editorial papers were not included. However, some proceeding with content strongly related to the topics also included.
2) The search start from record of paper published in January 2002 until August 8, 2012. The paper published in 2012 after the search period will not be incuded.
3) The search term were used to search title, abstract and keywords of paper in database.
4) We did not use single search term in each research area for Risk management, Project Management or New Production Development due to broad description results excessive number of paper in each major research areas but we search the paper in overlap areas of each major areas instead.
5) Some search term does not direct relate to "Risk" but relate to Product development and project management also include in the review.

The search term;

- (Project Risk) AND (Product Development)
- (Project Risk) AND (Project Management)
- (Risk Analysis) AND (Product Development)
- (Risk Analysis) AND (Project Management)
- (Risk Assessment) AND (Product Development)
- (Risk Assessment) AND (Project Management)
- (Risk Management) AND (Product Development)
- (Risk Management) AND (Project Management)
- (Product Development) AND (Project Management)

We found 2,271 papers from search criteria, 427 papers from ProQuest database; 1507 papers from EBSCOhost database; 248 papers from Elsevier Science Direct

database; and 89 papers from Emerald database. After remove duplication and papers type out of scope, including and some items that we do not have access to full paper, total number of paper reduce to 1266 papers to go next step for screening process.

3.2.3 Inclusion criteria

Papers were selected by inclusion criteria. They will be selected if they have.

1) Discuss on definition, framework, and methodology about project risk
2) Discuss about problem, success factor and risk factor of project from project management perspective
3) Case study or empirical study relate to project risk
4) Discuss about development of tools and technique and application of risk management
5) This study is focus on risk management of new product development project but paper about the risk management in other type of project also be considered to see the difference in approach and also find opportunity to apply in NPD project.
6) The search criteria focus on overall project risk management but also extent to specific step in risk management process for risk assessment and risk analysis.
7) Some paper which were not found from search criteria but related to some important topics or used as important reference in selected paper has been added in to collection of review papers.

From 2,271 paper from search result, we eliminate duplication from search term and also exclude the items without full paper in database then the number of paper reduce to 1278 and then the papers were screen by title to 541 papers before download the full paper for abstract screen at 326 paper and final full text screen until 182 papers remain at final step.

Table 3.2 Number of article in screening process

	ProQuest	EBSCOhost	ScienceDirect	Emerald
Total Search results	427	1507	248	89
Exclude duplication from search term	293	701	204	80
Screen by title	190	125	151	75
Screen by abstract	326			
Full text screening	182			

The final selected articles of 182 were collected by using an excel database as shown in Figure 10. The columns of the database was designed by title, author, year, focus of the study, research methodology, type of project, area of application (Industry segment), theory/tools used, contribution in risk management, type of risk and citation.

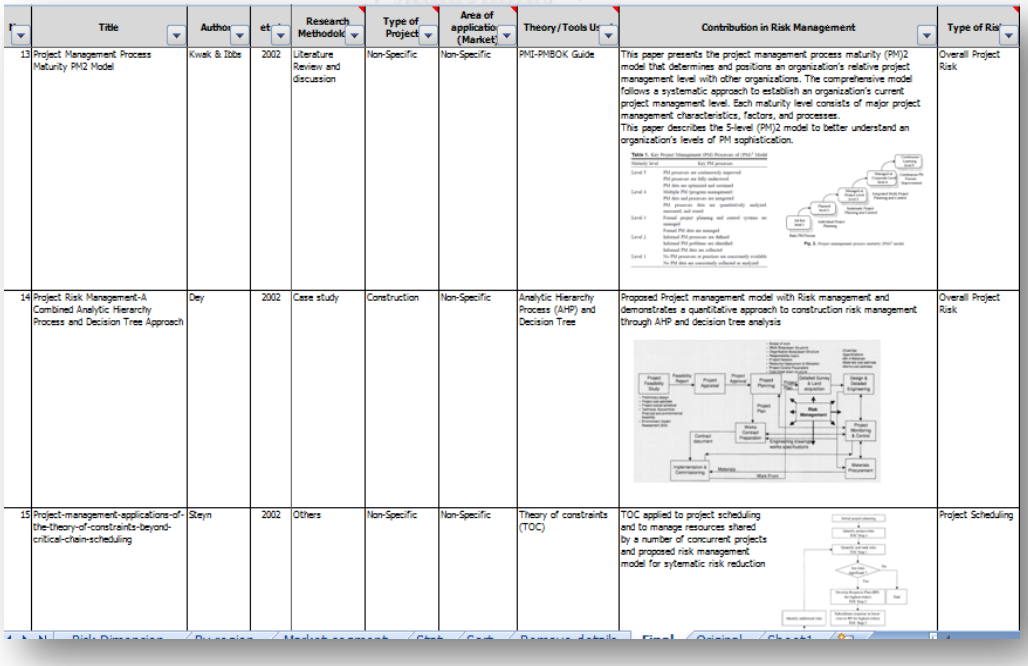


Figure 3.8 Excel database for summary of contribution in risk management

3.3 RISK MANAGEMENT MODEL DEVELOPMENT

The process to establish Risk Management model use the conceptual data from literature review in phase I combine with empirical data from food industry in Thailand which gathering by questionnaire survey and in-depth interview.

3.3.1 Questionnaire

Objective of Survey

1) To confirm common risk factors of NPD project in food industry obtained from literature review.

2) To study actual risk management practice of NPD project in food industry for model development.

Sample Selection and sample size

1) The target group of survey is the food companies in Thailand in medium and large size. (Turnover more than 50 million Baht or employee more than 50).

2) Include both of local and multinational companies which have NPD activities in organization.

3) The survey target on project leader and member of NPD team in food companies.

Questionnaire

Part 1 : Questions on company and Respondent profile; company name, name, gender, function and role in project, experience or year in service.

Part 2 : Questions on risk factors in NPD; provide the list of common risk factors from literature review and case study and ask respondent to rate level of importance of each factor by Likert scale from 1-5.

Part 3: Questions on risk response practice; ask open ended question for organization practice on how they dealing with identified project risks.

3.3.2 Expert interview

The objective of expert interview is to understand perception and practices of risk management in new product development projects in food industry. This process also seeks understanding of new product development process from expert's experiences in her/his organization, including involvements of their staff from each function and process steps that involved project risk assessment, including specific need and major risk factors that they found in each projects. This study selects experts from members of new product development teams from middle to large size company to ensure that they have some understanding in risk concept and see the importance of risk management, including have enough resource and interested in improvement of new product development process by adapt risk management procedure in their work.

<u>The objective of expert interview in food industry</u>

1) To study NPD process in Thai food industry
2) To study current risk management process, strategy and connection to NPD process
3) To confirm risk categories from conceptual background phase.

3.3.3 Risk assessment method

Risk assessment method used in this research consists of risk identification and risk analysis process. The methodology have been used to develop this assessment method are defined as following.

Risk Identification

The common risk factors from literature review and empirical study has been group and generate in deference level to use as risk break down structure for risk identification. The process to develop RBS is explained in Figure 3.9.

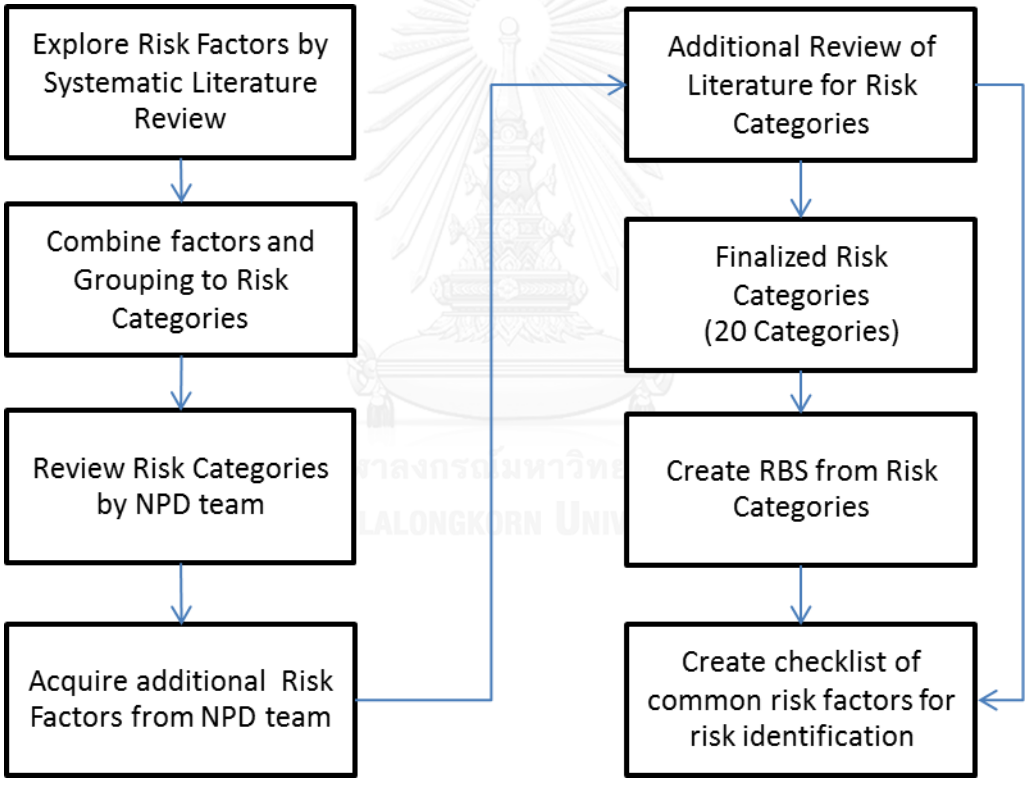


Figure 3.9 Development process of risk breakdown structure

Risk Analysis

The risk analysis process used in this research is performed by fuzzy inference system in MATLAB® software. The process step to create risk analysis module are explained in Figure 3.10.

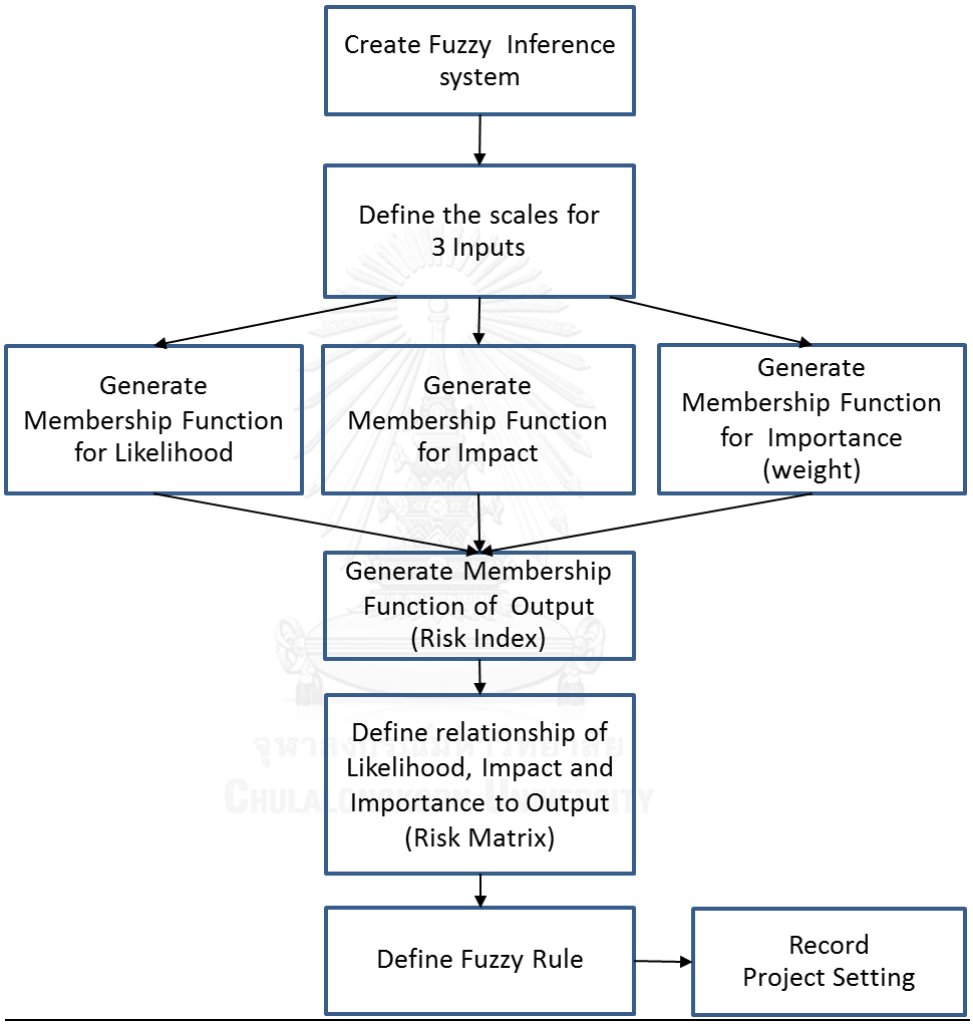


Figure 3.10 Process steps to create fuzzy risk assessment system

3.4 VALIDATION & REFINEMENT OF RISK MANAGEMENT MODEL

This phase of the research will use multiple case studies by obtaining data from four NPD projects in private segments of Food manufacturing in Thailand. According to the Thailand Development Research Institute report on the Situation and Trend for Employment in food industry (TDRI 1996), food companies in Thailand have been categorized based on assets (excluding land valve), into a small size with assets less than 10 million baht, a medium size with assets 10 to 50 million Baht and a large size with assets with more than 50 million Baht. The case study for this research will be selected from medium and large food companies due to the few small food companies that do much NPD in Thailand (Suwannaporn and Speece 2000).

Criteria for case study selection from industry collaboration will include.

1) Projects that started within the last 5 years. It can be a completed project that already passed product launch and mass production or can be an ongoing project that has enough information for project planning on all NPD phases.
2) The criteria also includes projects with all in-house NPD activities in an organization or a project that has some outsource activities and has access to research data from an outside partner.
3) The NPD project must include a strategic or annual plan of the organization with a clear responsibility and team assigned to ensure involvement of all related functions and an official NPD process that will be used by organization..

Methodology for a case study research will follow the process steps proposed by Yin (2003) which has four stages for design of the case study, conduct the case study, analyze the case study evidence and develop the conclusions, recommendations and implications.

3.4.1 Design the case studies

The research design of a case study is planned according to the process steps defined by Yin (2003) and Rowley (2002) recommendation as following.

1) The study's question: these case studies aim to understand the effectiveness and appropriateness of a risk assessment model used in current NPD projects in food companies. The outputs of the study also include an understanding in the perceived risk factors in each NPD project and their importance in the viewpoint of the NPD team member. These data can be used to improve risk assessment model and risk assessment tools in further steps of research.
2) The study's propositions: use a proposed risk assessment model developed from the literature review and empirical studies in previous research steps which consists of new a NPD process modified for the food industry, risk management process and a fuzzy risk assessment method proposed by this research.
3) The study's unit of analysis: plan to collect data from members of a NPD project who is involved in 6 phases of the NPD process. A NPD team members who was selected for this process, came from following function.
   - Marketing
   - Research and development staffs
   - Designer
   - Finance
   - Manufacturing & engineering
   - Legal
   - General management
   - Others function as required by each project
4) The logic linking the data to proposition.
5) The criteria for interpreting findings.

3.4.2 Conduct the case studies

The process to conduct case studies will be a guide by using a case study protocol. The protocol will be developed in a further research step which will include the following components.

1) Overview of case studies: include case study details, target group and methods to conduct case experiments. This information used to explain the objective and procedure to participants.
2) Field procedures: explain the process step to conduct a case study
3) Case study questions: used for asking questions or remind the interviewer during data collection.

3.4.3 Analyze case studies

The data from the case studies are collected by the observation of risk assessment activities by the NPD team and utilize questionnaires to collect data at the end of experiment session. The data was analyzed in 3 areas consisting of 1) NPD process; 2) Risk management process; 3) Risk assessment method (consist of risk identification by common risk factors and risk analysis by a fuzzy risk analysis). The methods for data analysis are as following.

1) NPD Process: The specific NPD process from a proposed risk assessment model has been used to organize the NPD activities included in the risk assessment. The input from participants after the case experiment are obtained and used for validation of the NPD process in a model.

2) Risk Management Process: The appropriateness of steps and sequences of risk management process in proposed model are analyzed using the input from participant after case experiment sessions.

3) Risk assessment method: The effectiveness of a risk assessment method using risk breakdown structures and checklists for risk identification and the fuzzy inference system for risk analysis, are evaluate after each case experiment session.

3.4.4 Develop the conclusion

The inputs of case studies from observations and the data gathering method defined in previous steps, are used to refine risk management models which consist of three major elements: 1) NPD process; 2) Risk Management Process and connection to the NPD phase; and 3) Risk assessment method using a Fuzzy Inference system.

3.5 RISK MANGEMENT TOOL DEVELOPMENT

3.5.1 Development process

The software development process for prototype of risk management tool in this research will follow Rapid Application Development (RAD) methodology which first developed and successfully deployed by the New York Telephone Co's Systems Development Center during the mid of 1970s.

Four phase of RAD for software development are as follow.

Table 3.3 Four phases of RAD

Phase	Activities
Phase 1: Requirements Planning phase	Activities included combines elements of the system planning and systems analysis phases of *the System Development Life Cycle (SDLC).*
Phase 2: User design phase	Users communicate with systems analysts to provide requirement and develop models or prototypes that represent all system processes, inputs, and outputs of application.
Phase 3 : Construction phase	This phase focuses on program and application development tasks, The activities include programming, application development, coding, unit-integration and system testing. In this phase users can continue to participate and can still suggest changes or improvements as actual screens or reports are developed.
Phase 4 : Cutover phase	The tasks, including data conversion, testing, changeover or migrate to the new system, and providing user training.

Compared with traditional methods for application development, RAD can compressed the entire process; result in much sooner development time.

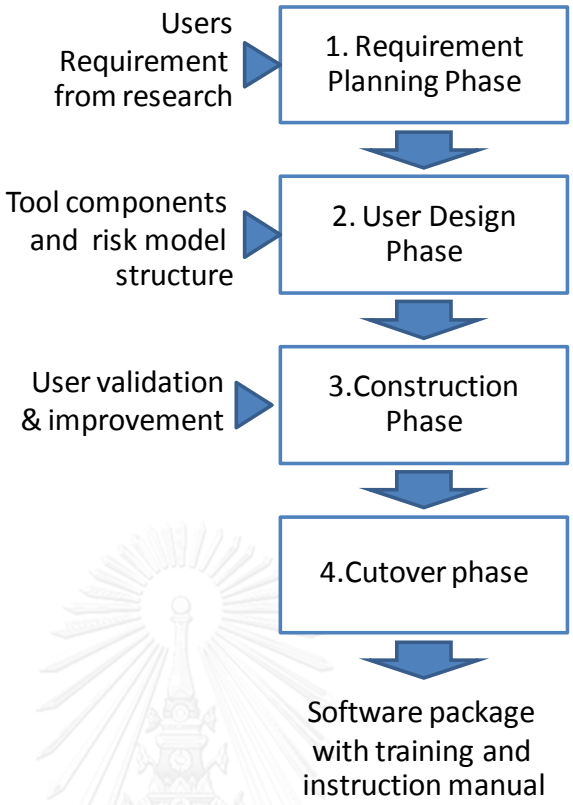


Figure 3.11 Process steps and inputs of software tool development

3.5.2 Tool validation

The researcher will strongly involve in Requirement planning and user design phase by using the data collected from this study. Then the prototype of this tool from construction phase will be tested by NPD team in industry by real NPD projects. Then the questionnaire survey is used to determine user acceptant and opinions for improvement. Then the change or improvement of software will implement in last step of construction phase and continue to Cut-over phase for final testing, training and user manual.

The validation of risk assessment tool was followed the concept of Technology acceptance model (TAM) (Davis 1989, Davis, Bagozzi, and Warshaw 1989) which separated the assessment area into four areas as following.

1) Feasibility/Actual Use

2) Usability/Perceive Ease of use

3) Utility/Perceived usefulness

4) Behavioral intend to use

The questionnaire survey for user acceptance has been used to collect data from NPD team. The results of user acceptance are presented in Chapter 7.

CHAPTER 4

ESTABLISHING CONCEPTUAL BACKGROUND

4.1 RISK MANAGEMENT MODEL IN RESEARCH

4.1.1 Research trend

In order to establish conceptual background that will be used for development of appropriate risk management model for NPD project in the food industry, the author has studied research trend and risk management model proposed by researchers in the past 10 years and the findings can be summarized as following.

Project Risk management model or framework in research papers that we have reviewed can be separated in two types for 1) high level conceptual model; and 2) detail flowchart diagrams of methods or systems used for risk management.

The high level conceptual models explain overall approach, process step and relation of each step of risk management in each context or applications. This type of conceptual framework may include influential factors or input-output in to the process.

One example for this type of framework can be seen in the paper about Aligning building information model tools and construction management methods by Hartmann et al. (2012) which proposed RISMAN model for construction work. However, all process steps follow general risk management approach that included determining of risk management goal, risk identification, risk analysis and prioritization and determining of risk control measure.

The second type of framework that founded in the literature review will have more details and specific information present in flowchart format to explain the details step for method or system that they used for risk management such as fuzzy assessment model by Nieto-Morote & Ruz-Vila, (2011) or risk management model for build-operate-transfer projects by Dey & Ogunlana (2004).

However, there is no significant difference in process step or approach to risk management and most of these conceptual frameworks will align with process step from well-known project management standard and guideline which Kutsch and Hall (2010) also compared main project risk management process in PMBOK(PMI,2004), Office of Government Commerce(OCG, 2007) and PRAM (APM) in table below.

4.1.2 Model comparison

PMBOK (PMI 2008) defines risk as an uncertain event or condition that, if it occurs, has an effect on at least one project objective. Similarly, risk management standard ISO31000 (2009) and AS/NZS 4360 (2004) define risk as the chance that something happening that will have an impact on an objective. Traditionally risk was perceived negatively but new but recent standards suggest the impact of risk could be either negative or positive.

The recent study by Jafari et al.(2011) which reviewed four well-known approaches to risk management: PMBOK (PMI, 2004), project risk analysis and management (PRAM) (Simon et al., 1997; Association for Project Management, 2004), management of risk (MOR) (Office of Government Commerce, 2002) and the standard AS/NZS4360 (Standards Australia/Standards New Zealand, 2004) indicated that there were no significant difference for risk management process among them. This study expand further review to additional standard for ISO31000 (ISO,2009), ISO1006 (ISO,2003) and ISO21500 (ISO, 2012), including and new released PMBOK 5th Edition (PMI, 2013).

