RISK MANAGEMENT FOR PREFABRICATED CLASSICAL THAI HOUSE CONSTRUCTION PROJECT

Mr. Navin Grueneberger

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering Program in Engineering Management
The Regional Centre for Manufacturing Systems Engineering
Faculty of Engineering
Chulalongkorn University
Academic Year 2009

การบริหารความเสี่ยงสำหรับโครงการก่อสร้างบ้านไทยโบราณผลิตสำเร็จรูปแบบประกอบ

นาย นาวิน กรูนเนเบอร์เกอร์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต
สาขาวิชาการจัดการทางวิศวกรรม ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต
คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2552

Thesis Title	RISK MANAGEMENT FOR PREFABRICATED CLASSICAL THAI HOUSE CONSTRUCTION PROJECT
By	Mr. Navin Grueneberger
Field of Study	Engineering Management
Thesis Advisor	Associate Professor Parames Chutima, Ph.D.

Accepted by the Faculty of Engineering, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master's Degree

…………………………………Dean of the Faculty of Engineering
(Associate Professor Boonsom Lerdhirunwong, Dr. Ing.)

THESIS COMMITTEE

……………………………………………….. Chairman
(Professor Sirichan Thongprasert, Ph.D.)

……………………………………….…….Thesis Advisor
(Associate Professor Parames Chutima, Ph.D.)

……………………………………………….. Examiner
(Associate Professor Jirapat Ngaoprasertwong)

……………………………………………….. External Examiner
(Associate Professor James Wallbank, D. Eng.)

นาวิน กรูนเนเบอร์เกอร์ : การบริหารความเสี่ยงสำหรับโครงการก่อสร้างบ้านไทยโบราณผลิตสำเร็จรูปแบบประกอบ (Risk Management for Prefabricated Classical Thai House Construction Project). อ. ที่ปรึกษาวิทยานิพนธ์หลัก : รศ.ดร. ปารเมศ ชุติมา , 229 หน้า.

งานวิจัยนี้มีจุดประสงค์เพื่อที่จะศึกษาความเสี่ยงในโครงการก่อสร้างบ้านทรงไทย การริเริ่มงานวิจัยดังกล่าวจำเป็นที่จะต้องค้นคว้าหาข้อมูลสนับสนุนเพิ่มเติม จุดประสงค์หลักของงานวิจัยนี้คือ เพื่อลดและป้องกันความเสี่ยงที่มีผลในการกำหนดวันกำหนดส่งของโครงการก่อสร้างบ้านทรงไทยในจังหวัดพังงา โดยคำนึงถึงคุณภาพ รวมไปถึงเสนอแนะวิธีการป้องกันความเสี่ยงดังกล่าว

กลุ่มบริหารจัดการความเสี่ยงที่ถูกคัดเลือกมาจะทำการบริหารจัดการการประชุม และประเมินความเสี่ยงจากโครงการที่เป็นไปได้ ขั้นตอนดำเนินการได้ถูกแบ่งออกเป็น 7 ขั้นตอนเพื่อการประเมินอย่างละเอียด FMEA (Failure Mode and Effect Analysis) ถูกนำมาใช้เพื่อการประเมิน กลุ่มบริหารจัดการความเสี่ยงได้ทำการระบุความเสี่ยงขึ้นมาทั้งสิ้นรวม 83 หัวข้อ จากนั้นได้นำการวิจัยโดยใช้เทคนิคพาเรโต้ (Pareto Analysis) มาคัดเลือกหัวข้อความเสี่ยงลำดับที่มีความสำคัญ เพื่อทำการแก้ไขจำนวนทั้งสิ้น 17 หัวข้อ แผนภูมิก้างปลา (Fish bone analysis) และ เทคนิคการวิเคราะห์สาเหตุแห่งความผิดพลาด (Fault tree analysis) ได้ถูกนำมาวิเคราะห์ความเสี่ยงหลัก เพื่อหาสาเหตุหลักที่นำมาซึ่งความเสี่ยงนั้นๆ มาตรการป้องกันความเสี่ยงได้ถูกจัดทำขึ้นสืบเนื่องมาจากการเชื่อมต่อระหว่างความเสี่ยงหลักนั้นๆ กับสาเหตุที่แท้จริง มาตรการป้องกันความเสี่ยง 6 มาตรการได้ถูกจัดทำขึ้นเพื่อลดค่า RPN ในกลุ่มความเสี่ยงหลัก ผลที่ได้จากการให้คะแนน RPN หลังจากมาตรการป้องกันความเสี่ยงถูกนำไปใช้ พบว่าลดความเสี่ยงลงได้ถึง 70-90% ผลจากการพัฒนาทำให้ความล่าช้าในการดำเนินการลดลง ช่วงเวลาในการดำเนินการก่อสร้างช่วงสุดท้ายสามารถดำเนินการจนเสร็จก่อนกำหนดเวลา 2 สัปดาห์ เป็นการพิสูจน์ถึงผลจากการทำวิจัยบริหารจัดการความเสี่ยงที่ทำให้เกิดความก้าวหน้าทั้งในด้านเวลาและคุณภาพ

ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต	ลายมือชื่อนิสิต...
สาขาวิชา การจัดการทางวิศวกรรม	ลายมือชื่ออ.ที่ปรึกษาวิทยานิพนธ์หลัก..................
ปีการศึกษา 2552	

507 16109 21 : MAJOR ENGINEERING MANAGEMENT
KEY WORDS: PROJECT RISK MANAGEMENT

RISK MANAGEMENT FOR PREFABRICATED CLASSICAL THAI HOUSE CONSTRUCTION PROJECT. ADVISOR: ASSOC. PROF. PARAMES CHTIMA, PH.D. 229 pp.

The purpose of this research is to study the risks from the prefabricated Thai classical house construction project. The extended research on its characteristics will be necessary. The objectives of this research are to minimize and prevent the risks of a prefabricated construction project taken place in Phang-nga (Southern Thailand) in terms of time and quality. Preventive methods will also be created.

Risk management team will be selected to arrange meetings. The team will evaluate the risks from the prefabricated house construction. The process of construction will be broken down into 7 processes. FMEA (Failure Mode and Effect Analysis) will be used to assess the risk sensitivity from 83 risks identified. Pareto analysis is also applied. The assessment of the RPN (Risk Priority Number) using Pareto Analysis shows that there are in total of 17 critical risks. The analysis of critical risks is done by using Fish bone analysis and Fault tree analysis to find the root cause if each of the risks. The preventive actions can be organized, using linkage between each critical risk and its root cause. Six preventive actions would resolve the intensity of these risks to lower the RPN value of the critical risks. The results show that the RPN after applying preventive actions has reduced by 70-90%. After implementation of some of the critical risks, there were improvements in the delaying schedule. The last phase of construction project finished 2 weeks before the dead line, showing a big improvement compared with to the last two phases. It is proven that risk management for the prefabricated house construction project has improved the result of the project in terms of time and quality.

The Regional Centre for Manufacturing Systems Engineering Student's Signature………………..
Field of Study :Engineering Management Advisor's Signature.......................
Academic Year : 2009

ACKNOWLEDGEMENTS

The author would like to express sincere appreciation to Associate Professor Dr. Parames Chutima, the thesis advisor, for his support and his patience which has helped to complete this thesis. His guidance and comments has helped the author to understand and be motivated to finish this research. Grateful thanks also are express to Professor Dr. Sirichan Thongprasert, Associate the members of research committee, for their constructive comments.

The author would like show gratitude all the members from Cutting and Machinery Company Limited for their cooperation and help that they have given to complete this thesis. Without them, this thesis would not have been possible.

Finally, the author would like thank his beloved family, especially his parent's patience and guidance throughout this thesis. A lot of appreciation is expressed to the friends that have given support when ever needed. Lastly, the author would like to thank a special person that has help, supported, and understand all the problems that the author had come across during this time no matter how difficult it might be. Thank you to everyone that was involved in any step of the thesis, without them, it would not have been possible to complete.

CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

CHAPTER I

INTRODUCTION

1.1 Background of the Research

Everyday, our business world become more and more globalized, more competitive and the less competitive businesses are eliminated. Every company is trying to gain competitive advantage in any ways as they can. Competitive advantage consists of 2 main parts, which are the external factors and the internal factors. These two factors are combined together to form a competitive position in the market and this follows the rule of nature, which applies to all for thousands of years, “the better wins”. The external factors consist of for example the economic and the market condition of each sector of the business. The internal factors of a business consist of financial status, Operation Managements, Human Resource, Project Management, or Logistics Management of each company. They are all different in each company depending on the capital, management skills and the sector and type of the business.

In the construction business, the most important management skills will be in the field of Project Management. Construction Projects are one of the hardest projects to manage due to the numerous factors involved in the process. In the project management field, the 3 most important factors are time, costs, and quality. The difference between a normal project and a construction project is the scale. This is why construction project management became one of the famous topics being discussed by many management Guru and senior project managers.

Project management is the involving of many aspects into one subject. The topic that is being concentrate on in the paper is the Risk Management. Every project consists of risks. The risk of losing time, money, or quality is hidden behind every movement and decision. This is why it is important to have a risk management program to guide the project to success without having to lose a lot unnecessary resources.

1.2 Company Background

ABC Company Limited is an OEM company producing machines for iron and wood related work such as cutting, shaping, bending, joining or punching. ABC headquarter is located in Bangkok, which is managed by the owner himself. The product of this company is distributed to many countries but the main target group is the neighbor countries around Thailand such as Laos, Vietnam etc.

ABC is not only involved in the machinery of Iron and Wood but the owner is also involved in the consultation and production of a Prefabricated classical Thai House made of wood. The House is separated into parts, joints and walls, where it can be transported to the side and can be built in a short period of time. This company is involved in this product for more than 10 years and became well known in selling the product. They started their own construction contractor team just a few months ago (2008), where they will manufacture, distribute, sell in both retail and single houses and then implement the construction by themselves. There are already some medium sized hotels that decided to use such Thai style prefabricated house to be used in their resort for example in P.P. Island, in the Northern Thailand in Maehongsorn Province.

In the fourth quarter of year 2008, ABC signed contract to start a resort business to a client (owner). The purpose of building a resort is first to advertise the market of the prefabricated classical Thai house and to build a medium size resort business by the beach. The location of the resort will be in Takuapa, Phang-nga Province. ABC signed to build on 3 plots of land and decided to build up a 35 Units prefabricated classical Thai House, with 10 Units on market demand standby. The construction will start at the beginning of year 2009. This is the biggest construction project for ABC Company.

The ABC Company has subcontracted the infrastructure work to a contractor to take care of. The infrastructure work will include all electrical installation system, all watering system and the wastewater treatment system. Therefore, there will be two teams of construction worker working on this project. The supervisor and foreman of ABC will be controlling the quality and the process of the construction. The project size is considered a challenge to ABC due to the unskilled team.

1.3 Prefabricated Classical Thai House Specifications

Figure 1-1. An example of Prefabricated Classical Thai House

There are many designs of the Prefabricated Thai Classical House; the inner area can be from the range of 36 m^2 to 90 m^2 or more (Figure 1-1). The house construction is done with a concrete base to elevate from the ground; this makes the house more flexible in the landscape because with the elevated base, it can also be located in the mountain area. In construction period, all the parts will be manufactured beforehand and then it will be transported to the location. On average, with about 3-5 workers, 1 unit can be completed within 1 month.

This style of house is very attractive to the foreigners because it represents the Thai culture and urban comfort. It is also very appealing to the investors because it is very fast constructing house, which means the time from project starts to the operation period takes a little time. This means if the project is funded with a loan from the bank, therefore, the faster the project makes profit; the sooner it can repay the bank and shorten the interest payment period. So it is a good choice for both renovation and initiating bungalows in resorts in tropical area.

1.4 Statement of Problem

ABC Company Limited decided to construct a Bungalow Resort in the Phang-nga province, in Southern Thailand. In the beginning of the year 2009, the client has signed a contract with the tour agency to be ready for customer in tourist season of the year 2010, which is approximately in January 2010. This means the project time will be around 12-13 months to build 45 units of Thai prefabricated house in the southern Thailand. After creating a project plan, it is just enough to construct all units within the time period including the infrastructure.