All standards that were included in this review connect to project risk management in different perspective. AS/NZS4360 and ISO31000 cover risk management for all organization activities (included project) while the ISO10006, ISO21500 and PMBOK limit the scope for project activities only and risk management is one important process (or knowledge area) in their project activities. The relation to project management and risk management process for this fours standard and PMBOK are explain in Table 4.2.

Table 4.1 Summary of standard and PMBOK related to project risk management

Standard	Relation to Project Management	Risk Management Process
AS/NZS 4360:2004 Risk Management	Included but not specific to project risks	Defines risk management process as 1) Communicate and consult 2) Establish the context 3) Identify risks 4) Analyse risks 5) Evaluate risks 6) Treat risks 7) Monitor and review
ISO 31000 :2009 Risk management	Included but not specific to project risks	Defines risk management process as 1) Communication and consultation 2) Establishing the context 3) Risk assessment 4) Risk treatment 5) Monitoring and review
ISO10006 :2003 Guidelines for quality management in projects	Defines project management to 7 process grouping for 1) Inter dependency-related processes, 2) scope-related processes, 3) time-related processes, 4) cost-related processes, 5) communication-related processes, 6) risk-related processes and 7) purchasing-related processes	Defines risk-related processes group as 4 processes 1) Risk identification 2) Risk assessment 3) Risk treatment 4) Risk control
ISO 21500 :2012 Guidance on project management	Defines project management to 10 subject groups for 1) integration, 2) stakeholder, 3) scope, 4) resource, 5) time, 6) cost , 7) risk , 8) quality, 9) procurement and 10) communication.	Defines risk subject group into 4 processes 1) Identify risks 2) Assess risk 3) Treat risk 4) Control risks

PMBOK 5th Edition (PMI, 2013)	Defines project management to 10 knowledge area for 1) Project integration management, 2) Project scope management, 3) Project time management, 4) Project cost management, 5) Project quality management, 6) Project human resource management , 7) Project communication management , 8) Project risk management, 9) Project procurement management and 10) Project stakeholder management.	Defines risk management process as 6 processes as following 1) Plan risk management 2) Identify risks 3) Perform qualitative risk analysis 4) Perform quantitative risk analysis 5) Plan risk responses 6) Control risks

Comparison of process step for risk management in related standard and PMBOK are illustrated in Figure 4.1.

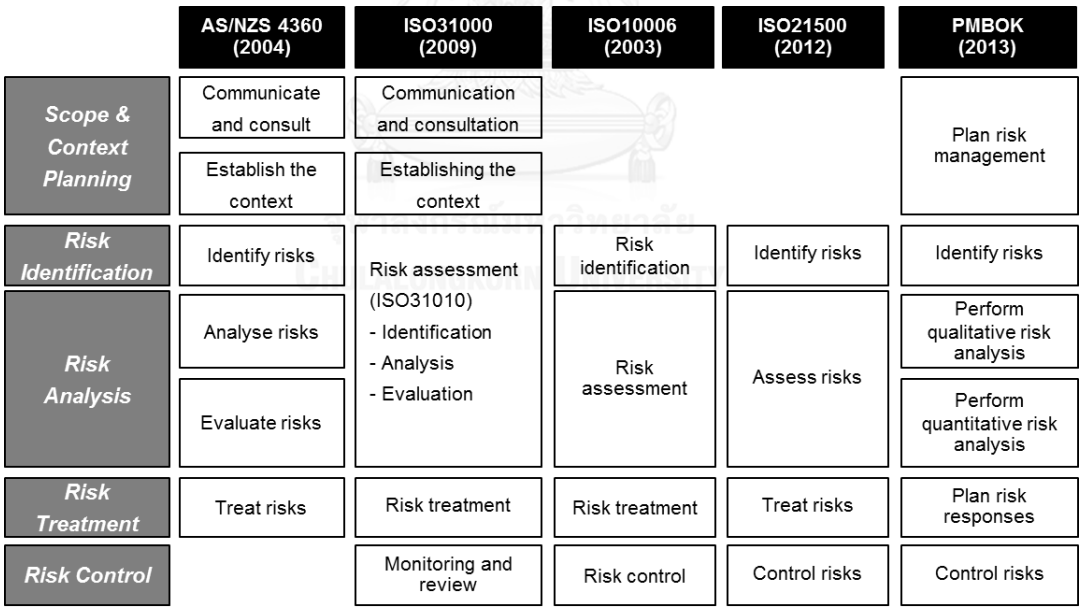


Figure 4.1 Comparison of risk management process in standard and PMBOK

4.2 INDUSTRY ANALYSIS

4.2.1 Market size and opportunity

The document published by BOI (2013) indicated that Thailand is the largest sole net food exporter in Asia, Thailand is one of the world's largest producers of food products such as rice, canned tuna, frozen seafood, chicken and canned pineapple. In 2011, the value of Thai food exports increased 20% from the previous year owing to strengthened economic performance amongst major food importers such as the US, Japan, and ASEAN countries.

Table 4.2 Thailand's export food products 2008-2011 (BOI, 2013)

Export Items	2008		2009		2010		2011	
	Metric Ton	Million US$	Metric Ton	Million US$	Metric Ton	Million US$	Metric Ton	Million US$
Total Food	29,035,481	25,935	28,767,703	25,140	28,368,985	26,755	33,247,743	32,150
Fisheries	1,672,737	7,139	1,652,205	7,004	1,729,549	7,321	1,734,829	8,168
Shrimp	358,928	2,807	398,894	3,114	427,581	3,365	392,616	3,676
Tuna	506,097	2,152	534,878	1,915	588,727	1,981	594,751	2,357
Other canned fish	193,761	555	182,770	560	190,681	560	205,036	644
Frozen fish	408,117	781	343,833	670	325,476	643	303,853	651
Cuttlefish	81,778	449	78,400	400	73,638	413	67,269	447
Others	124,056	396	113,430	344	123,447	359	171,303	393
Cereal	10,376,414	6,830	8,677,883	5,757	8,983,099	5,625	11,121,224	6,717
Rice	10,218,286	6,775	8,638,842	5,741	8,939,630	5,606	10,706,229	6,537
Others	158,128	54	39,042	16	43,469	19	414,995	180
Meat	858,584	2,119	782,067	2,016	636,067	2,073	545,194	2,371
Chicken (Prepared/ Preserved)	400,057	1,922	388,931	1,798	427,610	1,853	441,343	2,061
Others	458,527	198	393,136	217	208,457	219	103,851	310
Fruit	2,016,352	2,014	2,148,655	2,044	2,055,885	2,117	2,163,149	2,296
Pineapple (Canned/ Preserved)	650,783	683	539,297	554	550,018	552	641,185	669
Pineapple Juice	152,793	183	151,396	217	139,877	220	146,771	227
Mango	36,333	48	45,343	53	42,987	50	59,691	56

Others	1,176,443	1,100	1,412,619	1,218	1,323,003	1,295	1,315,501	1,343
Vegetable	491,487	550	451,410	548	465,634	544	559,543	654
Sweet Corn (Canned)	172,872	173	170,179	182	182,821	182	184,178	190
Baby corn (Fresh/Canned)	48,615	52	44,523	49	45,587	49	46,092	51
Others	270,000	325	236,708	316	237,227	313	329,274	413
Others Food	13,619,908	7,283	15,055,482	7,773	14,498,751	9,075	18,858,632	20,112
Sugar	5,011,802	1,588	5,052,570	2,053	4,500,969	2,311	6,520,480	3,648
Non-Alcoholic Beverage	425,723	240	355,476	307	400,444	409	551,900	541
Seasoning	177,128	328	195,097	388	222,151	432	237,502	482
Palm oil	498,115	551	185,823	157	222,000	218	482,599	532
Tapioca (Flour/starch)	1,286,513	511	1,817,735	566	1,764,107	836	1,918,374	963
Tapioca (Pellet/chip)	2,851,433	524	4,357,028	682	4,273,225	866	3,731,027	985
Feed	695,028	289	796,044	274	988,775	417	878,463	409
Pet food	268,687	651	242,483	609	275,040	658	305,038	715
Others	2,405,478	2,601	2,053,227	2,738	1,852,040	2,927	4,233,249	11,837

Thailand Food Industry offers a number of outstanding advantages for companies in the food processing industry. These include:

1) Competitive workforce: According to the Thai National Food Institute, there are proximately 800,000 laborers in Thailand's food industry. Furthermore, the government's numerous training and support organizations will ensure a robust and technically-equipped workforce today and into the future.

2) Strong Business Climate: Thailand's economy is one of the fastest growing in Asia, with 2012 GDP projected to grow by around 6.5 percent, and the World Bank Doing Business 2012 report indicated that Thailand was ranked 17th in the world and 2nd in Southeast Asia in terms of ease of doing business.

3) Hub of Asia: The reduction of tariff and non-tariff barriers articulated in free trade agreements between Thailand and India, China, Japan, Australia and ASEAN extends trade opportunities with neighboring countries. Thailand stands out amongst neighboring countries because of its bilateral and multilateral collaboration,

excellent infrastructure, abundant raw materials, skilled labor, government support, and the central location among ASEAN countries with close proximity to India and China. Furthermore, the launch of ASEAN Economic Community (AEC) in 2015 will expand the market of Thai food to around 600 million consumers over Southeast Asia.

4) Excellent logistics systems: Thailand boasts world-class infrastructure, including state-of-the-art ports, airports and communication facilities. Suvarnabhumi International Airport and Laem Chabang Deep Seaport offer manufacturers the transportation foundation investors need for their export operations. The 225 km of inter-city motorways currently in expansion linking Bangkok to other regions of the country also facilitate overall domestic transportation. In addition, Thailand is a hub of transportation in the Southeast Asia region; the perfect route through the east-west and northsouth corridor that can distribute products to nearby countries including Laos, Cambodia, Vietnam, Myanmar, Malaysia, Singapore and also southern China from the North and Northeast of the country.

5) Attractive Investment Incentives: Thailand Board of Investment offers a wide range of fiscal and non-tax incentives for investments. Tax incentives include exemption or reduction of import duties on machinery and raw materials, and corporate income tax exemption and reduction. The BOI can offer up to 8 years of corporate income tax exemption. Non-tax incentives include facilitation as regards the entry and sojourn of expatriates and the right to own land.

4.2.2 Food industry segmentation

The Federal of Thai industry has categorized segment in Food industry to 12 Segments as following.

1) Livestock Products (Prepared/Preserved)
2) Fishery products Shrimp Tuna Other canned fish Frozen fish Cuttlefish Others
3) Fruit and Vegetable Products t Pineapple (Canned/Preserved) Pineapple Juice Mango Others
4) Flour and starch
5) Seasonings and Ingredients

6) Dairy and Milk Product
7) Sugar and Sugar product
8) Non-Alcoholic Beverage and Alcoholic Beverage
9) Coffee, Tea and Cocoa product
10) Oil and Fat product
11) Pet and Animal food
12) Nutrition Food, Healthy food and Others

4.2.3 Need of industry

Risk management practice in food industry

The author has conducted preliminary study to understand the needs of food industry by questionnaire survey asking the target group about their practice for project risk management for NPD, including risk management standard and tools that they used in past projects and also asked them to rate the importance of comment risk factors that concluded from literature review of research paper related to risk factors in last decade. The details of questionnaire survey, profile of respondents and finding from survey and risk management practice and important of risk factors are summary as following.

Profiles of Survey Respondents

Total 33 respondents from several functions and business units in CPF Group

Profile of respondent is separated to 5 functions.

- High-level Management (VP, AVP, GM) 6 persons
- Business Manager 8 persons
- Engineering & Maintenance 6 persons
- Manufacturing 7 persons
- Development and Innovation staffs 6 persons

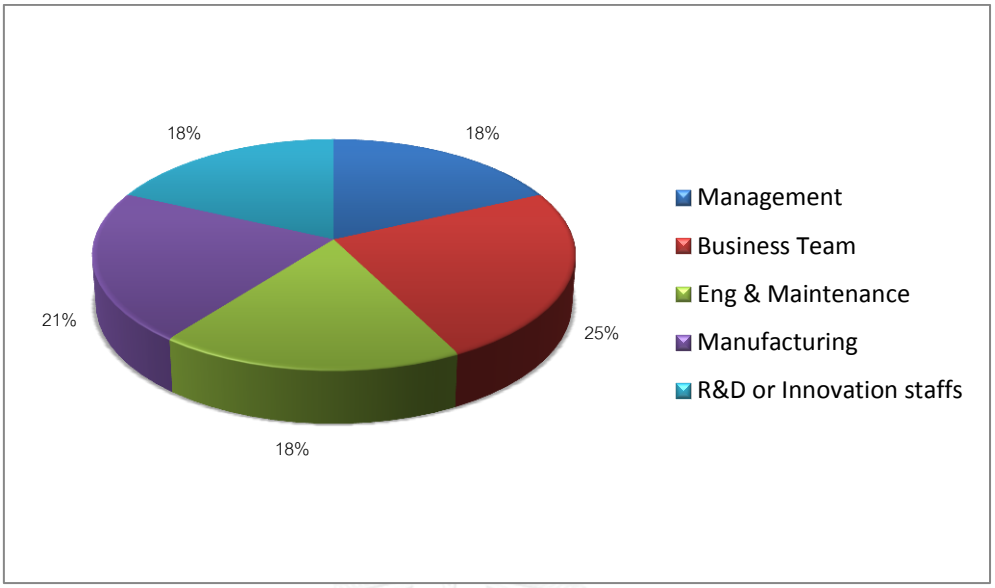


Figure 4.2 Distribution of respondents' profile

Survey question asked for risk management practice in their organizations when working in innovation projects. The response for their practice can be divided in to 3 groups as following.

No risk management : This group usually did not conduct risk assessment during their innovation project due to lack of knowledge or may not realized the importance of risk management in their projects (30%).

Non-systematic risk management: This group may conduct risk assessment during some step in high risk project but do not use systematic methods or tools for risk management (61%).

Use systematic risk management: This group followed systematic risk management process and included risk management process as a part of their standard work procedure (9%).

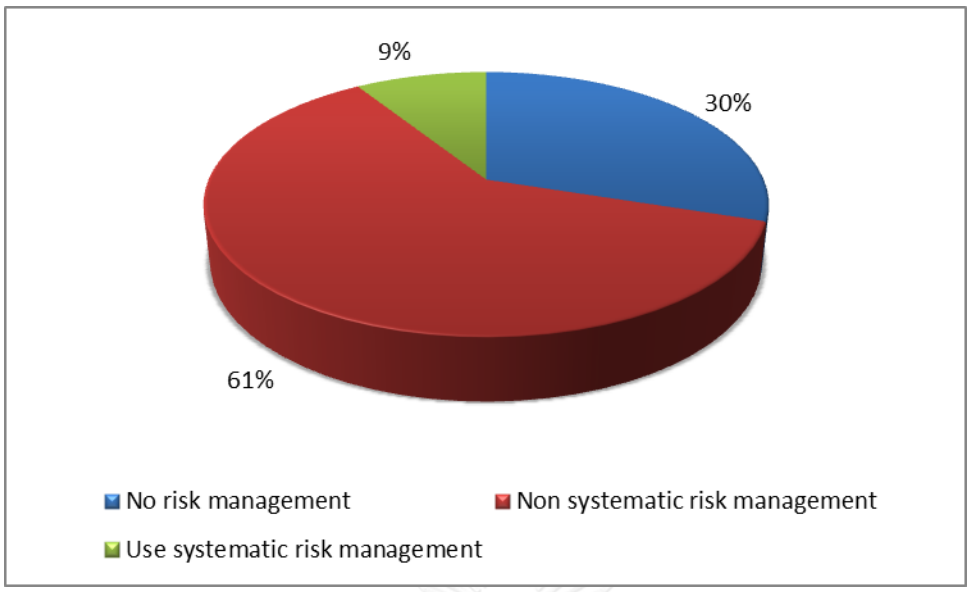


Figure 4.3 Risk management practices in innovation project

Risk factors and importance of risk factors in food industry

The risk factors from literature review has been selected and combined to 19 risk factors (Table 4.3) that mostly related to NPD projects in each phase to use in questionnaire survey.

Table 4.3 NPD phase and risk factors

No.	NPD phase	Risk Factors	Type of risk
1	Planning	Schedule risk	Internal
2		Organization structure	Internal
3		Project communication	Internal
4		Economic risk	External
5	Concept Development	Technical complexity	Internal
6		Location selection	Internal
7		Resource planning	Internal
8		Team knowledge	Internal
9	System-Level design	Design risk	Internal
10		Manufacturing technology	Internal
11	Detail design	Intellectual properties	Internal
12		Sourcing and materials planning	Internal
13	Testing & Refinement	Customer requirement	External
14	Production Ramp-up	Manufacturing capability	Internal
15		Logistic & Transportation	Internal/External
16		Procurement and contract	Internal/External
17	All phase	Social risk	External
18		Political risk	External
19		Natural risk	External

Survey for importance of risk factors

The survey question asked participants to rate importance of 19 risk factors from literature review by Likert scale 1-5 (1 is least important and 5 for most important). From questionnaire survey we can summarize the importance scores of each risk factor in table 4.7 below. The results show minimum, maximum score, average score and standard deviation score.

Table 4.4 Survey result for importance of risk factors

No	Risk Factors	Min	Max	Mode	Mean	Std DEV
1	Schedule risk	2	5	4	4.0	0.8
2	Organization structure	2	5	4	4.0	0.9
3	Project communication	2	5	4	3.9	1.0
4	Economic risk	2	5	3	3.7	0.9
5	Technical complexity	1	5	3	3.7	1.0
6	Location selection	1	5	4	3.6	1.1
7	Resource planning	2	5	3	3.6	1.0
8	Team knowledge	2	5	4	3.9	1.0
9	Design risk	2	5	4	4.2	0.8
10	Manufacturing technology	1	5	4	3.8	1.0
11	Intellectual properties	1	5	3	3.1	1.1
12	Sourcing and materials planning	1	5	3	3.4	1.1
13	Customer requirement	2	5	5	3.9	1.1
14	Manufacturing capability	1	5	3	3.2	1.2
15	Logistic & Transportation	1	5	3	3.1	1.2
16	Procurement and contract	1	5	3	3.0	1.1

17	Social risk	1	5	3	3.0	1.1
18	Political risk	1	5	3	2.6	1.1
19	Natural risk	1	5	3	2.8	1.2

From results of survey, Risk factor # 9 (Design risk) and #1(Schedule risk), #2 (Organization risk) got the highest score by average while risk factor# 13 (Customer requirement) has the highest important score by mode.

Additional Risk Factors

This part of the survey asked for additional comment from survey respondents for additional risk factors that they anticipated during innovation projects in food industry in the past.

Additional risk factors can be identified from their response are as following

1) Person responsibility change
2) Company policy change
3) Conflict of interest in team
4) Property loss
5) Incomplete training (can be combine to team knowledge)
6) Management support
7) Believe, social value, culture and religion
8) Customer acceptance (readiness of market)
9) Knowledge transfer

CHAPTER 5

DEVELOPMENT OF RISK ASSESSMENT MODEL

5.1 EMPIRICAL STUDY OF RISK MANAGEMENT FOR NPD

The empirical study of risk management in food industry has been done by in-depth interview of NPD expert. The objective of this interview was to understand the practice in food industry for their perception and understanding in risk management for new product development project. This study will also seek understanding in their new product development process, involvement of their staffs from each functions and process step that involved project risk assessment.

Expert selection and study process

The experts have been selected from new product development project from middle to large size company to ensure that they have some understanding in risk concept and see the importance of risk management, including have enough resource and want to invest in improvement of new product development process by adapt risk management procedure in their work. Eight experts from five companies have been selected for data collection. The company profile and industry segment can be seen in table 5.1

Table 5.1 Company profiles for experts selection

Expert	Company	Size	Segment in Food Industry	Product in Focus
1,2	A	Large size (Employee over 200 and turn over more than 200 MB	Dairy and Milk Product	Milk-powder products for Infants and Children
3	B	Large size (Employee over 200 and turn over more than 200 MB	Non-Alcoholic Beverage	Soft drink

4	C	Large size (Employee over 200 and turn over more than 200 MB	Fishery products , Canned fish and Others	Instant food in can
5,6,7	D	Large size (Employee over 200 and turn over more than 200 MB	Pet and Animal food, Livestock product and Fishery products	Livestock feed, Frozen food and Ready Meal Products
8	E	Large size (Employee over 200 and turn over more than 200 MB	Sugar and Sugar products	Sugar

5.1.1 New product development process

The new product development process in food industry has been studied in 5 companies that descript in Table 5.1. The company background and details about their NPD process are summarized as following.

Company A

This is the part of large US Base Corporation with operation and several subsidiaries in North America, Latin America, Europe and Asia-pacific. They have manufacturing facility in several countries include Thailand and also have regional R&D office in Thailand to support new product development activities in Southeast Asia. With long history for manufacturer of premium quality nutrition for infants, children and adults, they have well established NPD process which developed from Stage-Gate model but simplified process step in 3 phases for idea phase, development phase and launch phase. The flow chart of NPD process with activities in each phase can be seen in figure 5.1

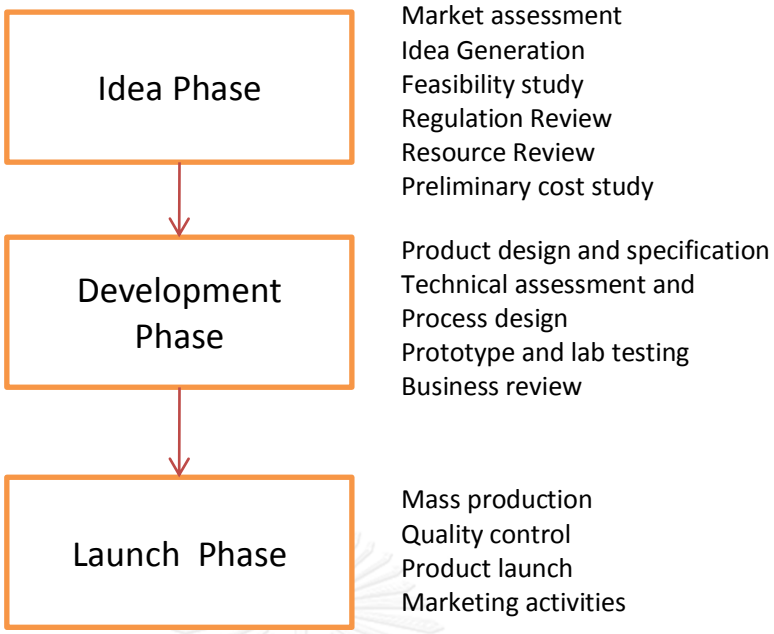


Figure 5.1 New product development process for company A

Their NPD process also includes risk management activity since idea phase and carries over until launch phase. The risk management process consists of Risk identification, Risk evaluation and Risk response & Contingency plan. All functions related to product development activity includes sales, marketing, R&D engineering, QA, production involved and provide their input to risk assessment and they also use results of risk management process and contingency plan as the review criteria for gate review of new product development project before move to the next phase in NPD. The flow chart of risk management process can be seen in figures 5.2

Figure 5.2 Risk management process for company A

Company B

This company is manufacturer and distributor of various high quality beverages with more than 60 years history. Their products included carbonated beverages, drinking water, soda water and energy drink product and they also work as distributor for others well-known brand non-alcoholic beverage such as lemon tea and green tea with high revenue of more than 20,000 Million Baht in 2012.

By characteristics of the products which are not so complicated in term of product specification and customer requirement. The life cycle of product also longer than other product in food industry, then the company was more focus on distribution channel and marketing activities rather than product development or product innovation. However form the competitive situation in beverage market and some problem in brand and licensing issue force then to start looking for new product under their own brand. They just started new organization for R&D department and start new product development activity less than one year. So they just use simple product development work flow without official process and standard activities. Their R&D staffs also understand and see the importance or risk

management concept for project management but still need some time until they ready and have enough R&D resource for this kind of activity. However, the risk management tool with standard process that can navigate the users to each process step should be able to help them develop formal process faster and more effective.

Company C

The vision of this company is to create delicious smile and better living for people in Thai society, with the finest experience from ongoing nutritional seafood innovations. This company started this family business in southern part of that land for more than 30 year ago. Today, they are one of the Thailand leading manufactures and professors of canned seafood both in domestic and international market. Part of our success is the recognition of change in consumers' behavior and resulting in continuous improvement. This approach has influenced them to enhance product quality to match worldwide standard, and is presently well known in many countries in Asia, Europe, U.S.A. and Middle East.

Today beside canned seafood they also have wide variety of food product such as seafood appetizer, Snack, Thai Curry, Thai Spicy food, Steam rice and continue to have new development of Thai food with special recipe to Thai and export market. New product innovation is one of their strategic focuses that make them looking for new idea and new business process that improve rate of new product success.

As the originated from family business, they don’t have develop their own process for new product development that they called “Timeline”. This process step descripts the activities and sequence of activities that each department have to performed during development process of new products. This process also included consideration of project risks during project review but do not have systematic process for risk management.

Company D

In 1978 company register under the different name for feed mill business and then become public company limited in 1994. Few year later they expand to food company and rename to current name in 1999 and announce vision for "Kitchen of the world". The company expand business to UK in 2002 and continue grow to other country until have 185 subsidiaries companies around the world. Recently they just started new business in Thailand for a food-court business which expects high return in the near future.

The company operates fully integrated agro-industrial business comprising the manufacturing of animal feed, animal farming, the manufacturing of food products (including semi-cooked meat, fully-cooked meat and read-to-eat products and the food retailer business. According to information from their corporate website, the core business divides into 2 main business lines 1) the livestock business and 2) the aquaculture business. Both these business lines comprise fully integrated operations, from sourcing raw materials for animal feed production, manufacturing and distributing animal feed, breed the animals, animal farming, processing meat, to manufacturing further processed food products, mainly chicken, duck, swine, shrimp and fish.

This company has research teams comprise high caliber professionals who are highly regarded in Thailand's agriculture industry. They cooperate with other outside parties, including research institutes both in Thailand and overseas, specialists, customers and various public agencies, with the mutual objective of sustaining the industry, while having business adhering to environmental friendliness. Aside from developments for the sustainability of the overall industry, company emphasizes product development to satisfy consumer requirements. Manufacturing food products to meet the differing regulations and standards of each customer throughout the world, together with the Company's ability to develop products and improve its animal breeding process to meet international standards, have resulted

in customers being confident that products are of high quality, tasty and safe for consumption.

With the large size of company that divided to several business units. They share the company vision and corporate strategy from top management while having different management team focus on each business areas. Each business unit may have different structure and operate on different procedure. For example in product development activities some business may not have dedicate staff working on R&D activities but may utilize resource from manufacturing, quality, and engineering while some business unit has separate department for R&D with formal procedure and systematic process to management NPD

The example of NPD process used for development of frozen food and ready meal products in one of their business unit can be seen in Figure 5.3. The process consist of six process step for 1) market assessment 2) R&D and manufacturing review 3) development Phase 4) marketing evaluation 5) final product design and 6) up-scale and mass production

Regarding risk management issue of product development project, they include risk assessment activities during gate review before move the next phase but did not have systematic process to manage risk in their project and by opinion of product development team also agreed that company should have more systematic approach to risk management in project and appropriate risk management tool should be able to help in this area.

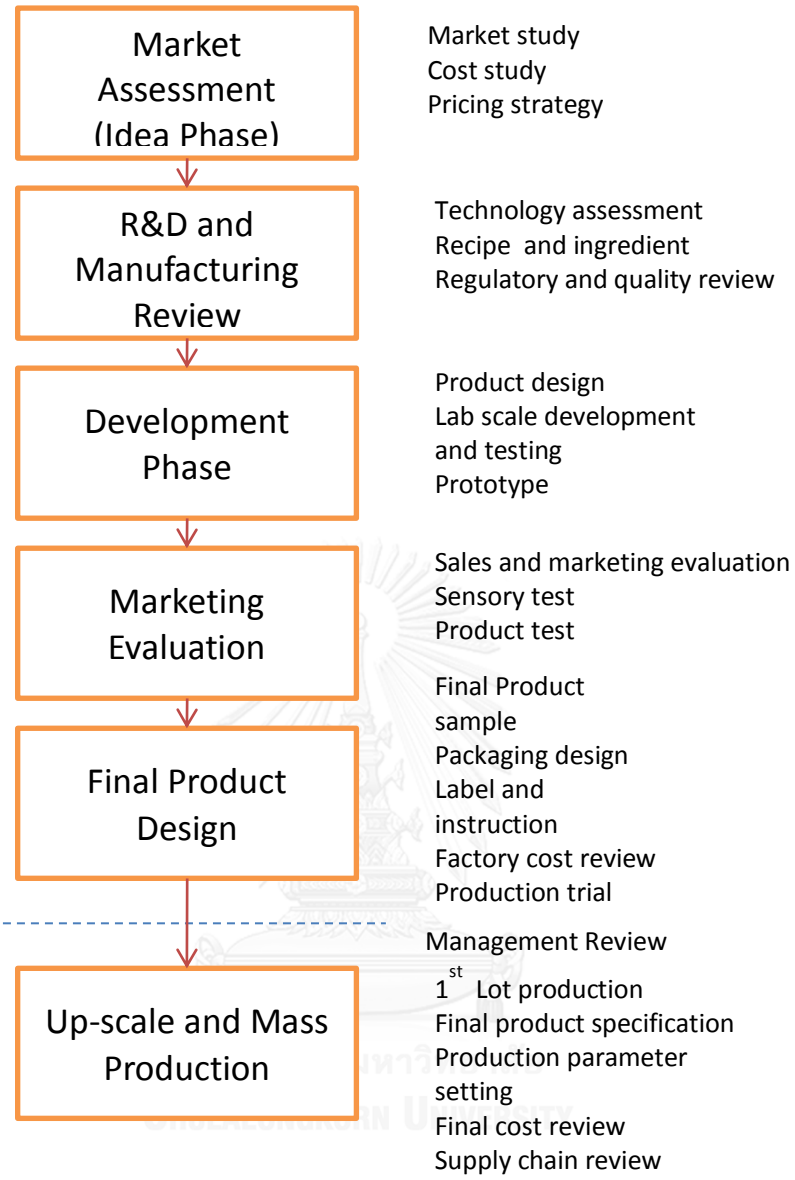


Figure 5.3 Risk management process for company D

Company E

This company has the vision to become the most widely known company in the sugar and bio-technology industries, by applying innovative technologies and enhancing management talent. This company growth from small household industry producing syrup, sold it to nearby sugar mill in small province turned into a sugar factory and kept expanding to serve the continued rising demands until become Thailand's No. 1 sugar producer and exporter and have several innovative product for

white sugar, brown sugar, gold sugar, rock sugar, coffee sugar, paste sugar, sprinkle, mitte flavor syrup, bee crystal and molasses.

According to their corporate website, today company divided to five business groups for 1) plantation business 2) sugar business 3) particle board business 4) renewable energy business and 5) investment.

By realizing the importance of raw material (cane) quality development, company has established cane and sugar research Company in 1997 to find the solutions for productivity development, management efficiency improvement and give guidance on new business development to enhance Thai cane and sugar industry competitiveness. Their research focuses on creating innovation and developing cane growing technology to cut production cost as well as enhance environmental friendly procedures. Several innovations were created, such as applying information technology system to analysis and compare cane growing areas, developing white leaf disease checking kit (the world first such kit) and developing bio-pest control system to reduce chemical uses in cane growing. This innovative knowledge was transferred to cane growers via our researchers and cane promotion officers.

Table 5.2 NPD process and risk management activities

Product	NPD Process and Project Management	Functional Involvement	Risk Management Approach
1,2	Corporate NPD process developed from Stage Gate Model	Marketing, R&D, Production	Formal Risk Management process consist of - Risk Identification - Risk Evaluation - Risk Response & Contingency plan
3	No formal NPD process (under development)	Sales & Marketing, Product Development	No formal process,
4	Internal procedure call "Timeline" with checklist of process step for project planning	Sales & Marketing, R&D, Production and Top management	No formal process, consider risk during project planning

5	Internal procedure for project management use for all type of projects	Sales & Marketing, and Production	No formal process, consider risk during project planning
6	Internal procedure for project management with project tracking software and database with R&D function using PLM software	Sales & Marketing, R&D, Production and Business Leader	No formal process, consider risk during gate review
7	NPD internal development process using PLM Software (Oracle)	Sales & Marketing, R&D, Production and Business Leader	No formal process, consider risk during gate review and before product launch
8	Internal Self Develop NPD process	Sales & Marketing, R&D and Production	Review risk of project during planning phase and review product risk before product launch

5.1.2 Risk management process

In parallel to NPD process study, risk management process has been studies for each NPD projects in those five companies. Total eight NPD projects have been discussed during in-depth interview as detail below.

Product 1

The first case study is the product development project in year 2011 which company was suffers from unexpected problem from government regulation change. At the beginning of project, product development team in Thailand have been assigned to develop new formulation of milk powder for infant age under one year for manufacturing in Thailand and supply to other neighbor country. The company has done this many times for the same product in other country. So they just follow the NPD process with the similar formulation until found out at almost final step that there was some change in food safety regulation in that country that cause the product formulation fail to meet the regulatory requirement. To solve this problem ,company has to change one important raw material to improve shelf life of the product but due to the time limitation and team realize about this problem too late

caused the project did not pass final gate review and company decided to terminate project before completion.

Product 2

This case happened within the same company as case 1. As the regional developer and manufacturing for company product in South East Asia, there was requirement from customer in neighbor country prefer the new formulation of milk power for wide range of customer from three year old age until adults age. The challenge of product development team is to find new formulation that fulfill requirement for nutrition standard while provide the good taste for all group of customer. However with good assessment of project risk, the product development team realized this critical success factors for customer acceptant and can manage the project to find the good source of raw materials to meet requirement and complete project within target.

With the problem from this two case the product development staff suggest for requirement of risk management tools that can be used for all function and should be able to capture risk in early stage, including provide some suggestion for risk response actions

Product 3

This case is the development of beverage product which the success factor more focus on understanding of customer requirement and well preparation for product launch, promotion activities and distribution channel. However, product development team and all related function will need to make sure that all require process step has been performed and all potential risks has been reviewed and prevented to avoid unexpected problem that will delay the project.

Product 4

This case is the development of new product that plan to launch at the end of 2013 or beginning of 2014. The product is new for both of company and new to the market and because this is the Thai food product that unique to the world which

no one ever produce before, the product development team will face many risk in product development from risk of distribution channel selection, time line of project launch, risk from competitive product, risk from FDA registration.

The product development team also addresses their need for risk management tools that should help navigate team without experience in formal risk management to perform this task and report results to management to use for making final decision before product launch

Product 5

Even the animal feed are consider as the product in food industrial by the Federal of Thai industry but regulatory requirement and issues in product development may different from human food. So the project risk assessment for this kind of product will be more focus on problem of manufacturing and supply chain management so the product development team requires more support on risk identification to address all kind of risks during supply chain process.

Product 6

This case is the product development of frozen food product which raw materials come from contract farming. The major risk come from quality of raw materials and transportation process, include product design to serve customer need. The product development team in this company also management product development project and other innovation project using project management database that track all project planning, progress and benefit and also link all project to company strategy. However the organization still does not have formal risk management process to management project risk.

Product 7

This is the case of ready meal product development from same company with case 5 and case 6. However, the product development team are under different business unit and used different process for new product development (see detail of NPD process in figure 4,4)

The major risk for this product address by R&D head are change in company direction, customer requirement change or life style change, change in local/export country regulation, change in trade barrier and materials shortage from some situation or problem such decease in livestock or aquatics animal.

Product 8

This company has researcher and development activities in several areas from raw material quality development, the development of products using wastes or by-product from manufacturing process of main products or even the research for renewable energy from solid waste. However, the case study focused in product development of sugar products which is the main business of this company and potential project risks address by product development team are customer and market acceptance.

The requirement for risk management tool will focus on precision of risk analysis, scope to cover all process step in product development and function that can customized to match with different need of each organization.

5.1.3 Requirement for risk management

Table 5.3 User's requirements for risk management tool

Company	Segment in Food Industry	Requirement for Risk Management Tool
A	Dairy and Milk Product	Support risk identification in early stage & Suggestion for risk response
B	Non-Alcoholic Beverage	Tools for navigate risk management process
C	Fishery products , Canned fish and Others	Risk identification and Evaluation

D	Pet and Animal food, Livestock product and Fishery products	Risk identification, Guidance for formal risk management process, Compatible with NPD process used by organization
E	Sugar and Sugar products	High Precision Include all process step Customize

5.1.4 Risk factors from empirical study

From in depth interview we have identify the important risk factors for each group of product in Table 5.4. These risk factors was consider as additional risk factors and will be add to risk identification tool in addition to risk factors from literature review and survey of NPD team in previous phase

Table 5.4 Important risks from NPD project**s**

Product	Products	Important Risk
1	Milk-powder products for Infants under 1 year	Regulatory and material sourcing
2	Milk-powder products for Children over 3 year	Regulatory and Customer acceptance (taste)
3	Soft drink	-Substitute product from competitor -Distribution channel
4	Instant food in can	-Distribution channel and timeline for product launch -FDA registration -No information support for key decision -Confidentiality in new product launch
5	Livestock feed	- Safety Risk - Management support - Communication

6	Frozen food	- Raw materials quality - Alignment with business strategy
7	Ready meal product	- Change in company direction - Customer requirement change or life style change - Change in local/export country regulation - Change in trade barrier - Materials shortage from outbreak
8	Sugar product	Customer and Market acceptant

5.2 RISK ASSESSMENT METHOD

5.2.1 Risk identification

Risk factors

The 39 risk factors from literature review plus additional risk factor from empirical study has been review and grouping to 20 risk categories as the details in Table 5.5.

Table 5.5 Risk categories of common risk factors

No.	Risk Categories	Risk Factors from LR	Risk Factors from empirical study
1	Schedule risk	Schedule risk	Timeline for product launch
2	Organization structure	Organizational Risk Management Risk	Management support Alignment with business strategy Change in company direction
3	Project communication	Communication Risk Project Complexity Risk	No information support for key decision
4	Economic risk	Financial Risk Commercial Viability Risk Market Risk Economical Risk	Change in trade barrier
5	Technical complexity	Technical Risk	
6	Location selection	Location Risk	
7	Resource planning	Resource Risk	
8	Team knowledge	Lack of Knowledge Risk	

9	Design risk	Product Positioning Risk Competitors Risk Screening and Appraisal Risk Product Reliability Risk Contractual Risk Design Risk Dependencies Risk	Substitute product from competitor Confidentiality in new product launch Customer acceptance (taste)
10	Manufacturing technology	Manufacturing Technology Risk Production Risk Construction Risk	Safety Risk
11	Intellectual properties	Manufacturing Technology Risk	
12	Sourcing and materials planning	SC and Sourcing Risk Planning Risk	Material sourcing Raw materials quality
13	Customer requirement	Customer/User Risk Requirement Risk	Customer requirement change Customer life style change
14	Manufacturing capability	Manufacturing Technology Risk Production Risk Construction Risk	
15	Logistics & Transportation	Delivery/Operation Risk	Distribution channel
16	Procurement and contract	Procurement/Contract Risk	
17	Social risk	Environmental Risk Social Risk	
18	Political risk	Political Risk	
19	Natural risk	Geological Risk Natural Risk	Materials shortage from outbreak
20	Compliance risk	Legal Risk	Product regulatory FDA registration Change in local/export country regulation

Risk break down structure (RBS)

The information about risk factors from literature review and empirical study in conceptual development phase have been analyze and classify into 3 different level as risk dimensions, risk categories and risk factors.

Table 5.6 Risk breakdown structure hierarchy

Risk Dimensions	Risk Categories	Example of common risk factors
Product Risk	Technical complexity	Quality of material Problem in development process
	Design risk	Product specification Prototype development
	Manufacturing technology	Process capability Limitation from production machine
	Customer requirement	Lack of understanding in VOC Lack of data from market testing
	Manufacturing capability	Type of process do not match with product Capacity constraint
	Compliance risk	Product regulatory Regulation in products and manufacturing process
Project Management Risk	Schedule risk	Time management and review method Time sensitivity of project
	Project communication	Communication method and media Stakeholder analysis
	Resource planning	Project core team member Limit resource from support function
	Team knowledge	Technical knowledge Market knowledge Project management concept
	Intellectual properties	Confidential disclosure agreement IP protection and proprietary issues

Enterprise Environmental Risk	Organization structure	Management support Alignment with company strategy
	Location selection	Physical location of related functions Location for source of materials & supply
	Sourcing and materials planning	Sourcing policy Material replenishments process
	Logistic & Transportation	Distribution channel Mode of transportation
	Procurement and contract	Relationship with supplier Pricing of materials Collaboration policy
External Risk	Economic risk	Direct cost of product increase Customer income Alternative product cost
	Social risk	Image of company Image of brand and product
	Political risk	Political unrest Government policy
	Natural risk	Effect of natural disaster to customer, source of supply and manufacturing facility

The risk dimensions identified by this research consist of product risk, project management risk, enterprise environmental risk and external risk. The risk categories consist of 20 categories as shown in table 5.6. See Figure 5.4 for completed RBS used in risk identification phase during risk assessment process. This RBS has been developed by literature review and additional inputs from empirical study in food industry. Even the risk dimensions and risk categories was established in high level and might be applied for NPD project in other industries, but the specific risks for food industry have been addressed in risk checklist which used in conjunction with RBS during risk identification activity. Table 5.7 shows the examples of specific risk factors for food industry that include in risk checklist.

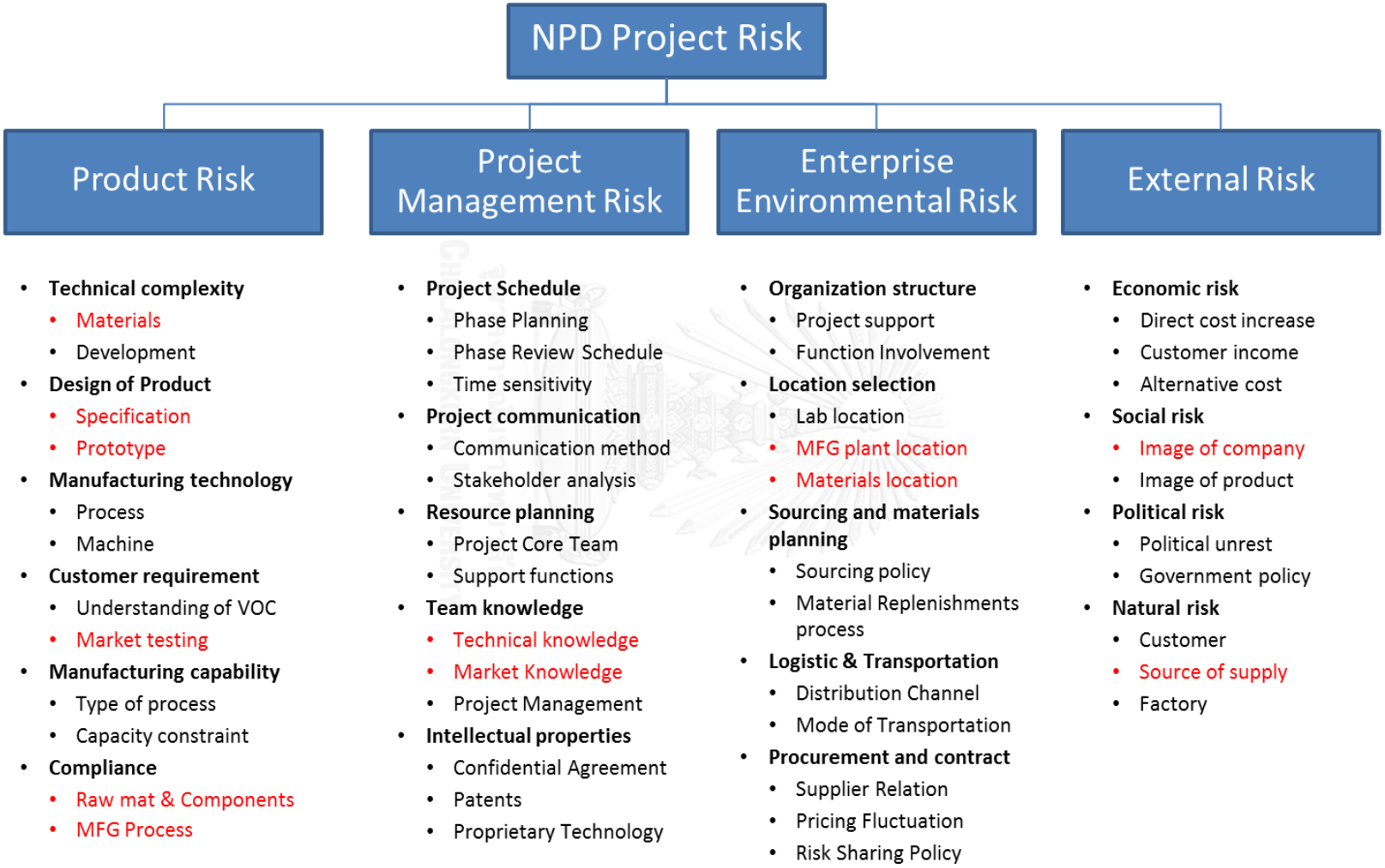


Figure 5.4 Risk breakdown structure for NPD project

Table 5.7 Example of specific risk factors for NPD in food industry

Risk Categories	Example of common risk factors
Technical complexity	Raw material quality cause problem in food safety.
Design risk	Problem during storage and food preparation by consumers.
Customer requirement	Lack of appropriated market testing for target group
Compliance risk	Requirement of regulation relate to food safety New legislation for food products
Location selection	Location of manufacturing plant and surrounding area. Time limitation for materials transportation.
Sourcing and materials planning	Relationship and collaboration with other parties in supply chain.
Logistic & Transportation	Special transportation method required by materials or products characteristics.
Social risk	Image and reliability of company and product.
Political risk	Political unrest Government policy
Natural risk	Natural disaster cause interruption in production of agricultural or natural products used as raw materials

5.2.2 Risk analysis

Fuzzy risk analysis

Fuzzy logic is a set of mathematical principles for knowledge representation based on degrees of membership. Fuzzy set theory was developed by Zadeh (1965) to solve fuzzy phenomenon problem existing in the real world. This theory has an advantage over the traditional set theory when measuring the ambiguity of concepts that are associated with human beings' subjective judgments. Figure 5.5. illustrate the basic structure of a fuzzy inference system consists of fuzzification or the process

of making a crisp quantity fuzzy; a fuzzy rule which define relationship of each input and output; a database which define membership function and a reasoning mechanism which performs the inference procedure upon the rules to derive output or conclusion.