According to the past experience, ABC did some construction projects but there are still no relevant risk management programs for their construction because the management style is Thai style and no base system to support like models, tools and techniques.

These are the lists of Problems that will be concentrated on:

- High Volume (45 Units) construction in a tight time frame with no float time for flexibility
- Definite Deadline from the Tour Agency with tight schedule
- No risk management plans to support the construction before and with the tight schedule, it causes stress and worry to the owner.
- Thai Style Prefabricated House is a fast construction method; therefore it must be well planned.
- The working of two teams, where one team is inexperienced in prefabrication construction work might cause problems.

The statement of problem of the construction project is listed for as an initiation of a thesis to construct a **Risk Analysis to manage the risks of the construction project of the prefabricated classical Thai house.**

1.5 Objective of Thesis

To develop Risk Management for Prefabricated Thai Classical House Construction Project in order to have a smooth project from beginning of planning to the end of the construction.

1.6 Scope of Thesis

The thesis on Risk Management of Thai Style Prefabrication house construction project in southern Thailand will be researched and written under the following scope:

- The Risks in Production and Fabrication of the Classical Thai house.
- The Risks in Logistics Management and planning of the houses.
- The Risks in Construction Operation at the site.

The thesis will be concentrating from the beginning of the production phase of the wooden houses until the operations of the house being constructed in the site.
This Thesis will **exclude**:

- Financial and Costing Risks
- Business Strategy and Management Risks
- Marketing Risks

To conclude the scope of this thesis, the thesis will **include** the risk of project management in terms of operations in construction, the logistics management of the houses, and the Production and fabrication planning of the classical Thai house, but the thesis will **exclude** the project finance, business strategy of the project and the marketing risks.

1.7 Expected Benefits

From the result that the thesis will generate, the risk manage program direct benefit is to create a smooth operation of the project by preventing, delegating, allocating all the risks that might occur. These are some of the benefits of the risk management program in both direct and indirect way.

- Smooth running construction operation
- Successful project
- Less last minute problem solving, which might not be the best decision
- No loss of resource on non-value adding tasks occurred in risks
- Less complication in project monitoring
- Gain more resources to improve other aspects in the projects
- Able to apply the project planning of the whole process from planning, production, prefabrication, logistics and construction operations to other projects
- Possibly improve any factors to gain more benefits, efficiency or assurance to this and other projects

1.8 Methodology

The research procedure of the thesis about risk management will be following these steps, which are:

1. Literature Review
    - Study the literature that includes the concept of Risk Management in the aspects of production, logistics, construction and project management
    - Study Tools, Techniques and Models of Risk Management that can be applied to the total project.
2. Process study and information gathering
    - Study process of prefabrication production, logistics and operational tasks that is needed to be done within the project
    - Gather detailed information about topics within the scope of the thesis
    - Gather information about other projects that was implemented in other location and the risks/incident that occurred
3. Risk Management Process
    - Identify Risk Factors from all the possible operations according to the scope from project planning and risks occurred from other projects
    - Assess the Risk Sensitivity of the Risks from the identified risks
    - Allocate Risks into Priorities of solving
    - Develop Strategies to mitigate identified Risks
    - Invoke a contingency plan
4. Summary
    - Summary of the Project Risk Management Program
    - Thesis write up

1.9 Organization of Thesis

The first chapter describes the ABC business and its problem about the construction of the prefabricated classical Thai houses. It is mentioned that the construction project will contain a lot of risks and should be properly and systematically managed. The chapter also includes the objective, scope, expected benefits and the methodology of the thesis. This information will be fulfilled in this thesis in the following chapters. In the second chapter, risk management and its tools and techniques will be explored and researched. All the important information about the thesis will be done including reviewing the past journals that could be useful in this thesis. The third chapter will begin with explaining the whole picture of the project along with its detailed information. The information will be presented to cover all the risks that would be managed in the next step. The third chapter also shows the detailed methodology of the thesis and how it will be conducted. In the fourth chapter, the content will show the result and analysis of the risks. This chapter will show the results of the risk management process step by step along with the analysis of the information from the results. The chapter will present out all the critical risks as a result from the risk management process and the preventive actions that would manage them. In the fifth chapter, the conclusion of the total process of the risk management will be presented. This last chapter will also include recommendations and further studies of this thesis.