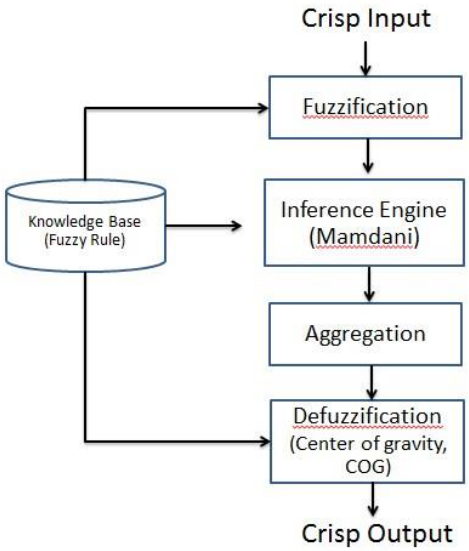


Figure 5.5 Overview of Fuzzy risk assessment system

The membership function value of output obtained from fuzzy inference is still a fuzzy value which requires a defuzzification process to convert the output into a scalar, or non-fuzzy value. In this study Center of gravity (COG) method is used as defuzzification methods to covert fuzzy output to crisp output in form of Risk Index number that will be used for risk prioritization.

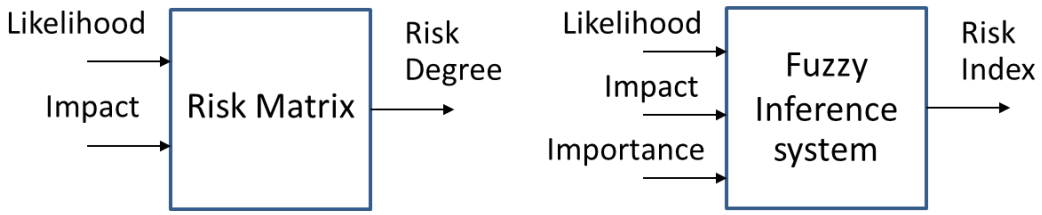


Figure 5.6 Comparison of traditional and fuzzy risk assessment process

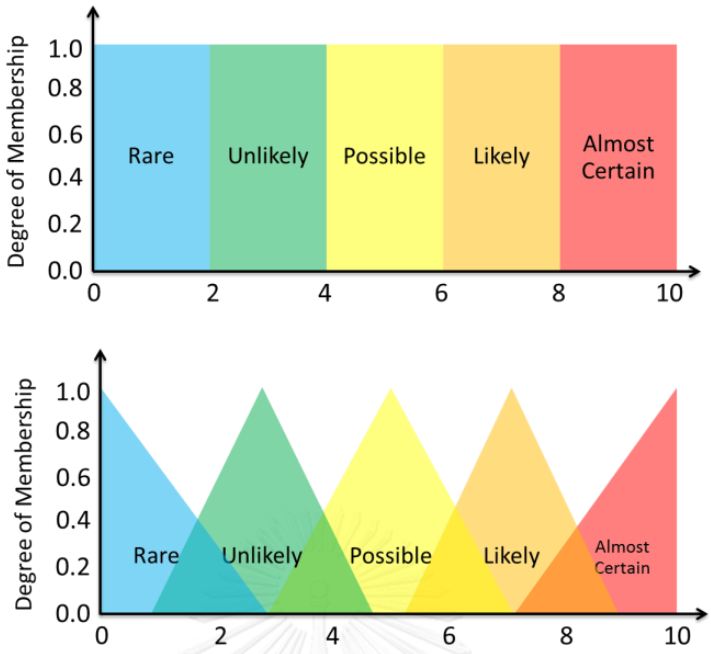


Figure 5.7 Example of normal set and fuzzy set for risk impact

Benefit of Fuzzy risk assessment over traditional risk matrix

1) Fuzzy rules are linguistic rather than numerical, thus the users often find fuzzy rules to be a convenient way to express their knowledge of a situation.
2) The calculation of risk score by traditional risk matrix may produce an identical value. However, the risk implication may be totally different. Fuzzy risk assessment will use inference method which provides specific output for specific set of input.
3) The risk score in traditional risk matrix will be convert to risk degree in 4 level (Extreme, High, Medium, Low) which is very low resolution and limit use for future prioritization or analysis, while Fuzzy risk analysis provide the continues output from 0.0 to 1.0 (as design for this research) which can be used for future analysis or calculation of overall risk factor in project level.

Define Scale for Input and Output

Likelihood (Input)

Table 5.8 Scale of Likelihood (input)

Linguistic Term	Criteria	Fuzzy Number (Tri-angularity)
Rare	It would be very unlikely for these failures to be observed once	[0 0 2]
Unlikely	Likely to occur once but unlikely to occur more frequently	[0 2 5]
Possible	Likely to occur more than once	[2 5 8]
Likely	Near certain to occur at least once	[5 8 10]
Almost Certain	Near certain to occur several times	[0 10 10]

Impact (Input)

Table 5.9 Scale of Impact (input)

Linguistic Term	Criteria	Fuzzy Number (Tri-angularity)
Insignificant	Almost no impact to project objective and project activity	[0 0 3]
Minor	Impact to some project activity	[0 3 6]
Moderate	Impact to major objective, cause project delay or over budget or product quality	[3 6 8]
Major	Impact several objective in project with high financial loss	[6 8 10]
Catastrophic	Cause project termination or serious impact to company performance	[8 10 10]

Importance (input)

Table 5.10 Scale of Importance weight (input)

Linguistic Term	Score from Expert Rating	Fuzzy Number (Tri-angularity)
Very Low	1-2	[0 0 2.5]
Low	3-4	[0 2.5 5]
Medium	5-6	[2.5 5 7.5]
High	7-8	[5 7.5 10]
Very High	9-10	[7.5 10 10]

Risk Index (Output)

Table 5.11 Scale of Risk Index (output)

Linguistic Term	Criteria	Fuzzy Number (Gaussian)
Low	Risk acceptance strategy can be used	[0.1416 0]
Medium	Need contingency plan and closely monitor	[0.1416 0.33]
High	Need mitigation plan to reduce impact or likelihood	[0.1416 0 .66]
Extreme	Need immediately action before proceed to further NPD process	[0.1416 1]

Importance weight determination

The input to fuzzy inference system of each identified risk factor consists of rating score of Likelihood and Impact combine with Importance score. The Importance weights are defined for each risk category of those risk factors. Table 5.10 show the value of Importance score that use for input to fuzzy risk analysis. This data came from survey of NPD expert opinions from two organizations as importance weight of risk category in each organization. The priority weight of company A was used for case study 1 and 2, and the priority weight of company B was used for case study 3 and 4.

Table 5.12 Importance weight for each risk category

No.	Risk Categories	Importance weight (Company A)	Importance weight (Company B)
1	Schedule risk	7.4	7.4
2	Organization structure	7.3	7.8
3	Project communication	7.2	7.7
4	Economic risk	7.2	7.7
5	Technical complexity	6.0	6.8
6	Location selection	6.5	7.5
7	Resource planning	7.2	8.0
8	Team knowledge	7.4	8.2
9	Design risk	6.4	8.8
10	Manufacturing technology	6.2	8.6
11	Intellectual properties	5.5	6.8
12	Sourcing and materials planning	7.2	7.7
13	Customer requirement	8.0	7.8
14	Manufacturing capability	6.8	7.1
15	Logistic & Transportation	5.8	5.5
16	Procurement and contract	6.2	6.3
17	Social risk	5.5	4.6
18	Political risk	5.9	4.5
19	Natural risk	6.6	6.2
20	Compliance risk	6.6	6.9

Fuzzy Inference System in MATLAB®

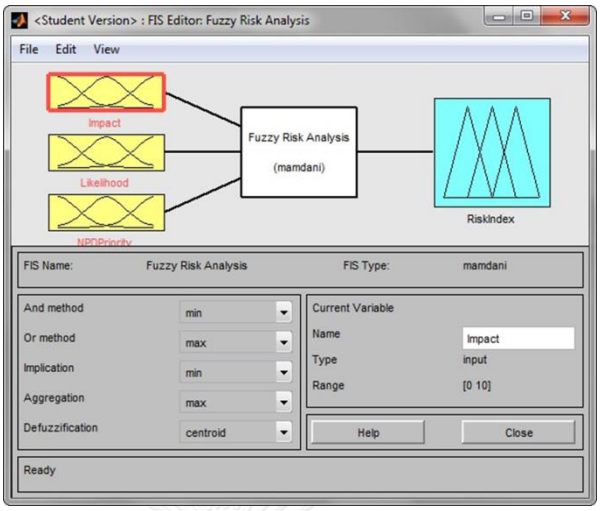


Figure 5.8 Fuzzy inference system in MATLAB®

Generate Membership Function

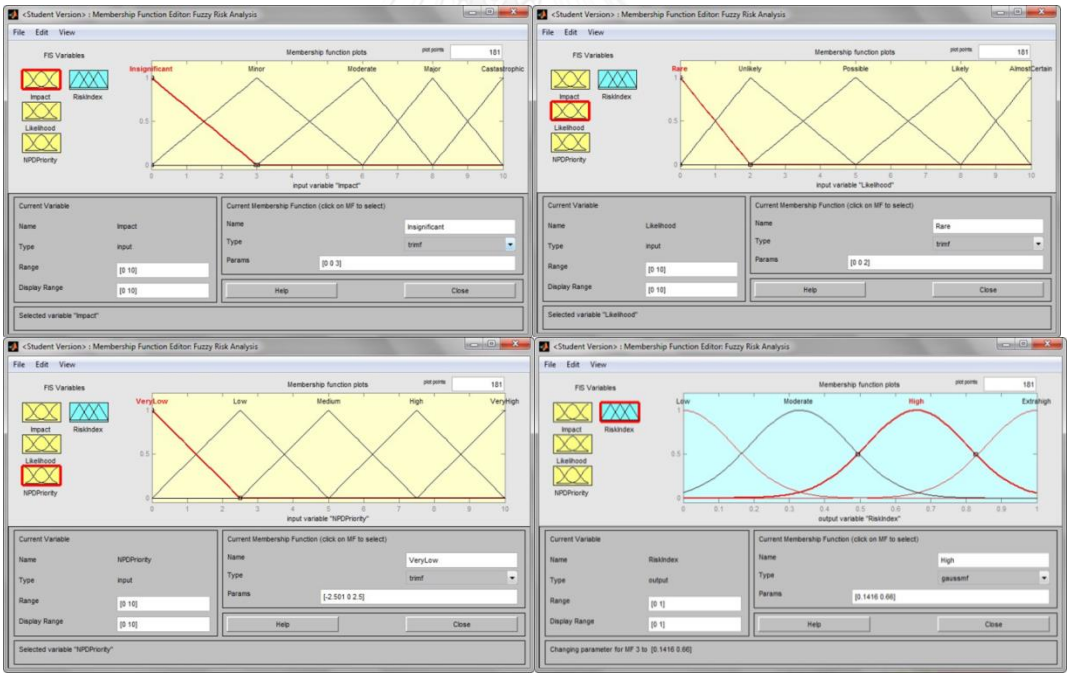


Figure 5.9 Membership function setting in MATLAB®

The relationship of input and output are defined as fuzzy rule using the concept of traditional risk matrix. The comparison of Risk matrix and fuzzy risk surface can be seen in Figure 5.9.

Fuzzy Rule

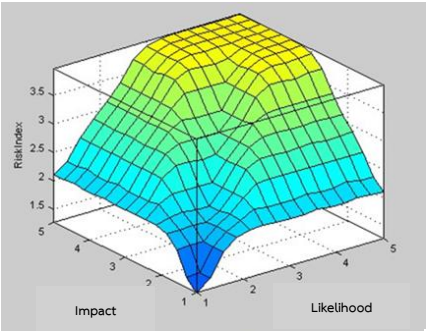
1) if (Impact is Castrophic) and (Likelihood is Rare) and (Importance is VeryHigh) then (RiskIndex is Moderate)
2) if (Impact is Castrophic) and (Likelihood is Unlikely) and (Importance is VeryHigh) then (RiskIndex is High)
3) if (Impact is Castrophic) and (Likelihood is Possible) and (Importance is VeryHigh) then (RiskIndex is Extrahigh)
4) if (Impact is Castrophic) and (Likelihood is Likely) and (Importance is VeryHigh) then (RiskIndex is Extrahigh)
5) if (Impact is Castrophic) and (Likelihood is AlmostCertain) and Importance is VeryHigh) then (RiskIndex is Extrahigh)
6) if (Impact is Major) and (Likelihood is Rare) and (Importance is VeryHigh) then (RiskIndex is Moderate)
7) if (Impact is Major) and (Likelihood is Unlikely) and (Importance is VeryHigh) then (RiskIndex is High)
8) if (Impact is Major) and (Likelihood is Possible) and (Importance is VeryHigh) then (RiskIndex is Extrahigh)
9) if (Impact is Major) and (Likelihood is Likely) and (Importance is VeryHigh) then (RiskIndex is Extrahigh)
10) if (Impact is Major) and (Likelihood is AlmostCertain) and (Importance is VeryHigh) then (RiskIndex is Extrahigh)

:

125). if (Impact is Insignificant) and (Likelihood is AlmostCertain) and (Importance is VeryLow) then (RiskIndex is Low)

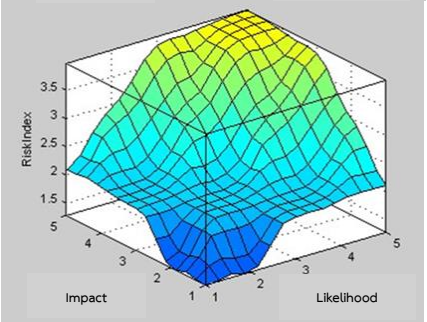
Importance Level 5 (Very High)

Impact						
	5	M	H	E	E	E
	4	M	H	E	E	E
	3	M	H	H	E	E
	2	M	M	H	H	H
	1	L	M	M	M	M
		1	2	3	4	5
		Likelihood				



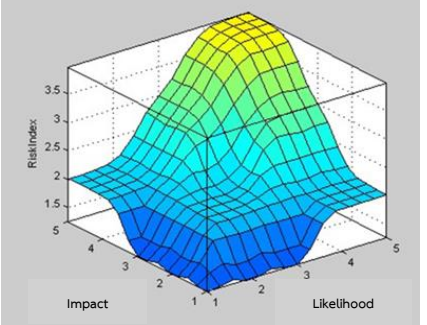
Importance Level 4 (High)

Impact						
	5	M	H	E	E	E
	4	M	M	H	E	E
	3	M	M	M	H	E
	2	L	M	M	M	H
	1	L	L	M	M	M
		1	2	3	4	5
		Likelihood				



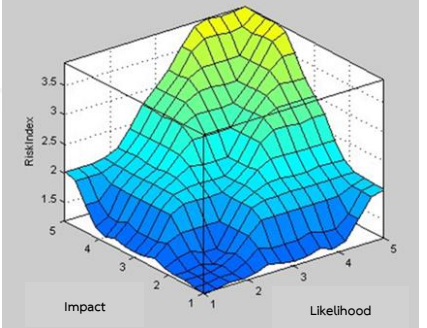
Importance Level 3 (Medium)

Impact						
	5	M	M	H	E	E
	4	M	M	H	E	E
	3	L	M	M	H	H
	2	L	M	M	M	M
	1	L	L	L	M	M
		1	2	3	4	5
		Likelihood				



Importance Level 2 (Low)

Impact						
	5	M	M	H	E	E
	4	L	M	H	H	E
	3	L	M	M	H	H
	2	L	L	M	M	M
	1	L	L	L	L	M
		1	2	3	4	5
		Likelihood				



Importance Level 1 (Very Low)

Impact						
	5	L	M	M	H	E
	4	L	M	M	H	H
	3	L	M	M	M	M
	2	L	L	M	M	M
	1	L	L	L	L	L
		1	2	3	4	5
		Likelihood				

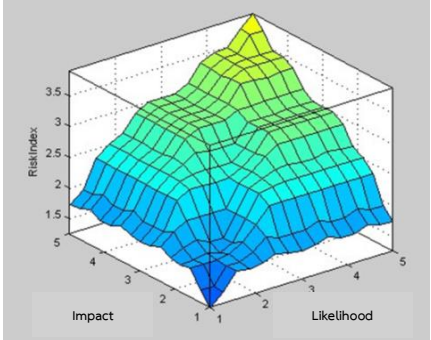


Figure 5.10. Comparisons of standard risk matrix and fuzzy risk surface.

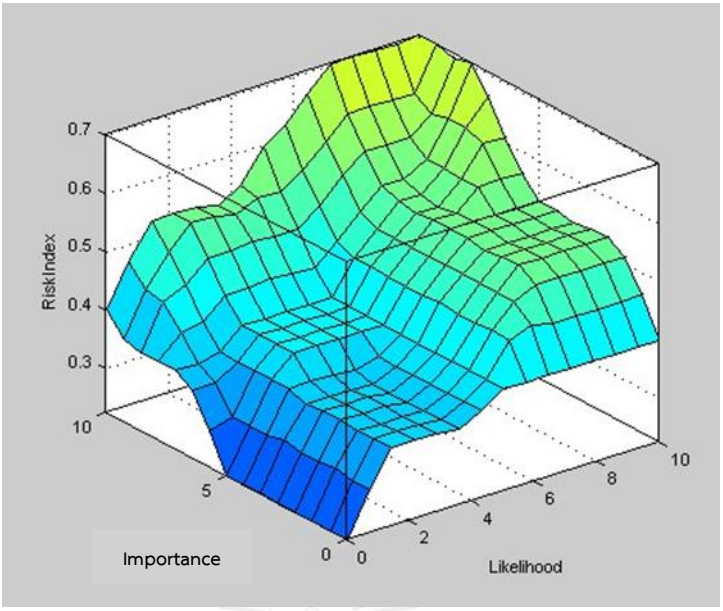


Figure 5.11 Surface plot of Importance and Likelihood with Risk Index (Output)

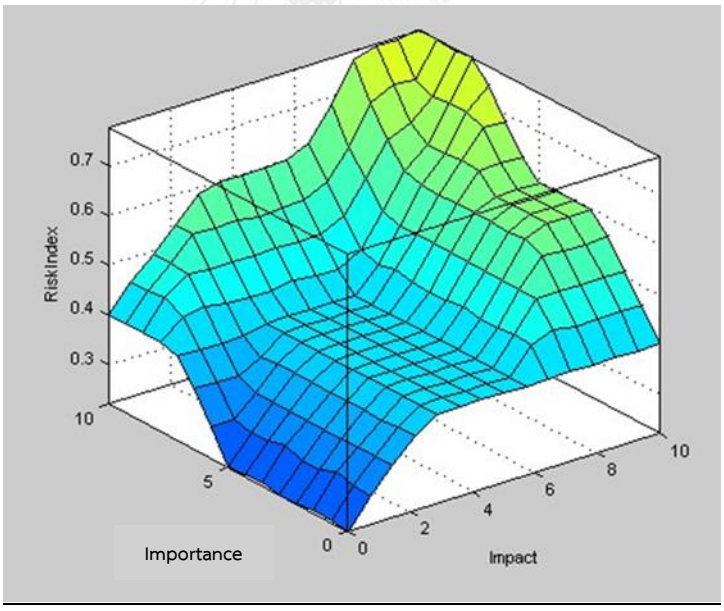


Figure 5.12 Surface plot of Importance and Impact with Risk Index (Output)

5.2.3 Risk response and control

Risk response and control is the next step follow risk assessment process according to standard risk management process. Even this part is not the focus of this research which scoped the activities in risk identification and risk analysis. However, it will be benefit for NPD team to have some guideline for risk response action. Then some common actions for risk response have been further study by literature review and are summary in Table 5.10.

Table 5.13 Risk response/resolution for NPD project

No.	Risk Categories	Response/Resolution suggest by research
1	Schedule risk	Use project tracking methods to detect problem and provide corrective action. A top-down project tracking approach is recommended for project networks with a serial activity structure and a bottom-up approach should be used in a parallel structured project network. (Vanhoucke 2011) Use project management tools for schedule projection such as CPM and PERT or Stochastic Simulator (Sharma and Suri 2011)
2	Organization structure	Consider the structural implications of project designs during the feasibility and planning stages as risk analysis and risk mitigation processes. (Bannerman 2009)
3	Project communication	Include the plan to ensure sufficient knowledge transfer in project management plans. Especially in case of virtual team or team member working remotely. Moreover, knowledge that is traditionally shared implicitly might be considered to share explicitly through electronic means. (Reed and Knight 2010)
4	Economic risk	Signing of long-term contracts in which measures of anticipating effects of fluctuations are taken to minimize monetary risks. (Florescu 2012) Use Risk analysis tools, such as the cost-benefit analysis, sensitivity and scenario analysis and Monte Carlo Simulation (Katrin and Stefan 2011)
5	Technical complexity	Under conditions of high technical complexity, training has a strong effect on implementation success. Also try to reduce project complexity by to keeping uncertainty in the manageable domain (Giezen 2012)
6	Location selection	Use some methodology such as Monte Carlo Simulation to help determine candidate locations and then conduct a financial risk analysis to determine the ideal location of a new facility. (Ridlehoover 2004)
7	Resource planning	To manage the risk posed by uncertainties in resource planning, flexibility and robustness are two key classes of strategies that organization should focus. (Andrews 1995)

8	Team knowledge	Knowledge management of the projects should be an integral part of the activities of the modern efficient product development organizations (Kettunen 2003)
9	Design risk	Use knowledge management to learn from experience and implement some advanced principles such as intelligent failure (McGrath 2011)
10	Manufacturing technology	In advanced manufacturing technology environment appropriate tools for successfully managing a project should be consider by risk profile. When faced with high technology risk, management should first attack risk at its sources. Then organization should focus all efforts on making the new technology work. (Hottenstein and Dean 1992)
11	Intellectual properties	Walker (2012) suggested organization to perform several task relate to IP issues. 1) Register IP to guard against risk and maximize value to the organization. 2) Develop culture that value IP, provide training and create awareness of IP 3) Form part of an organization's integrated IP management strategy which include policies, processes and system. 4) Establish processes for an IP auditing program and IP infringement monitoring Cauthorn (2008) published paper about IP insurance that can be used for balance sheet protection, contractual liability protection, and deal facilitation.
12	Sourcing and materials planning	Christopher et al. (2011) proposed the solution for creating a global sourcing risk management culture and Establishing global sourcing continuity teams as following. 1) Training 2) Global organizational focus 3) Performance measurement 4) Long-term relationships with Suppliers 5) Staggered new product introductions; standardization across products 6) Internal integration; external integration
13	Customer requirement	Use QFD or Kano to translate customer requirements (CRs) into engineering characteristics (ECs) (Wang and Chin 2011, Li et al. 2011, Li, Chin, and Luo 2012, Zhou et al. 2013)
14	Manufacturing capability	Use process incapability index to evaluate manufacturing risk (Pan and Lee 2009)
15	Logistic & Transportation	Wright and Datskovska (2012) provide suggestion to deal with Logistic & Transportation problems as following. 1) Development of the trusted networks for effective collaboration. 2) Sharing data and information between businesses and governments to provide a clearer global picture of supply chain and transportation networks' vulnerabilities and support the coordination of backup plans in the event of a disruption. 3) Conducting scenario planning on a regular basis for reducing systemic risk across networks.

16	Procurement and contract	The use of incentives and collaboration or partnering arrangements help to establish a collaborative approach to risk management. Using a decision support system to model risks for procurement processes and to design a robust purchasing plan, including supplier selection and order allocation in the presence of spot market by consider the effects of correlated demand, yield and price uncertainties. (Hong and Lee 2013)
17	Social risk	
18	Political risk	Use of Political Risk Insurance (El-Diraby and Gill 2006)
19	Natural risk	Have a central agency for disaster response (Moynihan 2013) or pursue risk-reduction strategies such as develop a natural-hazards “super generalist” who is well versed in the application of multiple disciplines to real-world problem solving (Nelson 2013)
20	Compliance risk	Develop organization to monitor compliance or use 3rd party service or software such as as "governance, risk, and compliance" (GRC) software (Bamberger 2009)

These response actions are the common resolutions by risk categories which were studied by researcher. However the risk factors that will be found in each NPD project may different from the problem in those research and NPD team may need specific action that more appropriate for each risks and this area can be further study in the future.

5.3 PROPOSED RISK ASSESSMENT MODEL

The risk assessment model proposed in chapter consists of 1) NPD process developed from literature review of NPD research; 2) risk management process developed from comparison of risk management method from international standard related to risk management and risk assessment method used impact and probability for risk analysis. Figure 5.11 illustrate the proposed model in this phase of research.

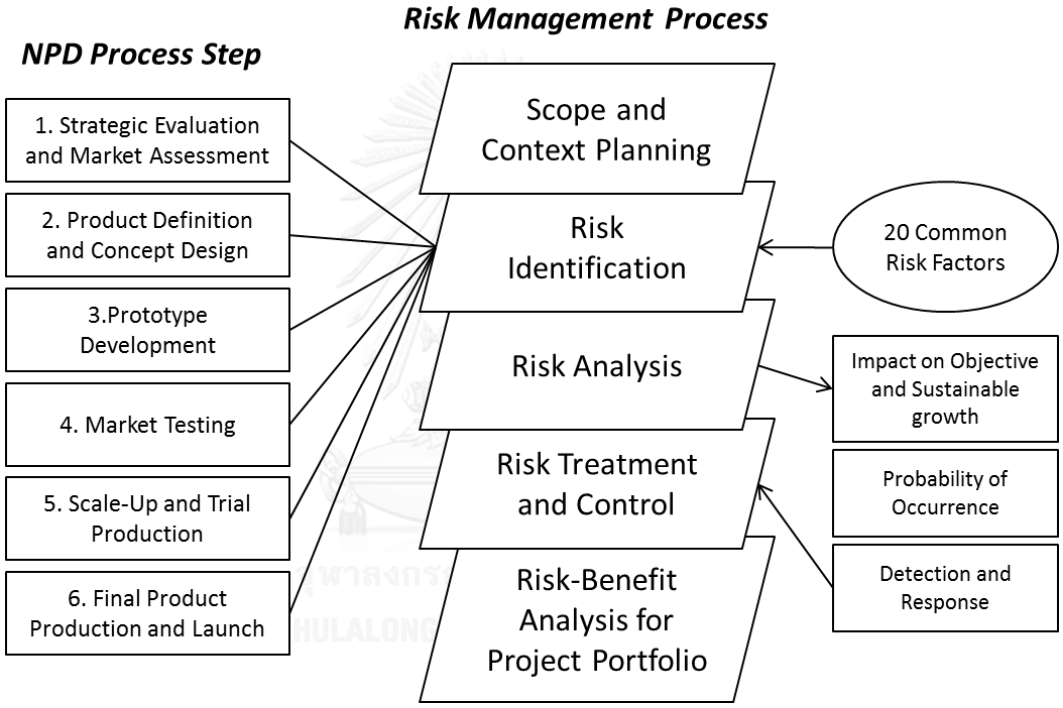


Figure 5.13 Proposed risk assessment model

CHAPTER 6
VALIDATION OF RISK MANAGEMENT MODEL

6.1 BACKGROUD OF CASE STUDIES

The proposed risk management model (Section 5.3) has been validated by case studies of NPD project in food study. The cases have been selected according to methodology in Section 3.4. The profile of case studies with type of product and details of NPD process are shown in Table 6.1

Table 6.1 Profile of case study

Case	Company	Type of Product	Type of NPD	NPD Phase
No.1	Company A	Instant Food	OEM customer	Scale-up and Launch
No.2	Company A	Ready to eat food	New Market	Product Definition and Design
No.3	Company B	Seafood snack	Line Extent ion	Market Testing
No.4	Company B	Rice Seasonings	New Market	Prototype Development

6.2 FINDING FROM CASE STUDY

6.2.1 Case study 1

Total 21 members from several functions involved in case study. See the function and distribution of each function below.

1) Sale & Marketing 3
2) Productivity Improvement 2
3) Engineering 1

4) Manufacturing 2
5) R&D 12
6) Quality 1
7) Planning 1
8) Accounting 1
9) Distribution and Warehouse 2

Risk Identification

The new product during Scale-up and Launch phase has been selected for risk assessment in this case study. Seven risk factors have been identified using NPD Risk Breakdown Structure. The details are display in table below.

Table 6.2 Risk factors and descriptions (case study 1)

Code	Risk Category (from RBS)	Risk Factor	Description and Impact
R1	Economic risk	Customer Buying power	The economic situation may cause impact to customer income and reduce buying power
R2	Team knowledge	Product knowledge	New type of product which R&D team do not have experience
R3	Manufacturing technology	Manufacturing Equipment	New process, need modification of manufacturing equipment which may cause the delay
R4	Sourcing and materials planning	Inconsistency of raw material quality	Raw materials (shrimp) from different source may have variation in size
R5	Social risk	Labor force	Use of migrant worker in area may cause unstable work force
R6	Natural risk	EMS disease	The natural EMS disease in shrimp cause interruption of raw materials supply
R7	Compliance risk	Trade Policy	The regulation in country of export customers may cause compliance issue

Risk Analysis

The risk factors from risk identification process have been analyzed in next step by using traditional risk matrix (Figure 6.1) and compare the results with Fuzzy Risk Analysis method (Table 6.3 and Table 6.4)

Analysis Matrix		Impact				
		1	2	3	4	5
Likelihood	5	M 5	H 10	H 15	E 20	E 25
	4	M 4	M 8	H 12	E 16	E 20
	3	L 3	M 6	M 9	H 12	H 15
	2	L 2	M 4	M 6	M 8	H 10
	1	L 1	L 2	L 3	M 4	M 5

Figure 6.1 Risk matrix for case study

Table 6.3 Risk analysis by traditional risk matrix (case study 1)

Code	Risk Factor	Likelihood Level	Impact Level	Score	Risk Degree
R1	Customer Buying power	2	4	8	Medium
R2	Product knowledge	1	3	3	Low
R3	Manufacturing Equipment	2	3	6	Medium
R4	Inconsistency of Raw material quality	3	4	12	High
R5	Labor force	1	1	2	Low
R6	EMS disease	1	4	4	Medium
R7	Trade Policy	2	5	10	Medium

Table 6.4 Fuzzy input and output for risk analysis (case study 1)

Code	Risk Categories	Risk Factors	Fuzzy Input			Fuzzy Output
			Likelihood	Impact	Importance	
R1	Economic risk	Customer Buying power	4	8	7.2	0.45
R2	Team knowledge	Product knowledge	2	6	7.4	0.33
R3	Manufacturing technology	Manufacturing Equipment	4	6	6.2	0.45
R4	Sourcing and materials planning	Inconsistency of raw material quality	6	8	7.2	0.66
R5	Social risk	Labor force	2	2	5.5	0.32
R6	Natural risk	EMS disease	2	8	6.6	0.33
R7	Compliance risk	Trade Policy	4	10	6.6	0.56

The comparison of results from traditional risk matrix and fuzzy risk analysis showed different level of details in output score, which benefit for better prioritization of risk factors. However, for some risk factors that input values are not significant different, we might see the output value from fuzzy system in the same level.

Table 6.5 Traditional risk matrix and fuzzy risk analysis (case study 1)

Risk Code	Traditional Risk Degree	Ranking (Traditional)	Fuzzy Risk Index	Ranking (Fuzzy)
R1	Medium	2	0.45	4
R2	Low	3	0.33	5
R3	Medium	2	0.46	3
R4	High	1	0.66	1
R5	Low	3	0.32	6
R6	Medium	2	0.33	5
R7	Medium	2	0.56	2

6.2.2 Case study 2

Risk Identification

The new product during Product Definition and Design has been selected for risk assessment in this case study. Nine risk factors have been identified using NPD Risk Breakdown Structure. The details are display in Table 6.6.

Table 6.6 Risk factors and descriptions (case study 2)

Code	Risk Category (from RBS)	Risk Factor	Description and Impact
R1	Economic risk	Customer Buying power	The economic situation may cause impact to customer income and reduce buying power
R2	Location Selection	Food contamination	Manufacturing plant located near by animal food plant with high odor in environment
R3	Manufacturing technology	Manufacturing Equipment	New process, need modification of manufacturing equipment which may cause the delay
R4	Customer Requirement	Product design may not match with customer need	The characteristic of product are defined by R&D team with limit knowledge of customer preference
R5	Social risk	Labor force	Use of migrant worker in area may cause unstable work force
R6	Procurement and Contract	Seasonal effect for cost of raw materials	The raw material is agricultural products which the price can be varied in each season and also can be effect by climate change.
R7	Political Risk	Government policy such as Rice subsidy scheme	Problem from government policy may affect the market situation for raw materials
R8	Natural Risk	Flooding	Natural disaster such as flooding can cause interruption of materials supply
R9	Natural Risk	Drought	Natural risk such as drought may affect to continuous supply and cost of agricultural product use as raw materials

Risk Analysis

The risk factors from risk identification process have been analyze in next step by using traditional risk matrix and compare the results with Fuzzy Risk Analysis method

Table 6.7 Risk analysis by traditional risk matrix (case study 2)

Code	Risk Factor	Likelihood Level	Impact Level	Score	Risk Degree
R1	Economic risk	3	4	12	High
R2	Location Selection	2	4	8	Medium
R3	Manufacturing technology	3	3	9	Medium
R4	Customer Requirement	3	5	15	High
R5	Social risk	3	4	12	High
R6	Procurement and Contract	3	4	12	High
R7	Political Risk	1	4	4	Medium
R8	Natural Risk	1	3	3	Low
R9	Natural Risk	2	3	6	Medium

Table 6.8 Fuzzy input and output for risk analysis (case study 2)

Code	Risk Categories	Risk Factor	Fuzzy Input			Fuzzy Output
			Likelihood	Impact	Importance	
R1	Economic risk	Customer Buying power	6	8	7.2	0.68
R2	Location Selection	Food contamination	4	8	6.5	0.54
R3	Manufacturing technology	Manufacturing Equipment	6	6	6.2	0.46
R4	Customer Requirement	Product design may not match with customer need	6	10	8.0	0.88
R5	Social risk	Labor force	6	8	5.5	0.68
R6	Procurement	Seasonal effect	6	8	6.2	0.68

	and Contract	for cost of raw materials				
R7	Political Risk	Government policy	2	8	5.9	0.33
R8	Natural Risk	Flooding	2	6	6.6	0.33
R9	Natural Risk	Drought	4	6	6.6	0.33

Table 6.9 Traditional risk matrix and fuzzy risk analysis (case study 2)

Risk Code	Traditional Risk Degree	Ranking (Traditional)	Fuzzy Risk Index	Ranking (Fuzzy)
R1	High	1	0.68	2
R2	Medium	2	0.54	3
R3	Medium	2	0.46	4
R4	High	1	0.88	1
R5	High	1	0.68	2
R6	High	1	0.68	2
R7	Medium	2	0.33	5
R8	Low	3	0.33	5
R9	Medium	2	0.33	5

6.2.3 Case study 3

Risk Identification

The new product during Market Testing phase has been selected for risk assessment. Ten risk factors have been identified using NPD Risk Breakdown Structure. The details are display in Table 6.10.

Table 6.10 Risk factors and descriptions (case study 3)

Code	Risk Category (from RBS)	Risk Factor	Description and Impact
R1	Customer requirement	Taste of product do not meet customer requirement	Problem in product design and specification cause problem in customer acceptance
R2	Compliance risk	Product registration	Delay in product registration process
R3	Project communication	Ineffective communication between R&D and manufacturing plant	Communication problem due to different physical location of R&D and manufacturing plant
R4	Team knowledge	Lack of knowledge in PM	NPD team did not apply Project Management methodology for project planning and control cause deviation from project plan
R5	Organization structure	Inefficient resource of R&D staff	High workload from several development project with limit resource
R6	Sourcing and materials planning	Interruption of materials supply	Raw material shortage cause by problem from supplier
R7	Economic	Customer Buying Power	The economic situation cause impact to customer income and buying power
R8	Economic	Price fluctuation of raw materials	The economic situation cause price of raw materials change
R9	Natural risk	Flooding	Flooding cause interruption in development process or logistics of materials/product
R10	Natural risk	Raw material shortage	Natural disaster causes impact on raw material source

Risk Analysis

The risk factors from risk identification process have been analyze in next step by using traditional risk matrix and compare the results with Fuzzy Risk Analysis method

Table 6.11 Risk analysis by traditional risk matrix (case study 3)

Code	Risk Factor	Likelihood Level	Impact Level	Score	Risk Degree
R1	Taste of product do not meet customer requirement	1	5	5	Medium
R2	Product registration	2	3	6	Medium
R3	Ineffective communication between R&D and manufacturing plant	4	4	16	Medium
R4	Lack of knowledge in PM	5	3	15	High
R5	Inefficient resource of R&D staff	4	2	8	Medium
R6	Interruption of materials supply	2	4	8	Medium
R7	Customer Buying Power	2	2	4	Medium
R8	Price fluctuation of raw materials	2	3	6	Medium
R9	Flooding	1	4	4	Medium
R10	Raw material shortage	4	5	20	Extreme

Table 6.12 Fuzzy input and output for risk analysis (case study 3)

Code	Risk Categories	Risk Factor	Fuzzy Input			Fuzzy Output
			Likelihood	Impact	Importance	
R1	Customer requirement	Taste of product do not meet customer requirement	2	10	7.8	0.66
R2	Compliance risk	Product registration	4	6	6.9	0.33
R3	Project communication	Ineffective communication between R&D and manufacturing plant	8	8	7.7	0.89
R4	Team knowledge	Lack of knowledge in PM	10	3	8.2	0.66
R5	Organization structure	Inefficient resource of R&D staff	8	4	7.8	0.45
R6	Sourcing and materials planning	Interruption of materials supply	4	8	7.7	0.54
R7	Economic	Customer Buying Power	4	4	7.7	0.37
R8	Economic	Price fluctuation of raw materials	4	6	7.7	0.45
R9	Natural risk	Flooding	2	8	6.2	0.33
R10	Natural risk	Raw material shortage	8	10	6.2	0.87

Table 6.13 Traditional risk matrix and fuzzy risk analysis (case study 3)

Risk Code	Traditional Risk Degree	Ranking (Traditional)	Fuzzy Risk Index	Ranking (Fuzzy)
R1	Medium	3	0.66	3
R2	Medium	3	0.33	7
R3	Medium	3	0.89	1
R4	High	2	0.66	3
R5	Medium	3	0.45	5
R6	Medium	3	0.54	4
R7	Medium	3	0.37	6
R8	Medium	3	0.45	5
R9	Medium	3	0.33	7
R10	Extreme	1	0.87	2

6.2.4 Case study 4

Risk Identification

The new product during Prototype Development phase has been selected for risk assessment. Total 14 risk factors have been identified using NPD Risk Breakdown Structure. The details are display in Table 6.14

Table 6.14 Risk factors and descriptions (case study 4)

Code	Risk Category (from RBS)	Risk Factor	Description and Impact
R1	Technical complexity	Product formulation in lab scale	The specific product requirement cannot be achieved by product formulation in lab.
R2	Design risk	Packaging design	Packaging design do not match with target customer.
R3	Customer requirement	Customer Acceptance	Taste of product do not satisfy customer.
R4	Customer requirement	Market information	Lack of information from target market.

R5	Manufacturing capability	Machine capability	The current manufacturing process/equipment cannot be used for new product.
R6	Compliance risk	Product registration	Delay in product registration process
R7	Project communication	Ineffective communication between R&D and manufacturing plant	Communication problem due to different physical location of R&D and manufacturing plant
R8	Team knowledge	Lack of knowledge in PM	NPD team did not apply Project Management methodology for project planning and control cause deviation from project plan
R9	Organization structure	Inefficient resource of R&D staff	High workload from several development project with limit resource
R10	Sourcing and materials planning	Interruption of materials supply	Raw material shortage cause by problem from supplier
R11	Economic	Customer Buying Power	The economic situation cause impact to customer income and buying power
R12	Economic	Price fluctuation of raw materials	The economic situation cause price of raw materials change
R13	Natural risk	Flooding	Flooding cause interruption in development process or logistics of materials/product
R14	Natural risk	Raw material shortage	Natural disaster causes impact on raw material source

Risk Analysis

The risk factors from risk identification process have been analyze in next step by using traditional risk matrix and compare the results with Fuzzy Risk Analysis method.

Table 6.15 Risk analysis by traditional risk matrix (case study 4)

Code	Risk Factor	Likelihood Level	Impact Level	Score	Risk Degree
R1	Product formulation in lab scale	3	4	12	High
R2	Packaging design	2	4	8	Medium
R3	Customer Acceptance	3	5	15	High

R4	Market information	3	4	12	High
R5	Machine capability	3	3	9	Medium
R6	Product registration	2	2	4	Medium
R7	Ineffective communication between R&D and manufacturing plant	4	4	16	Extreme
R8	Lack of knowledge in PM	5	3	15	High
R9	Inefficient resource of R&D staff	4	2	8	Medium
R10	Interruption of materials supply	3	4	12	High
R11	Customer Buying Power	2	2	4	Medium
R12	Price fluctuation of raw materials	2	3	6	Medium
R13	Flooding	1	4	4	Medium
R14	Raw material shortage	4	5	20	Extreme

Table 6.16 Fuzzy input and output for risk analysis (case study 4)

Code	Risk Categories	Risk Factor	Fuzzy Input			Fuzzy Output
			Likelihood	Impact	Importance	
R1	Technical complexity	Product formulation in lab scale	6	8	6.8	0.68
R2	Design risk	Packaging design	4	8	8.8	0.52
R3	Customer requirement	Customer Acceptance	6	10	7.8	0.88
R4	Customer requirement	Market information	6	8	7.8	0.68

R5	Manufacturing capability	Machine capability	6	6	7.1	0.45
R6	Compliance risk	Product registration	4	4	6.9	0.33
R7	Project communication	Ineffective communication between R&D and manufacturing plant	8	8	7.7	0.89
R8	Team knowledge	Lack of knowledge in PM	10	6	8.2	0.88
R9	Organization structure	Inefficient resource of R&D staff	8	4	7.8	0.45
R10	Sourcing and materials planning	Interruption of materials supply	6	8	7.7	0.68
R11	Economic	Customer Buying Power	4	4	7.7	0.37
R12	Economic	Price fluctuation of raw materials	4	6	7.7	0.37
R13	Natural risk	Flooding	2	8	6.2	0.33
R14	Natural risk	Raw material shortage	8	10	6.2	0.87

By comparison of results from traditional risk matrix and fuzzy risk analysis, fuzzy risk analysis show better level of detail as risk index which provide better results for risk prioritization.

Table **6**.17 Traditional risk matrix and fuzzy risk analysis (case study 4)

Risk Code	Traditional Risk Degree	Ranking (Traditional)	Fuzzy Risk Index	Ranking (Fuzzy)
R1	High	2	0.68	4
R2	Medium	3	0.52	5
R3	High	2	0.88	2
R4	High	2	0.68	4
R5	Medium	3	0.45	6
R6	Medium	3	0.33	8
R7	Extreme	1	0.89	1
R8	High	2	0.88	2
R9	Medium	3	0.45	6
R10	High	2	0.68	4
R11	Medium	3	0.37	7
R12	Medium	3	0.37	7
R13	Medium	3	0.33	8
R14	Extreme	1	0.87	3

6.3 SUMMARY OF CASE STUDY

From four case studies used for validation process, we can summarize the results of identified risk with high priority in Table 6.18.

Table 6.18 Data summary for case studies

Case	Company	Type of Product	Type of NPD	NPD Phase	Identified important risks
No.1	Company A	Instant Food	OEM customer	Scale-up and Launch	Quality of raw materials, Trade barrier for export
No.2	Company A	Ready to eat food	New Market	Product Definition and Design	Understand of customer requirement, Inconsistency of raw material cost
No.3	Company B	Seafood snack	Line Extent ion	Market Testing	Communication between R&D and MFG, Team knowledge in project management, Human resource constraint
No.4	Company B	Rice Seasonings	New Market	Prototype Development	Communication between R&D and MFG, Product formulation for scale-up, Understand of customer requirement,

6.4 REFINED RISK ASSESSMENT MODEL

The risk assessment of NPD projects in four case study confirmed that the risk assessment method in refined risk management model (Figure 6.2) is useful for NPD team to navigated risk identification and risk analysis. The risk management model consists of 1) NPD process; 2) Risk management process and 3) Risk identification by RBS and checklist; and 4) Fuzzy risk analysis has been used in next phase for development of risk management tools.