CHAPTER II

LITERATURE REVIEW

The literature review of the thesis proposal about Risk Management in Construction will be covering the following aspects.

2.1 Risk in Project Management Introduction

2.2 Construction Risk Management

2.3 Risk Management Procedure

2.4 Contingency Plan and Other Risk Prevention Methods

2.5 Academic Resources and Information Source Review

2.6 Conclusion on Risk management

2.1 Risks in Project Management

The term Project Management is defined as “The planning monitoring and control of all aspects of a project and the motivation of those involved in it to achieve the project objectives on time and to the specified cost, quality and performance” (Gemmell, 2008; British Standards, 2000)

There are many factors involved in the subject of project management but at the when it is minimized to the end of the chain, it comes to **cost, time and quality** as the shown in figure 2-1.

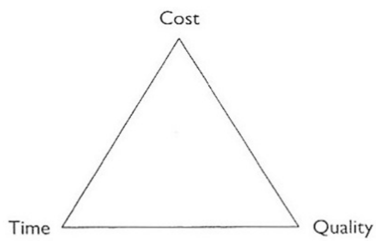


Figure 2-1. Three dimensions of project management. (Fewings, 2005)

The main topic area that is going to be discussed is going to be the Risk management. In the 1990s, project management caught the attention to most of the professional managers in many countries and became one of the highest attentions paid topic area. (WMG Course Note, 2008)

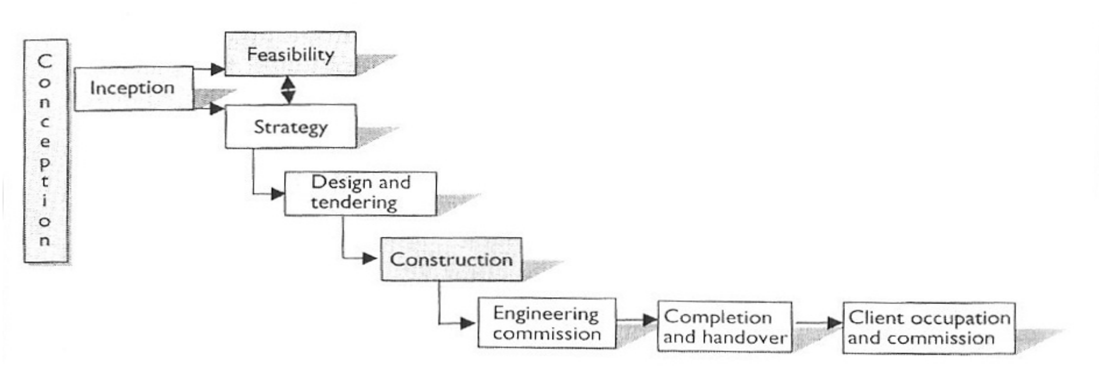


Figure 2-2. Life cycle of Construction project. (CIOB, 2002)

To understand the risk in project management, we first have to understand the life cycle (figure 2-2) or procedure of a typical organized construction project. Like every project, it begins with a concept of business idea. (Fewings, 2005) The inception of possibilities of a business; it might take some period of time to generate it into an actual business plan, where all the feasibility studies are carefully done and magnified. In this stage of feasibility, many factors will come into the picture such as the funding resources, the life cycle costing, design option appraisal and investigation of alternative site location. Once all of that is completed, then strategies are formed. Strategies of how the project will be controlled and executed such as protocols, or the control system will then combine together to form a Project Execution Plan (PEP) that fully analyzes and allocates the risk issues, also the stages of the project or even the client requirements. Some of the constraints such as construction strategies, the designs and the client requirements will be established and coordinated in this PEP. Once the strategies are sorted out, the design and tendering stage is where all the main documents and designs will be finalize. In this stage, the main objective is to finalize the design and procurement to be able to identify the start date of construction, which will be related to the handover stage as well. The design and tendering stage is very vital because the difficulty of controlling the diverse design activity to meet the required deadline. Then the construction stage, where the actual development is executed and it all narrows down to cost, time and quality, but there are many detailed issued involved such as supply chain etc. The rest of the stages are post- construction activities. The key of this diagram is to show the stages of construction project and see how much it can go wrong.