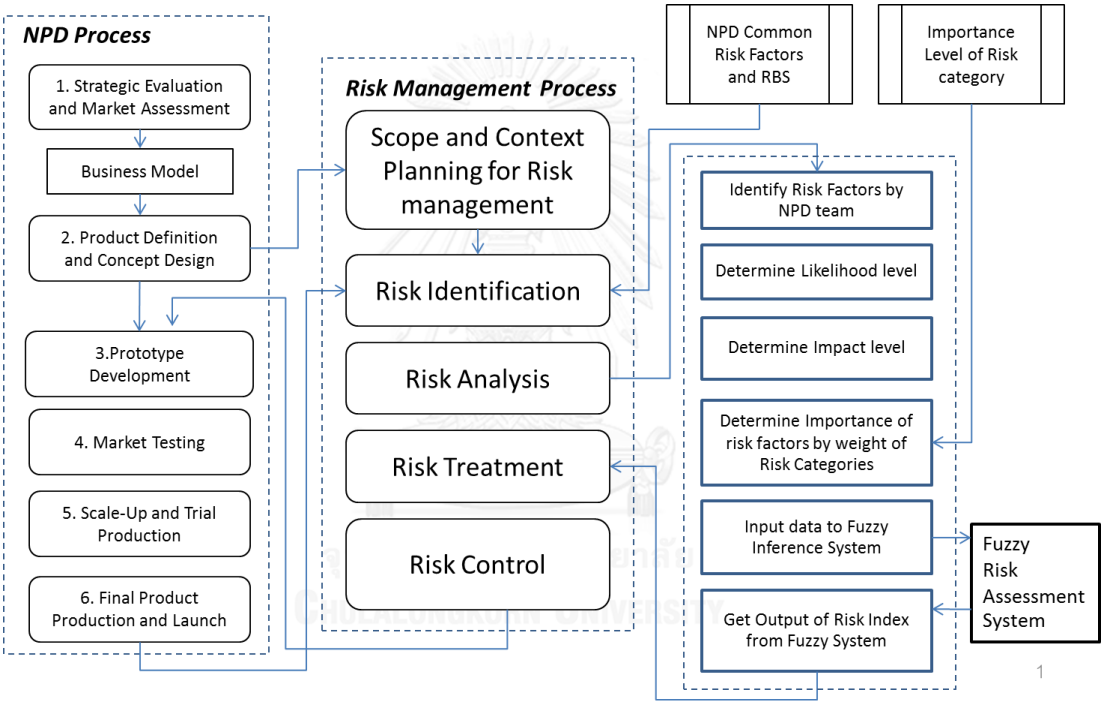


Figure 6.2 Refined risk assessment model

CHAPTER 7
DEVELOPMENT OF RISK ASSESSMENT TOOL

7.1 NEED OF INDUSTRY FOR RISK ASSESSMENT TOOL

From literature review and empirical study of NPD process in food study, the requirement for risk assessment tools can be summarize as following.

- Prefer integrated tool with all process step for risk assessment, include extend function to assist for risk response, risk monitor and control activities.
- Can be integrated or compatible with current project management software or NPD system/database used by organization.
- Require tool that focus on both of risk identification and analysis (most of the risk management software in the market focused on risk analysis only)
- Include functionality to record risk assessment data such as risk register from previous project as organizational process asset for future use.
- Provide precise result for risk analysis but also flexible for different project type and characteristics.

7.2 TOOL DEVELOPMENT

7.2.1 Platform selection

The risk assessment tool can be developed using the concept from risk assessment model. The options of platform that can be used for risk assessment tool are summarized in Table 7.1. In order to test the concept and validate the risk assessment model in this research, we have develop the prototype system of risk assessment tool by used separate system of excel worksheet with risk breakdown structure and checklist of risk factors in each categories for risk identification process and manually input the data of risk factors to fuzzy inference system in MATLAB software.

Table 7.1 Software platform comparison

Platform	Advantage	Disadvantage
Web base Tool	Easy to use, no compatibility issue	Concern of confidentiality
Mobile/Tablet Application	Low cost, high mobility	Limit data sharing across platform
Cloud database	Central database with data sharing	High investment cost, not appropriate for small organization
Standalone PC application	High flexibility	Limit data sharing capability
Workflow Integrated software	Custom design for specific requirement of organization	Compatibility issue, take time for development, high investment cost

7.2.2 Structure of risk assessment tool

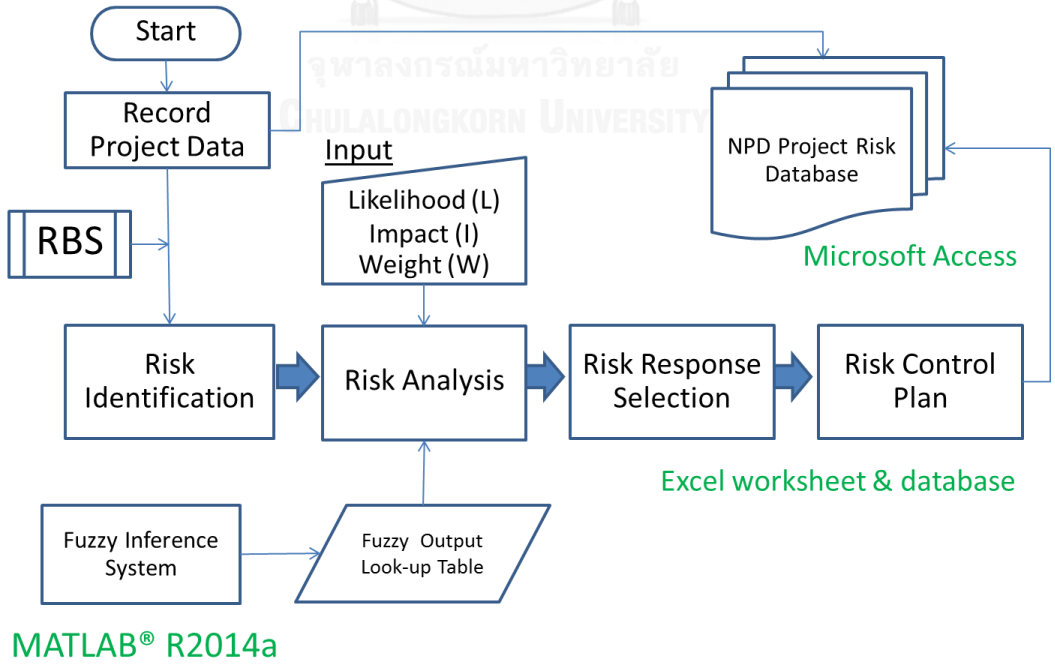


Figure 7.1 Structure of risk assessment system

7.3 TOOL VALIDATION

7.3.1 User acceptance test

The prototype of risk assessment tools has been used in case study and the opinion of users have been collect by questionnaire consist of separated question in four topics according to Technology Acceptance Model (TAM) (Davis 1989, Davis, Bagozzi, and Warshaw 1989). The topics in Questionnaire survey includes.

- Feasibility (performance, job fit, accuracy)
- Usability/Perceive Ease of use (easy to learn, user friendly)
- Utility/Perceived usefulness (outcome, advantage)
- Behavioral intend to use (compatibility)

The results of validation results can be seen in Table 7.2. The majority of user rate this tool at level 4 for feasibility, utility and behavioral intend to use with percentage of 47.6, 61.9 and 61.9 respectively, and rate level 3 and 4 in with percentage of 42.9 for usability of the tool and total acceptance rate of 90.5%.

Table 7.2 User's rating for acceptance of software tool

	1 (Very un-satisfy)	**2** (Un-satisfy)	**3** (Fair)	**4** (Satisfy)	**5** (Very Satisfy)
Feasibility	0%	0%	28.6%	47.6%	23.8%
Usability/Perceive Ease of use	0%	9.5%	42.9%	42.9%	4.8%
Utility/Perceived usefulness	0%	0%	23.8%	61.9%	14.3%
Behavioral intend to use	0%	0%	33.3%	61.9%	4.8%
Total	**0%**	**2%**	**32%**	**54%**	**12%**

7.3.2. Internal validity test of risk assessment tool

The internal validity test has been conducted with NPD project in case study to identified number of true-positive, true-negative, false-positive (type I) and false-negative (type II) the result of validity test are shown in Table 7.3 and Table 7.4.

Table 7.3 Result of validity test for success case

Outcome (Tool)	**Condition** (actual)		
	Positive	**Negative**	**Total**
Positive	5 (71.4%)	2 (28.6%)	7
Negative	0 (0%)	13 (100%)	13
Total	5	15	20

Table 7.4 Result of validity test for fail case

Outcome (Tool)	**Condition** (actual)		
	Positive	**Negative**	**Total**
Positive	3 (75.0%)	1 (25.0%)	4
Negative	3 (18.7%)	13 (81.3%)	16
Total	6	14	20

The internal validity test showed high percentage in True-Positive and True-Negative area with low percentage in both of type 1 and type 2 error.

7.4 COMMERCIALIZATION

7.4.1 Market Potential

The concept of this tool can be further developed to software tool for commercial use. The market target is the NPD professionals in food manufacturing firms in Bangkok and surrounding area with the number of company in middle to large size for 292 firms as data published by ministry of industry in 2011 (Table 7.5).

Table 7.5 Number of potential users in food industry

Province	Number of food companies	Number of medium and large size companies
Bangkok	598	29
Chachoengsao	91	15
Chonburi	911	28
Rayong	112	6
Samutprakarn	304	46
Samutsongkram	66	5
Samutsakorn	435	82
Ayutthaya	83	19
Nonburi	122	4
Prathumthani	191	23
Ratchaburi	160	16
Saraburi	103	19
	3176	292

Source: Department of industrial works, Ministry of Industry (Last update: 12/7/2011)

7.4.2 Options for commercialization

Options for commercialization of risk assessment model are suggested as follow.

1. Provide risk identification tools via web page or internet media for free of charge and gain income from advertising or membership fee.
2. Use information from risk identification tools for consultation service to improve the NPD process in organization.
3. Develop integrated tool as standalone application software and gain income from software license fee.
4. Develop software application for cloud computing and collect the member fee for access online application.
5. Develop custom application as extension module for risk assessment that integrates with NPD workflow application in food industry.
6. Provide model and risk analysis methodology to application developer and gain income from copyright or patent.

7.4.3 Business Plan

The further study has been done for the option of development of integrated tool as standalone application software and gain income from software license fee. The estimated man-day for software development are shown in Table 7.6.

Table 7.6 Workload for commercial software development

	PM	Archi-tecture	SA	Developer	Tester	Test Engineer	Writer
Analyze Requirements	1	1	2	1			
Design	0.5	2	2	1			
Complete Design	1		1				
Build & Test	2	0.5		5	2	1	
Build application				4			
Complete Build	0.5	0.5					
Test			2	2	4	1	
Integration Test	0.5		1.5	1	3	1	
Product Test	0.5		1.5	1	3	1	
UAT	0.5		0.5		1	0.5	
Complete Test	0.5	0.5	0.5	1.5	2	0.5	
Deploy	1			1			
Go-live	1.5		2	1			
Post Support	1		1.5	1			2
Project Completion	1.5	0.5	0.5	0.5			8

For estimated work load in Table 7.4 and current cost rate in the market, we can calculate the total cost for software development in Table 7.5.

Table 7.7 Cost estimation for commercial software development

Project Roles	Man-day	Unit cost (Baht/Man-day)	Total Cost
Project Manager	12	15,000	180,000
Architecture	5	12,000	60,000
System Analyst (SA)	15	10,000	150,000
Developer	20	6,500	130,000
Tester	15	5,500	82,500
Performance test engineer	5	8,000	40,000
Technical Document writer	10	4,000	40,000
Total Cost			682,500

Table 7.7 illustrates the software development cost with standard functionality only. For actual commercialization, the other cost such as programming for additional function, network and workflow or capability to integrates with exiting system have to be consider including other deliverable for service, user training, etc.

CHAPTER 8

RESEARCH SUMMARY

8.1 SUMMARY OF RESEARCH FINDING

The summaries of research finding by each research objectives are summarized in Table 8.1.

Table 8.1 Summary of research finding

Research Objective	Chapter	Research Method	Research Finding
1. To explore the risk management process for new product development (NPD) projects.	2	1. LR of PM body of knowledge and International Standard 2. Systematic LR for risk management research 3. LR of NPD process	1. Comparison of risk management process (Figure 4.1) 2. Review of tools used for risk management a. Analytic hierarchy process (AHP) b. Bayesian network (BN) c. FMEA d. Fuzzy set e. Expected utility theory f. Game theory g. Theory of constraints h. Monte Carlo simulation i. Bubble diagrams j. Control charts 3. Problems of risk management for NPD 4. Review of NPD process for all industries (Table 2.1)
2. To study risk management practice of NPD projects in food companies in Thailand.	4,5	1. Questionnaire survey for risk management practice 2. In-depth interview of NPD experts	1. Summary of risk management practices and tools for NPD in food industry (Table 5.2) 2. Requirement for risk management process and tool (Table 5.3)
3. To explore common risk factors in NPD projects for	2,4,5	1. In-depth interview of NPD experts	1. Common project risk factors (39 Risk factors) (Table 2.7)

food industry.			2. Common risk factors for NPD in food industry (20 Risk categories) (Table 5.5)
4. To develop risk assessment model for NPD Projects.	5	1. In-depth Interview of NPD experts	1. NPD process used for food industry 1) Strategic evaluation and concept design 2) Product definition and market assessment 3) Prototype development 4) Market testing 5) Scale-up and trial production 6) Final product production and launch 2. Proposed risk assessment model (Figure 5.12)
5. To validate & refine risk assessment model.	6	1. Case studies of NPD projects in Food industry	1. Risk breakdown structure (RBS) for risk identification 2. Risk analysis method by Fuzzy inference system 3. Refined risk assessment model (Figure 6.2)
6. To develop tool for risk assessment in NPD project.	7	1. Software development process 2. Questionnaire survey for Tools acceptance	1. User requirements for risk assessment tool (Section 7.1) 2. Option of tool platform (Table 7.1) 3. Structure of risk assessment system (Figure 7.1) 4. Result of user's acceptance test (Table 7.2)

8.2 DISCUSSION

The scope of this research focused on risk assessments on activities that have been performed during development of new products. However, some decisions during this development process will cause effects on operational risks of a manufacturing organization after mass production and products launched. The scope of a risk assessment model in this study is a combination of project risks and operational risks related to strategic decisions for a supply chain network and designs of the product and manufacturing process. The risks for food safety that have been studied by many researchers in this industry, also included as part of the Compliance risk but is not the main focus of this work.

The NPD process from the literature review has a different process step with different scopes and levels of detail. However, all processes used a similar approach starting from an opportunity assessment or identify market need, then to generate ideas for product definition and draft specification, then some of the process may move to market testing of those ideas, while some industries may need to work on the product prototype before bringing those prototypes for further testing in both technical characteristics and product performance, including market testing for user acceptance. Then, the process definition, or draft specification, may need to be improved or adjusted to match with the market demand before proceeding to the manufacturing process design for scale-up. If the product construction and manufacturing process can pass a review process, the NPD project will move to mass product and product launching. It is important for the developer of a risk assessment model and the risk assessment tools to understand these NPD processes due to the risk assessment that must be performed with every step of the NPD phases.

However, the findings from the case study indicated that the NPD team members cannot clearly separate the specific risk factors in each NPD phase as the original design of our tool, because during the gate review of each NPD phase, an organization will assess information and risks in those steps and also foresee any opportunity and treat it as such in the future phase of NPD. For example, in case study No. 2 the NPD team was working in the product definition and design phase

when conducting risk assessment, but they also expanded the scope of the assessment to other risks in the manufacturing process and risks in the supply of materials in the Final production and launch phase. This practice emphasized the importance of the systematic risk management process to identify, document and repeat the assessment of identified risks, while identifying other unknown risks in future phases as an iterative planning process.

From the empirical study in this research, most of the large to medium size of food manufacturers in Thailand have their own NPD process. Some organizations have completed the process, database and work flow to a management NPD process. Some organizations have some guidelines for the process step and checklists for each NPD phase. Then, there are opportunities to integrate formal risk assessment activity and the use of an assessment tool into those NPD systems to navigate systematic risk management for the NPD team to help reduce the impact of uncertainty and increase the success rate in product development.

The risk management processes seem similar in all standards and references. Both of the project and operational risk management also used the same approach start from a defined scope and context of risk management, and then moved to risk identification to explore all related risks that might have an impact on a project. This requires the risk analysis process to indicate the importance of each risk factor, and lead to the prioritization and find appropriate risks and response depending on the priority or the importance of each of the risk factors. The risk assessment process steps used in this research also follow the same approach. However, the novelty of this study can be seen on the development of the Risk breakdown structure (RBS) and risk checklists specifically for NPD projects in the food industry while most of RBS previously developed for a general type of project, and also not specific for food context. In the risk identification process of project works, the normal practice of an organization will acquire expert opinions by brain storming techniques from project team members and stakeholders of those projects. This approach might be effective and provide acceptable output for projects with a clearly defined scope and limit the number of related persons. However, for the NPD project, the stakeholder can be included in almost every function or department in an organization starting from

sales and marketing as a starting point for opportunity assessment, then involve R&D for development and production for the manufacturing process and other related functions for logistics of manufacturing and physical distribution. This makes the risk identification of NPD projects a required wider scope in many different areas of an organization. Without structural and a context of specific tools like RBS from this research, it will be difficult to have completed results of risk identification especially when the team member has limited knowledge and experience in that type of project.

From the case studies, the NPD teams with different levels of experience can effectively use the risk categories in RBS to review all areas related to NPD. However, in some instances, they also need the example of risk factors in each area in the form of a checklist and our tools that also provide some list of common risk factors in each risk category. This checklist can be further developed as a risk database for lessons learned and knowledge management from previous projects to be an organizational process asset that will be of benefit for risk identification in future projects. Then the commercialized tool for risk management should include this feature in the further development of tools.

For a risk analysis process using the fuzzy inference system, the application software like MATLAB made it easier for users to create the risk analysis system with the option to use different inference method, different settings and a type of membership function and different defuzzification methods. However, the use of a separate system to analyze the project risk may not be efficient for a user who needs integrated tools for the risk management process. So, it might be necessary to include this inference system in a way that will be deployable and used without MATLAB.

In conclusion, we can summarize key findings from this research as following.

1) NPD team realized the benefit of risk management but lack of knowledge for a systematic approach. Integrate tools can effectively help navigate the process for risk management.

2) Scope of risk management for NPD projects are much wider than other types of projects due to a bigger group of stakeholders who are related to all future activities of the company. This requires special design tools for this type of project and will be more effective if the tools are designed as context/industry specific tools.
3) The NPD activities in an organization must follow the NPD process steps and gate reviews while risk assessment should use holistic approaches to review risks in all NPD phases at the beginning, and revisit the risk register again in every phase of NPD.

8.3 CONTRIBUTION OF RESEARCH

Originality of Research

1) Risk assessment model for NPD in food industry.
2) Risk breakdown structure (RBS) and checklist of common risk factors for the NPD project in the food industry.
3) Fuzzy risk analysis method for NPD using Impact, Likelihood and Importance weight of risk categories.

Contribution to theory

1) Advance study of success factor in food NPD by project risk management (Suwannaporn and Speece 2003, Suwannaporn and Speece 2010)
2) Test application risk management theory from International Standard and PM Body of Knowledge (ISO 2009, 2012, PMI 2013)
3) Test application of Fuzzy set theory as risk degree determination (Choi and Ahn 2010)

Contribution to Practice

1) Enable effective systematic risk management process for food companies.
2) Support decision making for the NPD project investment and portfolio management.
3) Help NPD team to identify, analyze and control project risks, results in reducing NPD project lead-time and increasing success rate of NPD.

TIM

Technology : IT and MATLAB® software for fuzzy inference system

Innovation : 1) Risk Breakdown Structure and checklist of common risk factors specially developed for food industry.
2) Fuzzy risk assessment method using 3 inputs of Likelihood, Impact and Importance weight

Management : Project management and Risk management methodology

8.4 RESEARCH LIMITATION

1) Risk management is a subjective issue, with limited support from historical data. It will be difficult to measure the performance or success of these activities by using data and quantitative methods. Several parts of this research based on the opinion of experts in NPD team which might have questions in the validity of the data and results. However, in traditional risk management methods (risk matrix) used by the industry, the same problem exists with even less data for inputs used for risk analysis.
2) The fuzzy set and fuzzy rules are defined by expert opinions in the NPD team and also have direct effect to the accuracy and distribution of output from the fuzzy inference system. The fuzzy output of risk analysis in some case studies showed the same level of Risk Index when some input only changes in small

amounts. If the NPD team would like to have a higher level of accuracy in output, the fuzzy set of input needs to be adjusted to provide better distribution of output. And the risk map of inputs and output can be used to help for this optimization.

3) The NPD process is an internal process which is the core value of most manufacturing firms. The details information about these processes are considered confidential for most of organizations. The research in this area will need a close connection and a high level of support from industry collaboration.

8.5 OPPORTUNITY FOR FUTURE RESEARCH

The other areas in risk management process for risk treatment and risk control must be studied in further studies to complete all process steps for risk management. This will lead to the development of an integrated system for systematic risk management of the NPD project in an organization. From previous studies, most of the large to medium size food manufacturers in Thailand have their own NPD process. Some organizations have a complete process, database and work flow for management of NPD process. Some organizations have some guidelines for the process step and checklist for each NPD phase. This will be a good opportunity to integrate the risk management process and tool into those NPD systems to help reduce the impact of uncertainty in product development activities and increase the success rate of the NPD project in an organization.

REFERENCES

Abrahamsen, EB, and Terje Aven. 2011. "Safety oriented bubble diagrams in project risk management." *International Journal of Performability Engineering* 7 (1):91.

Ahlemann, Frederik, Fedi El Arbi, Michael G Kaiser, and Axel Heck. 2013. "A process framework for theoretically grounded prescriptive research in the project management field." *International Journal of Project Management* 31 (1):43-56.

Aleixo, Gonçalo G, and Alexandra B Tenera. 2009. "New product development process on high-tech innovation life cycle." *World Academy of Science, Engineering and Technology* 58 (135):794-800.

Alesina, Alberto, Sule Özler, Nouriel Roubini, and Phillip Swagel. 1996. "Political instability and economic growth." *Journal of Economic growth* 1 (2):189-211.

Aloini, Davide, Riccardo Dulmin, and Valeria Mininno. 2012. "Modelling and assessing ERP project risks: A Petri Net approach." *European journal of operational research* 220 (2):484-495.

Andrews, Clinton J. 1995. "Evaluating risk management strategies in resource planning." *Power Systems, IEEE Transactions on* 10 (1):420-426.

APM. 2004. Project Risk Analysis & Management (PRAM) Guide, 2nd edition. APM, High Wycombe.

Australia, Standards. 2004. Risk Management AS/NZS 4360:2004. Standards Association of Australia, Strathfield.

Badri, Adel, Sylvie Nadeau, and André Gbodossou. 2012. "Proposal of a risk-factor-based analytical approach for integrating occupational health and safety into project risk evaluation." *Accident Analysis & Prevention* 48:223-234.

Bamberger, Kenneth A. 2009. "Technologies of compliance: Risk and regulation in a digital age." *Tex. L. Rev.* 88:669.

Bannerman, Paul L. 2009. "Risk Implications of Software Project Organization Structures." Software Engineering Conference, 2009. ASWEC'09. Australian.

Bosch-Rekveldt, Marian, Yuri Jongkind, Herman Mooi, Hans Bakker, and Alexander Verbraeck. 2011. "Grasping project complexity in large engineering projects: The TOE (Technical, Organizational and Environmental) framework." *International Journal of Project Management* 29 (6):728-739.

Branquinho, Maria Regina, Renata TB Ferreira, and Paola Cardarelli-Leite. 2010. "Survey of compliance with labeling legislation in food containing GMOs in Brazil." *Journal of food composition and analysis* 23 (3):220-225.

Burman, Liv, and Nils Sandberg. 2014. "Project Communication's Impact on Risk Management and Goal Achievement: A case study of project communication's impact on risk management and goal achievement in public place branding projects."

Carbone, Thomas A, and Donald D Tippett. 2004. "Project risk management using the project risk FMEA." *Engineering Management Journal* 16 (4):28-35.

Cauthorn, Kimberly. 2008. "New and Improved Insurance Solutions for Managing Intellectual Property Risk." *IP Litigator* 14 (5):16-22.

Cervone, H Frank. 2006. "Project risk management." *OCLC Systems & Services* 22 (4):256-262.

Chapman, Chris, and Stephen Ward. 2004. "Why risk efficiency is a key aspect of best practice projects." *International Journal of Project Management* 22 (8):619-632.

Chin, Kwai-Sang, Da-Wei Tang, Jian-Bo Yang, Shui Yee Wong, and Hongwei Wang. 2009. "Assessing new product development project risk by Bayesian network with a systematic probability generation methodology." *Expert Systems with Applications* 36 (6):9879-9890.

Choi, Hoo-Gon, and Jungon Ahn. 2010. "Risk analysis models and risk degree determination in new product development: A case study." *Journal of Engineering and Technology Management* 27 (1):110-124.

Christopher, Martin, Carlos Mena, Omera Khan, and Oznur Yurt. 2011. "Approaches to managing global sourcing risk." *Supply Chain Management: An International Journal* 16 (2):67-81.

Cooper, Robert G. 1990. "Stage-gate systems: a new tool for managing new products." *Business horizons* 33 (3):44-54.

Cooper, Robert G. 1994. "Perspective third-generation new product processes." *Journal of Product Innovation Management* 11 (1):3-14.

Cooper, Robert G, and Elko J Kleinschmidt. 1991. "New product processes at leading industrial firms." *Industrial Marketing Management* 20 (2):137-147.

Cooper, Robert G, and Elko J Kleinschmidt. 1993. "Major new products: what distinguishes the winners in the chemical industry?" *Journal of Product Innovation Management* 10 (2):90-111.

Cooper, Robert G, and Elko J Kleinschmidt. 2007. "Winning businesses in product development: the critical success factors." *Research-Technology Management* 50 (3):52-66.

Davis, Fred D. 1989. "Perceived usefulness, perceived ease of use, and user acceptance of information technology." *MIS quarterly*:319-340.

Davis, Fred D, Richard P Bagozzi, and Paul R Warshaw. 1989. "User acceptance of computer technology: a comparison of two theoretical models." *Management science* 35 (8):982-1003.

De Meyer, Arnoud, Christoph H Loch, and Michael T Pich. 2002. "Managing project uncertainty: from variation to chaos." *Engineering Management Review, IEEE* 30 (3):91-91.

Dey, Prasanta K, and Stephen O Ogunlana. 2004. "Selection and application of risk management tools and techniques for build-operate-transfer projects." *Industrial Management & Data Systems* 104 (4):334-346.

Dey, Prasanta Kumar. 2010. "Managing project risk using combined analytic hierarchy process and risk map." *Applied Soft Computing* 10 (4):990-1000.

Ekinsmyth, Carol. 2002. "Project organization, embeddedness and risk in magazine publishing." *Regional studies* 36 (3):229-243.

El-Diraby, TA, and SM Gill. 2006. "A taxonomy for construction terms in privatized-infrastructure finance: supporting semantic exchange of project risk information." *Construction Management and Economics* 24 (3):271-285.

Florescu, Margareta Stela. 2012. "Analysis Of Economic Risk In European Investment Projects." *Romanian Journal of Economics* 34 (1 (43)):47-67.

Francis, Mark. 2006. "Stage model research in the UK fast moving consumer goods industry." *International Journal of Logistics: Research and Applications* 9 (4):351-368.

Giezen, Mendel. 2012. "Keeping it simple? A case study into the advantages and disadvantages of reducing complexity in mega project planning." *International Journal of Project Management* 30 (7):781-790.

Glueck-Chaloupka, Alicea A, Louis M Capella, and Patti C Coggins. 2005. "Food Product Development, Food Regulations and Policies—Compatible or Not?" *Journal of Nonprofit & Public Sector Marketing* 13 (1-2):199-212.

Griffin, Abbie. 1997. "PDMA research on new product development practices: updating trends and benchmarking best practices." *Journal of product innovation management* 14 (6):429-458.

Hamza, Salah Eldin Adam. 2009. "Monitoring and controlling design process using control charts and process sigma." *Business process management Journal* 15 (3):358-370.

Han, Wen-Ming, and Sun-Jen Huang. 2007. "An empirical analysis of risk components and performance on software projects." *Journal of Systems and Software* 80 (1):42-50.

Hartmann, Timo, Hendrik Van Meerveld, Niels Vossebeld, and Arjen Adriaanse. 2012. "Aligning building information model tools and construction management methods." *Automation in construction* 22:605-613.

Hirschauer, Norbert, Miroslava Bavorová, and Gaetano Martino. 2012. "An analytical framework for a behavioural analysis of non-compliance in food supply chains." *British Food Journal* 114 (9):1212-1227.

Hong, Zhen, and CKM Lee. 2013. "A decision support system for procurement risk management in the presence of spot market." *Decision Support Systems* 55 (1):67-78.

Hottenstein, Michael P, and James W Dean. 1992. "Managing risk in advanced manufacturing technology." *California Management Review* 34 (4):112-126.

Hu, Yong, Xizhu Mo, Xiangzhou Zhang, Yuran Zeng, Jianfeng Du, and Kang Xie. 2012. "Intelligent analysis model for outsourced software project risk using constraint-based bayesian network." *Journal of software* 7 (2):440-449.

ISO. 2003. ISO 10006:2003 Quality management systems – Guidelines for quality management in projects. International Organization for Standardization. Geneva, Switzerland.

ISO. 2009. ISO31000:2009 Risk management – Principles and Guidelines. Geneva, Switzerland: International Organization for Standardization.

ISO. 2012. ISO 21500:2012 Guidance on project management. International Organization for Standardization. Geneva, Switzerland.

Jafari, Mostafa, Jalal Rezaeenour, Mohammad Mahdavi Mazdeh, and Atefe Hooshmandi. 2011. "Development and evaluation of a knowledge risk management model for project-based organizations: A multi-stage study." *Management Decision* 49 (3):309-329.

Jharkharia, Sanjay, and Ravi Shankar. 2007. "Selection of logistics service provider: An analytic network process (ANP) approach." *Omega* 35 (3):274-289.

Junwu, Ding, Yang dongtao, and Bao zhenqiang. 2012. "Research on capturing of customer requirements based on innovation theory." *Physics Procedia* 24:1868-1880.

Karagozoglu, Necmi, and Warren B Brown. 1993. "Time-Based Management of the New Product Development Process." *Journal of Product Innovation Management* 10 (3):204-215.

Katrin, Bock, and Trück Stefan. 2011. "Assessing uncertainty and risk in public sector investment projects." *Technology and Investment* 2011.

Kayis, B, M Zhou, S Savci, YB Khoo, A Ahmed, R Kusumo, and A Rispler. 2007. "IRMAS–development of a risk management tool for collaborative multi-site, multi-partner new product development projects." *Journal of Manufacturing Technology Management* 18 (4):387-414.

Keizer, Jimme A, and Johannes IM Halman. 2007. "Diagnosing risk in radical innovation projects." *Research-Technology Management* 50 (5):30-36.

Keizer, Jimme A, Jan-Peter Vos, and Johannes IM Halman. 2005. "Risks in new product development: devising a reference tool." *R&D Management* 35 (3):297-309.

Kettunen, P. 2003. "Managing embedded software project team knowledge." *IEE Proceedings-Software* 150 (6):359-366.

Kutsch, Elmar, and Mark Hall. 2010. "Deliberate ignorance in project risk management." *International Journal of Project Management* 28 (3):245-255.

Lee, Eunchang, Yongtae Park, and Jong Gye Shin. 2009. "Large engineering project risk management using a Bayesian belief network." *Expert Systems with Applications* 36 (3):5880-5887.

Li, Yan-Lai, Kwai-Sang Chin, and Xing-Gang Luo. 2012. "Determining the final priority ratings of customer requirements in product planning by MDBM and BSC." *Expert systems with Applications* 39 (1):1243-1255.

Li, Yan-Lai, Jia-Fu Tang, Kwai-Sang Chin, Yu-Shi Jiang, Yi Han, and Yun Pu. 2011. "Estimating the final priority ratings of engineering characteristics in mature-period product improvement by MDBA and AHP." *International Journal of Production Economics* 131 (2):575-586.

Liu, Hu-Chen, Long Liu, Nan Liu, and Ling-Xiang Mao. 2012. "Risk evaluation in failure mode and effects analysis with extended VIKOR method under fuzzy environment." *Expert Systems with Applications* 39 (17):12926-12934.

Liu, Shan, Jinlong Zhang, Mark Keil, and Tao Chen. 2010. "Comparing senior executive and project manager perceptions of IT project risk: a Chinese Delphi study." *Information Systems Journal* 20 (4):319-355.

Luu, Van Truong, Soo-Yong Kim, Nguyen Van Tuan, and Stephen O Ogunlana. 2009. "Quantifying schedule risk in construction projects using Bayesian belief networks." *International Journal of Project Management* 27 (1):39-50.

Markowski, Adam S, M Sam Mannan, and Agata Bigoszewska. 2009. "Fuzzy logic for process safety analysis." *Journal of Loss Prevention in the Process Industries* 22 (6):695-702.

Marxt, Christian, and Fredrik Hacklin. 2005. "Design, product development, innovation: all the same in the end? A short discussion on terminology." *Journal of Engineering Design* 16 (4):413-421.

McGrath, Rita Gunther. 2011. "Failing by design." *Harvard business review* 89 (4):76-83.

Milosevic, Dragan, and Peerasit Patanakul. 2005. "Standardized project management may increase development projects success." *International Journal of Project Management* 23 (3):181-192.

Moynihan, Donald. 2013. "A central agency is crucial for disaster response." *Nature* 495 (7439):7-7.

Mu, Jifeng, Gang Peng, and Douglas L MacLachlan. 2009. "Effect of risk management strategy on NPD performance." *Technovation* 29 (3):170-180.

Murray, J Gordon. 2013. "Debate: The need for procurement risk management." *Public Money & Management* 33 (4):285-287.

Nassa, Vinay Kumar, and Sri Krishan Yadav. 2012. "Project Management Efficiency–A Fuzzy Logic Approach." *International Journal of Engineering and Advanced Technology (IJEAT)* 1 (3):34-38.

Nelson, Bryn. 2013. "Natural disasters: A calculated risk." *Nature* 495 (7440):271-273.

Nielsen, Kris R. 2006. "Risk management: Lessons from six continents." *Journal of management in engineering* 22 (2):61-67.

Nieto-Morote, Ana, and F Ruz-Vila. 2011. "A fuzzy approach to construction project risk assessment." *International Journal of Project Management* 29 (2):220-231.

Osipova, Ekaterina, and Per Erik Eriksson. 2011. "How procurement options influence risk management in construction projects." *Construction Management and Economics* 29 (11):1149-1158.

Pan, Jeh-Nan, and Chun-Yi Lee. 2009. "Development of a New Process Incapability Index with an Application to the Evaluation of Manufacturing Risk." *Communications in Statistics—Theory and Methods* 38 (8):1133-1153.

Park, Young H. 2010. "A study of risk management and performance measures on new product development." *Asian Journal on Quality* 11 (1):39-48.

Pinto, Jeffrey K, and Jeffrey G Covin. 1989. "Critical factors in project implementation: a comparison of construction and R&D projects." *Technovation* 9 (1):49-62.

PMI. 2009. Practice standard for project risk management. Project Management Institute, Pennsylvania, USA.

PMI. 2013. A Guide to the Project Management Body of Knowledge: PMBOK Guide, 5th ed.: Project Management Institute, Pennsylvania, USA.

Pons, Dirk. 2008. "Project management for new product development." *Project Management Journal* 39 (2):82-97.

Reed, April H, and Linda V Knight. 2010. "Effect of a virtual project team environment on communication-related project risk." *International Journal of Project Management* 28 (5):422-427.

Reeves, John D, Tim Eveleigh, Thomas Holzer, and Shahryar Sarkani. 2012. "The impact of early design phase risk identification biases on space system project performance." Systems Conference (SysCon), 2012 IEEE International.

Ridlehoover, Justin. 2004. "Applying Monte Carlo simulation and risk analysis to the facility location problem." *The Engineering Economist* 49 (3):237-252.

Rodriguez, Robert N. 1992. "Recent developments in process capability analysis." *Journal of Quality Technology* 24 (4):176-187.

Rowley, Jennifer. 2002. "Using case studies in research." *Management research news* 25 (1):16-27.

Savolainen, Paula, Jarmo J Ahonen, and Ita Richardson. 2012. "Software development project success and failure from the supplier's perspective: A systematic literature review." *International Journal of Project Management* 30 (4):458-469.

Segismundo, André, and Paulo Augusto Cauchick Miguel. 2008. "Failure mode and effects analysis (FMEA) in the context of risk management in new product development: A case study in an automotive company." *International Journal of Quality & Reliability Management* 25 (9):899-912.

Seising, Rudolf. 2007. "Fuzzy Sets and Fuzzy Systems." In *The Fuzzification of Systems*, 201-233. Springer Berlin Heidelberg.

Sharma, Isha, and PK Suri. 2011. "Schedule Risk Analysis Simulator using Beta Distribution." *International Journal on Computer Science and Engineering* 3 (6):2408-2414.

Sharp, JA. 2007. "Evaluating the effect of sourcing decisions on e-commerce process operations risk." *European journal of operational research* 180 (2):815-833.

Shi, Yuan, Feng Wu, Lap Keung Chu, Domenic Sculli, and YH Xu. 2011. "A portfolio approach to managing procurement risk using multi-stage stochastic programming." *Journal of the Operational Research Society* 62 (11):1958-1970.

Sicotte, Claude, Guy Paré, Marie-Pierre Moreault, and André Paccioni. 2006. "A risk assessment of two interorganizational clinical information systems." *Journal of the American Medical Informatics Association* 13 (5):557-566.

Sigelman, Lee, and Miles Simpson. 1977. "A cross-national test of the linkage between economic inequality and political violence." *Journal of Conflict Resolution*:105-128.

Spiring, Fred, Bartholomew Leung, Smiley Cheng, and Anthony Yeung. 2003. "A bibliography of process capability papers." *Quality and Reliability Engineering International* 19 (5):445-460.

Stevens, Greg A, and James Burley. 2003. "Piloting the rocket of radical innovation." *Research-Technology Management* 46 (2):16-25.

Steyn, Herman. 2002. "Project management applications of the theory of constraints beyond critical chain scheduling." *International Journal of Project Management* 20 (1):75-80.

Suh, Taewon, Mueun Bae, Hongxin Zhao, Seung H Kim, and Mark J Arnold. 2010. "A multi-level investigation of international marketing projects: The roles of experiential knowledge and creativity on performance." *Industrial Marketing Management* 39 (2):211-220.

Suwannaporn, Prisana, and Mark Speece. 2000. "Continuous learning process in new product development in the Thai food-processing industry." *British Food Journal* 102 (8):598-614.

Suwannaporn, Prisana, and Mark Speece. 2003. "Marketing research and new product development success in Thai food processing." *Agribusiness* 19 (2):169-188.

Suwannaporn, Prisana, and Mark W Speece. 2010. "Assessing new product development success factors in the Thai food industry." *British Food Journal* 112 (4):364-386.

Tang, Dawei, Jian-Bo Yang, Kwai-Sang Chin, Zoie SY Wong, and Xinbao Liu. 2011. "A methodology to generate a belief rule base for customer perception risk analysis in new product development." *Expert Systems with Applications* 38 (5):5373-5383.

Tatikonda, Mohan V, and Stephen R Rosenthal. 2000. "Technology novelty, project complexity, and product development project execution success: a deeper look at task uncertainty in product innovation." *Engineering Management, IEEE Transactions on* 47 (1):74-87.

TDRI. 1996. Report on the Situation and Trend for Employment in the Food Industry. Thailand Development Research Institute (TDRI), Bangkok

Teodorovič, Dušan, and Katarina Vukadinovič. 1998. "Basic Definitions of the Fuzzy Sets Theory." In *Traffic Control and Transport Planning:*, 1-67. Springer Netherlands.

Thal Jr, Alfred E, Adedeji Badiru, and Rupy Sawhney. 2007. "Distributed Project Management for New Product Development." *IJEBM* 5 (2):93-104.

Ting, Wang. 2010. "A Study of Intellectual Property Risk Evaluation in Virtual R & D Team Based on Rough Set Theory." E-Product E-Service and E-Entertainment (ICEEE), 2010 International Conference on.

Tivig, Thusnelda, Katharina Frosch, Stephan Kühntopf, and Rostock Center. 2008. "Mapping regional demographic change and regional demographic location risk in Europe." *Rostocker Zentrum zur Erforschung des Demografischen Wandels. Eigenverlag, Rostock*.

Ulrich, Karl T. , and Steven D Eppinger. 2008. *Product design and development-Forth Edition*. New York: McGraw-Hill.

Vairappan, Catherine, Hiroki Tamura, Shangce Gao, and Zheng Tang. 2009. "Batch type local search-based adaptive neuro-fuzzy inference system (ANFIS) with self-feedbacks for time-series prediction." *Neurocomputing* 72 (7):1870-1877.

Vanhoucke, Mario. 2011. "On the dynamic use of project performance and schedule risk information during projecttracking." *Omega* 39 (4):416-426.

Varkey, Prathibha, April Horne, and Kevin E Bennet. 2008. "Innovation in health care: a primer." *American Journal of Medical Quality* 23 (5):382-388.

Vidal, Ludovic-Alexandre, Franck Marle, and Jean-Claude Bocquet. 2011. "Measuring project complexity using the Analytic Hierarchy Process." *International Journal of Project Management* 29 (6):718-727.

Walker, John. 2012. "Intellectual property Risk management aspects." *Keeping Good Companies* 64 (11):655.

Wang, Lianjuan, and Liexu Tian. 2012. "Affinity and Tacit Knowledge Management in Project Team." *Journal of Software* 7 (9):2149-2157.

Wang, Ying-Ming, and Kwai-Sang Chin. 2011. "A linear goal programming approach to determining the relative importance weights of customer requirements in quality function deployment." *Information Sciences* 181 (24):5523-5533.

Winger, R, and G Wall. 2006. "Food product innovation: a background paper (Agricultural and Food Engineering Working Document 2)." *Food and Agriculture Organization of the United Nations, Rome*.

Wright, Jonathan, and Daniella Datskovska. 2012. "New perspectives on global risk." *Logistics Management* 51 (5):42-44.

Yang, Li-Ren. 2012. "Implementation of project strategy to improve new product development performance." *International Journal of Project Management* 30 (7):760-770.

Yin, Robert. 2003. "K.(2003). Case study research: Design and methods." *Sage Publications, Inc* 5:11.

Yüksel, İhsan, and Metin Dagdeviren. 2007. "Using the analytic network process (ANP) in a SWOT analysis–A case study for a textile firm." *Information Sciences* 177 (16):3364-3382.

Zadeh, Lotfi A. 1965. "Fuzzy sets." *Information and control* 8 (3):338-353.

Zeng, Sai X, Chun M Tam, and Vivian WY Tam. 2010. "Integrating safety, environmental and quality risks for project management using a FMEA method." *Inzinerine Ekonomika-Engineering Economics* 21 (1):44-52.

Zhang, Ke-ying, Rui Zhang, and Xiao-li Zhang. 2010. "Research on the Influence of Knowledge Management Capability to Intellectual Property Risk in Enterprise Independent Innovation." E-Business and E-Government (ICEE), 2010 International Conference on.

Zhang, Zaifang, and Xuening Chu. 2011. "Risk prioritization in failure mode and effects analysis under uncertainty." *Expert Systems with Applications* 38 (1):206-214.

Zhou, M., Kusumo, R., Ahmed, A., and Rispler, A. 2003. A Report on Commercially Off the Shelf Risk Management Software. In *CRC-IMST, Project SP4.2*. Australia.

Zhou, Zude, Zheng Xiao, Quan Liu, and Qingsong Ai. 2013. "An analytical approach to customer requirement information processing." *Enterprise Information Systems* 7 (4):543-557.

Zou, Patrick XW, and Jie Li. 2010. "Risk identification and assessment in subway projects: case study of Nanjing Subway Line 2." *Construction Management and Economics* 28 (12):1219-1238.

Zwikael, Ofer, and Mark Ahn. 2011. "The effectiveness of risk management: an analysis of project risk planning across industries and countries." *Risk analysis* 31 (1):25-37.

APPENDIX A: QUESTIONNAIRE FOR RISK FACTORS IN FOOD INDUSTRY

แบบสอบถามเรื่องการประเมินความเสี่ยงของโครงการพัฒนานวัตกรรม

บริษัท.....หน่วยงาน/แผนก .....

ชื่อผู้ให้ข้อมูล.....ตำแหน่ง.....

เบอร์โทรศัพท์ .....อีเมล์.....วันที่ประเมิน.....

<u>ส่วนที่ 1</u>

ในหน่วยงานของท่านมีการประเมินความเสี่ยง และบริหารความเสี่ยงของโครงการในการพัฒนานวัตกรรมอย่างไร

☐ ไม่มีการประเมิน เนื่องจาก .....

☐ มีการประเมินอย่างไม่เป็นทางการ หรือเฉพาะบางโครงการ

☐ มีกระบวนการประเมินที่ชัดเจน และเป็นส่วนหนึ่งของขั้นตอนในการพัฒนานวัตกรรม

☐ อื่นๆ.....

<u>ส่วนที่ 2</u> กรุณาประเมินความสำคัญของปัจจัยความเสี่ยงที่ท่านคิดว่ามีผลต่อความสำเร็จของโครงการ โดยให้คะแนนระดับความสำคัญดังต่อไปนี้

1= ความสำคัญน้อยที่สุด 2=ความสำคัญน้อย 3=ความสำคัญปานกลาง 4=ความสำคัญมาก 5= ความสำคัญมากที่สุด

ลำดับ	ปัจจัยเสี่ยง	1	2	3	4	5	คำอธิบาย
1	Schedule risk						ความเสี่ยงจากการวางแผน และกำหนดระยะเวลาที่ใช้ในการทำงานผิดพลาด
2	Organization structure						ความเสี่ยงจากโครงสร้างของทีมงาน และการบริหารที่ไม่เหมาะสม
3	Project communication						ความเสี่ยงจากความผิดพลาดในการสื่อสารในโครงการ
4	Economic risk						ความเสี่ยงจากผลกระทบด้านเศรษฐกิจ
5	Technical complexity						ความเสี่ยงจากความซับซ้อนของเทคโนโลยี

ลำดับ	ปัจจัยเสี่ยง	1	2	3	4	5	คำอธิบาย
6	Location selection						ความเสี่ยงจากการเลือกสถานที่ในการผลิต หรือแหล่งวัตถุดิบไม่เหมาะสม
7	Resource planning						ความเสี่ยงจากความผิดพลาดในการวางแผนทรัพยากร
8	Team knowledge						ความเสี่ยงจากการขาดความรู้ความเข้าใจของทีมงาน
9	Design risk						ความเสี่ยงจากการออกแบบผิดพลาด หรือไม่เหมาะสม
10	Manufacturing technology						ความเสี่ยงจากปัญหาเทคโนโลยีในการผลิตไม่เหมาะสม
11	Intellectual properties						ความเสี่ยงจากปัญหาเกี่ยวกับการคุ้มครองทรัพย์สินทางปัญญา
12	Sourcing and materials planning						ความเสี่ยงจากการหาแหล่งวัตถุดิบ หรือผู้จัดจำหน่าย และการวางแผนวัตถุดิบ
13	Customer requirement						ความเสี่ยงจากการไม่เข้าใจความต้องการของผู้บริโภค
14	Manufacturing capability						ความเสี่ยงจากปัญหาความสามารถ และกำลังการผลิตของโรงงาน
15	Logistics & Transportation						ความเสี่ยงจากการจัดการด้านโลจิสติกส์ และการขนส่ง
16	Procurement and contract						ความเสี่ยงจากการจัดซื้อ จัดจ้าง และการทำสัญญากับภายนอก
17	Social risk						ความเสี่ยงจากปัญหาด้านสังคม
18	Political risk						ความเสี่ยงจากปัญหาด้านการเมือง
19	Natural risk						ความเสี่ยงจากภัยธรรมชาติ

ปัจจัยเสี่ยงอื่นๆที่ท่านคิดว่ามีผลต่อความสำเร็จของโครงการนวัตกรรม (ตอบได้มากกว่า 1 ข้อ)

……

……

……

……

……..

APPENDIX B: QUESTIONNAIRE FOR RISK MANAGEMENT PRACTICES IN FOOD INDUSTRY

<u>หัวข้อคำถามสัมภาษณ์เรื่องการบริหารความเสี่ยงของโครงการพัฒนาผลิตภัณฑ์ใหม่</u>

ชุดคำถามนี้ใช้เพื่อเก็บข้อมูลความคิดเห็นของผู้เชี่ยวชาญในโครงการพัฒนาผลิตภัณฑ์ใหม่ของบริษัท หรือหน่วยงานธุรกิจในอุตสาหกรรมอาหารของประเทศไทย เพื่อศึกษาถึงกิจกรรมการประเมินความเสี่ยงของโครงการ และปัจจัยความเสี่ยงของโครงการในระหว่างการพัฒนาผลิตภัณฑ์ใหม่ ซึ่งการศึกษานี้เป็นส่วนหนึ่งของวิทยานิพนธ์ระดับดุษฎีบัณฑิต หลักสูตรธุรกิจเทคโนโลยีและการจัดการนวัตกรรม จุฬาลงกรณ์มหาวิทยาลัยซึ่งมีเป้าหมายในการพัฒนากระบวนการ และเครื่องมือในการบริหารความเสี่ยงของโครงการพัฒนาผลิตภัณฑ์ใหม่ในอุตสาหกรรมอาหาร เพื่อช่วยในการตัดสินใจในการแก้ปัญหา และเพิ่มโอกาสในความสำเร็จของการพัฒนาผลิตภัณฑ์

ทั้งนี้ข้อมูลที่ใช้ในงานวิจัย จะแสดงผลในภาพรวมโดยไม่ระบุชื่อผู้ให้ข้อมูลและชื่อหน่วยงาน รวมทั้งจะเก็บเป็นความลับเพื่อประโยชน์ในงานวิจัยและการศึกษาเท่านั้น

ชื่อผู้ทำวิจัย

นายดั้นดุสิต โปราณานนท์ นิสิตปริญญาเอก สหสาขาวิชาธุรกิจเทคโนโลยีและการจัดการนวัตกรรม

คณะกรรมการควบคุมวิทยานิพนธ์

ผู้ช่วยศาสตราจารย์ ดร.ณัฐชา ทวีแสงสกุลไทย อาจารย์ที่ปรึกษา

รองศาสตราจารย์ ดร.ฐิติวดี ชัยวัฒน์ อาจารย์ที่ปรึกษาร่วม

คำถามแบ่งออกเป็น 3 ส่วนดังนี้

ส่วนที่ 1 คำถามเกี่ยวกับผู้ให้ข้อมูล และองค์กร

ส่วนที่ 2 คำถามเกี่ยวกับข้อมูลของผลิตภัณฑ์ที่ใช้เป็นกรณีศึกษา

ส่วนที่ 3 คำถามเกี่ยวกับการพัฒนาเครื่องมือช่วยในการบริหารความเสี่ยง

<u>ส่วนที่ 1</u> คำถามเกี่ยวกับผู้ให้ข้อมูล และองค์กร		
1	ชื่อผู้ให้ข้อมูล	
2	ตำแหน่ง	อายุงานในตำแหน่งปัจจุบัน

3	ชื่อบริษัท แผนก/หน่วยงาน
4	ยอดขายและจำนวนพนักงาน ☐ จำนวนพนักงานน้อยกว่า 50 คน หรือยอดขายน้อยกว่า 50 ล้านบาทต่อปี ☐ จำนวนพนักงาน 50-100 คน หรือยอดขาย 50-100 ล้านบาทต่อปี ☐ จำนวนพนักงาน 100-200 คน หรือยอดขาย 100-200 ล้านบาทต่อปี ☐ จำนวนพนักงานมากกว่า 200 คน หรือยอดขายมากกว่า 200 ล้านบาทต่อปี
5	บริษัทมีทีมงานวิจัยและพัฒนา (R&D) หรือ ทีมงานพัฒนาผลิตภัณฑ์ (NPD) โดยตรงหรือไม่ และการพัฒนาผลิตภัณฑ์ประกอบด้วยผู้ที่เกี่ยวข้องจากแผนกใดบ้าง
6	บริษัทมีกระบวนการพัฒนาผลิตภัณฑ์อย่างเป็นทางการหรือไม่ ประกอบด้วยขั้นตอนอะไรบ้าง
7	ขั้นตอนการพัฒนาผลิตภัณฑ์ขององค์กรมีการประเมินความเสี่ยงด้วยหรือไม่(ถ้าไม่มีเพราะอะไร)
8	บริษัทเห็นความสำคัญ หรือทราบวิธีการและขั้นตอนในการประเมินความเสี่ยง และบริหารความเสี่ยงในการพัฒนาผลิตภัณฑ์หรือไม่
9	กรณีที่มีการประเมินความเสี่ยง บริษัทใช้มาตรฐาน หรือแนวทางอะไรในการประเมิน และบริหารความเสี่ยงของโครงการ
10	คิดว่าขั้นตอนใดของการบริหารความเสี่ยงมีความสำคัญ หรือมีผลต่อความสำเร็จของโครงการมากที่สุด (1) การค้นหาปัจจัยความเสี่ยง (Risk Identification)

	(2) การประเมินและวิเคราะห์ความเสี่ยง (Risk assessment) (3) การวางแผนรับมือกับความเสี่ยง (Risk response) (4) การติดตามและควบคุมความเสี่ยง (Risk monitor and control)
11	มีการใช้เครื่องมือ หรือเทคนิคอะไรบ้างในการประเมินความเสี่ยง และบริหารความเสี่ยงในกระบวนการพัฒนาผลิตภัณฑ์ และพบปัญหาอะไรบ้างในการใช้เครื่องมือเหล่านี้
12	ผู้เกี่ยวข้องในกระบวนการประเมินความเสี่ยงในกระบวนการพัฒนาผลิตภัณฑ์ขององค์กรมีใครบ้าง
<u>ส่วนที่ 2</u> คำถามเกี่ยวกับข้อมูลของผลิตภัณฑ์ที่ใช้เป็นกรณีศึกษา	
ชื่อผลิตภัณฑ์ที่ 1 :	
1	ลักษณะของผลิตภัณฑ์และตลาดเป้าหมาย
2	สถานะปัจจุบันของผลิตภัณฑ์ (อยู่ระหว่างการพัฒนา/เป็นผลิตภัณฑ์ที่มีจำหน่ายอยู่/หรือเลิกผลิตไปแล้ว)
3	ผู้ให้ข้อมูลมีหน้าที่อะไรในโครงการ และใครเป็นหัวหน้าโครงการ (Project Leader and Champion)
4	บริษัทได้ทำการประเมินความเสี่ยงในการพัฒนาผลิตภัณฑ์นี้ในระหว่างการพัฒนาหรือไม่
5	คิดว่าการประเมินความเสี่ยงช่วยจะช่วยในการเพิ่มโอกาสความสำเร็จของโครงการนี้หรือไม่
6	มีการใช้เครื่องมือ หรือเทคนิคอะไรบ้างในการประเมินความเสี่ยง และบริหารความเสี่ยงในโครงการนี้ และพบปัญหาอะไรบ้างในการใช้เครื่องมือเหล่านี้

7	หัวข้อ และปัจจัยความเสี่ยงที่สำคัญของโครงการนี้มีอะไรบ้าง
8	มีการนำข้อมูลจากการประเมินความเสี่ยงไปใช้ประโยชน์อย่างไรบ้าง
9	คิดว่าจะสามารถปรับปรุงกระบวนการบริหารความเสี่ยงของผลิตภัณฑ์นี้ให้ดีขึ้นได้อย่างไรบ้าง
ชื่อผลิตภัณฑ์ที่ 2 :	
1	ลักษณะของผลิตภัณฑ์และตลาดเป้าหมาย
2	สถานะปัจจุบันของผลิตภัณฑ์ (อยู่ระหว่างการพัฒนา เป็นผลิตภัณฑ์ที่มีจำหน่ายอยู่ หรือเลิกผลิตไปแล้ว)
3	ใครเป็นหัวหน้าโครงการ (Project Leader and Champion)
4	บริษัทได้ทำการประเมินความเสี่ยงในการพัฒนาผลิตภัณฑ์นี้ในระหว่างการพัฒนาหรือไม่
5	คิดว่าการประเมินความเสี่ยงช่วยจะช่วยในการเพิ่มโอกาสความสำเร็จของโครงการนี้หรือไม่

6	มีการใช้เครื่องมือ หรือเทคนิคอะไรบ้างในการประเมินความเสี่ยง และบริหารความเสี่ยงในโครงการนี้ และพบปัญหาอะไรบ้างในการใช้เครื่องมือเหล่านี้
7	หัวข้อ และปัจจัยความเสี่ยงที่สำคัญของโครงการนี้มีอะไรบ้าง
8	มีการนำข้อมูลจากการประเมินความเสี่ยงไปใช้ประโยชน์อย่างไรบ้าง
9	คิดว่าจะสามารถปรับปรุงกระบวนการบริหารความเสี่ยงของผลิตภัณฑ์นี้ให้ดีขึ้นได้อย่างไรบ้าง
<u>ส่วนที่ 3</u> คำถามเกี่ยวกับการพัฒนาเครื่องมือช่วยในการบริหารความเสี่ยง	
1	ถ้ามีเครื่องมือ (Tools) ที่ช่วยในการประเมินความเสี่ยงของโครงการพัฒนาผลิตภัณฑ์ใหม่จะมีประโยชน์กับทีมงานหรือไม่
2	ขั้นตอนใดบ้างของการบริหารความเสี่ยงที่ต้องการเครื่องมือมาช่วยในการดำเนินงาน
3	เครื่องมือที่ช่วยในการประเมินและบริหารความเสี่ยงควรมีคุณสมบัติอย่างไรบ้าง

4	กรณีที่มีการพัฒนาเครื่องมือช่วยในการบริหารความเสี่ยง ท่านยินดีมีส่วนร่วมในการทดสอบเครื่องมือบริหารความเสี่ยงด้วยหรือไม่

ข้อเสนอแนะเพิ่มเติม

.....

.....

.....

.....

.....

.....

APPENDIX C: QUESTIONNAIRE FOR USER ACCEPTANCE OF RISK ASSESSMENT METHOD

แบบสอบถามเรื่องการบริหารความเสี่ยงของโครงการพัฒนาผลิตภัณฑ์ใหม่

ชื่อบริษัท.....หน่วยงาน/แผนก .....

ชื่อผู้ให้ข้อมูล.....ตำแหน่ง..... .....

เบอร์โทรศัพท์ ……..……อีเมล์.....

.วันที่ให้ข้อมูล.....

<u>ส่วนที่ 1</u> ข้อมูลของผู้ตอบแบบสอบถาม และความคิดเห็นที่มีต่อกระบวนการและเครื่องมือบริหารความเสี่ยง

1. ลักษณะงานในปัจจุบัน

☐ ฝ่ายขาย ฝ่ายการตลาด ☐ ฝ่ายผลิต ☐ ฝ่ายวิศวกรรม

☐ ฝ่ายวิจัยพัฒนา ☐ ฝ่ายงานคุณภาพ ☐ อื่นๆ (โปรดระบุ).....

2. ประสบการณ์ทำงานในหน้าที่ปัจจุบัน ..... ปี.....เดือน

(ระดับคะแนน: 1 = น้อยมาก, 2 = น้อย, 3 = ปานกลาง, 4 = มาก, 5 = มากที่สุด)

No.	คำถาม	1	2	3	4	5	เหตุผล / คำแนะนำเพิ่มเติม (ถ้ามี)
3	ระดับความเข้าใจในเรื่องการประเมินความเสี่ยงและการบริหารความเสี่ยงก่อนเข้าร่วมกิจกรรม						
4	ท่านคิดว่าการบริหารความเสี่ยงมีความสำคัญมากน้อยเพียงใดต่อความสำเร็จของโครงการพัฒนาผลิตภัณฑ์ใหม่						

No.	คำถาม	1	2	3	4	5	เหตุผล / คำแนะนำเพิ่มเติม (ถ้ามี)
5	ขั้นตอนของกระบวนการพัฒนาผลิตภัณฑ์ใหม่ (NPD Process) ที่ใช้ในเครื่องมือบริหารความเสี่ยงมีความเหมาะสมหรือสอดคล้องกับกระบวนการทำงานของท่านมากน้อยเพียงใด						
6	กระบวนการบริหารความเสี่ยง (Risk Management Process) ที่ใช้มีความเหมาะสมมากน้อยเพียงใด						
7	รายการปัจจัยเสี่ยง (Common risk factors)ในเครื่องมือบริหารความเสี่ยงสามารถช่วยในการค้นหา และประเมินความเสี่ยงของโครงการได้ดีเพียงไร						
8	วิธีการวิเคราะห์ความเสี่ยงโดยพิจารณาจากคะแนนของผลกระทบ โอกาสเกิด และวิธีการป้องกัน มีความเหมาะสมมากน้อยเพียงใด						
9	การแบ่งระดับคะแนน (1-5) และคำจำกัดความของผลกระทบ โอกาสเกิด และวิธีการป้องกัน มีความชัดเจนและสะดวกในการให้คะแนนมากน้อยเพียงใด						

No.	คำถาม	1	2	3	4	5	เหตุผล / คำแนะนำเพิ่มเติม (ถ้ามี)
10	วิธีการวางแผนตอบสนองความเสี่ยงในเครื่องมือบริหารความเสี่ยงนี้มีความเหมาะสมมากน้อยเพียงใด						
11	ท่านคิดว่าเครื่องมือบริหารความเสี่ยงที่เสร็จสมบูรณ์แล้วจะมีประโยชน์ในการนำไปใช้งาน ในอุตสาหกรรมจริงมากน้อยเพียงใด						
12	ท่านคิดว่าเครื่องมือบริหารความเสี่ยงนี้จะช่วยลดปัญหา และ เพิ่มโอกาส ของความสำเร็จในโครงการพัฒนาผลิตภัณฑ์ใหม่ได้เพียงใด						
13	ความง่ายและความสะดวกในการใช้งานเครื่องมือบริหารความเสี่ยงนี้กับโครงการจริงอยู่ในระดับใด						
14	ความพึงพอใจโดยรวมที่มีต่อเครื่องมือในการบริหารความเสี่ยงนี้						

คำแนะนำสำหรับการปรับปรุงกระบวนการ และเครื่องมือบริหารความเสี่ยงสำหรับโครงการพัฒนาผลิตภัณฑ์ใหม่

.....

.....

.....

.....

.....

<u>ส่วนที่ 2</u> ความคิดเห็นเกี่ยวกับความสำคัญของปัจจัยเสี่ยงที่มีต่อโครงการพัฒนาผลิตภัณฑ์ใหม่

กรุณาประเมินความสำคัญของปัจจัยความเสี่ยงที่ท่านคิดว่ามีผลต่อความสำเร็จของโครงการ โดยให้คะแนนระดับความสำคัญดังต่อไปนี้

1= ความสำคัญน้อยที่สุด 2=ความสำคัญน้อย 3=ความสำคัญปานกลาง 4=ความสำคัญมาก 5= ความสำคัญมากที่สุด

No.	ปัจจัยเสี่ยง	1	2	3	4	5	คำอธิบาย
1	Schedule risk						ความเสี่ยงจากการวางแผน และกำหนดตารางเวลาในการดำเนินงานที่ผิดพลาด
2	Organization structure						ความเสี่ยงจากโครงสร้างของทีมงาน และการบริหารที่ไม่เหมาะสม
3	Project communication						ความเสี่ยงจากความผิดพลาดในการสื่อสารภายในโครงการ หรือระหว่างหน่วยงาน
4	Economic risk						ความเสี่ยงจากผลกระทบของปัญหาด้านเศรษฐกิจ
5	Technical complexity						ความเสี่ยงจากความซับซ้อนของเทคโนโลยี
6	Location selection						ความเสี่ยงจากการเลือกสถานที่ในการผลิตหรือแหล่งวัตถุดิบไม่เหมาะสม
7	Resource planning						ความเสี่ยงจากความผิดพลาดในการวางแผนทรัพยากรด้านต่างๆ
8	Team knowledge						ความเสี่ยงจากการขาดความรู้ความเข้าใจของทีมงานเกี่ยวกับงานในโครงการ
9	Design risk						ความเสี่ยงจากการออกแบบที่ผิดพลาด หรือกำหนดคุณลักษณะไม่เหมาะสม
10	Manufacturing technology						ความเสี่ยงจากปัญหาเทคโนโลยีในการผลิตไม่เหมาะสม
11	Intellectual properties						ความเสี่ยงเกี่ยวกับปัญหาทรัพย์สินทางปัญญา และการคุ้มครองทรัพย์สินทางปัญญา

No.	ปัจจัยเสี่ยง	1	2	3	4	5	คำอธิบาย
12	Sourcing and materials planning						ความเสี่ยงจากนโยบายเกี่ยวกับวัตถุดิบ หรือผู้จัดจำหน่าย และการวางแผนวัตถุดิบไม่เหมาะสม
13	Customer requirement						ความเสี่ยงจากการไม่เข้าใจความต้องการของผู้บริโภค
14	Manufacturing capability						ความเสี่ยงจากปัญหาความสามารถ และกำลังการผลิตของโรงงาน
15	Logistics & Transportation						ความเสี่ยงจากปัญหาการจัดการด้านโลจิสติกส์ และการขนส่ง
16	Procurement and contract						ความเสี่ยงจากการจัดซื้อ จัดจ้าง และการทำสัญญากับภายนอก
17	Social risk						ความเสี่ยงจากปัญหาด้านสังคม
18	Political risk						ความเสี่ยงจากปัญหาด้านการเมือง
19	Natural risk						ความเสี่ยงจากเหตุการณ์ หรือภัยธรรมชาติ
20	Compliance risk						ความเสี่ยงจากปัญหาเกี่ยวกับกฎหมาย ระเบียบข้อบังคับที่เกี่ยวข้อง

ปัจจัยเสี่ยงอื่นๆที่ท่านคิดว่ามีความเกี่ยวข้องกับโครงการพัฒนาผลิตภัณฑ์ใหม่

……

……

……

……

……

VITA

Mr. Dundusid Porananond

Date of Birth: 26 September 1968

Place of Birth: Bangkok, Thailand

Education:

BSc. in Chemical Engineering, Chulalongkorn University.

MS. in Internet and E-commerce Technology, Assumption University.

Professional Certification:

- Project Management Professional certificate (PMP), PMI, USA.
- Certified Supply Chain Professional (CSCP), APICS, USA.
- Certified in Production and Inventory Management (CPIM), APICS, USA.

Work Experience:

1990-1992 Process Engineer for food and chemical industries.

1992-2003 Technical Service Engineer/supervisor, 3M Thailand Ltd.

2004-2005 Six Sigma Black Belt, 3M Thailand Ltd.

2005-2007 Plant Engineering Manager, 3M Thailand Ltd.

2007-2009 Integration Manager and Plant Manager, 3M Thailand Ltd.

2009-2012 Project Engineering, W/H and EHS Manager, 3M Thailand.

2009-Present Lecturer at Ramkhamhaeng University, Thailand.

2012-Present Lecturer at GMI, KMUTT, Thailand.

2013-Present Lecturer at Technology Promotion Association (Thai-Japan).