2.1.1 Quantitative and Qualitative Risk Analysis

There are two types of analyzing the risk, which are qualitative and quantitative. (Troung et al., 2007) It is very much dependable on the type of risk, the tools used and also the techniques applied to determine the appropriate usage between the two methods, and each method has their own pros and cons, as presented in figure 2-3.

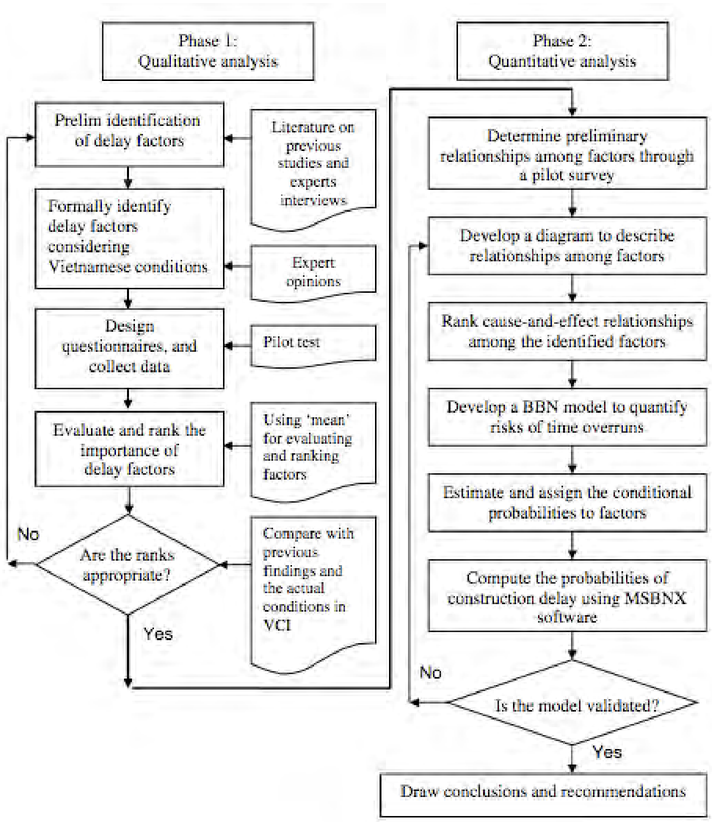


Figure 2-3. Conceptual Flowchart of Qualitative and Quantitative Risk Management on delaying factors in a project (Troung et al., 2007)

The debating question about the Risk Management (RM) is usually what method will the project be conducting the RM. In the modern society, great reliability is given to the quantitative side, due to accurate results and analysis; however, there is so much room for error in the analysis of the quantitative risk management. There are a lot of data that comes into the equations and so many processes that needs to be analyzed; therefore, it is difficult to determine whether this project risk management should be using an approach of Qualitative or Quantitative analysis. As it is defined in (Loosemore et al., 2006) that quantitative analysis should only be conducted when these criteria are fulfilled.

Criteria for Quantitative Risk Analysis Method

- When you have first conducted a qualitative analysis
- On the Risks which emerge as particularly important from qualitative analysis
- When you have sufficient time or when time becomes available
- When you have reliable data to assign numbers to probabilities or when data becomes available
- When it makes sense to attribute numbers to the consequences of a risk
- When you have the necessary expertise or support to conduct and interpret the results of a quantitative analysis.

Basically saying that Quantitative Risk Analysis is the follow-through analyzing of the Qualitative Risk Management. Some of the projects that are suitable for quantitative analysis are for example Life Cycle Costing projects, Economic Appraisal for a new business opportunity, or Plant reliability assessment.

2.1.2 Qualitative Risk Analysis

The basic analytical methodology of Quantitative and Qualitative Risk Management is the same. The only difference is, in the quantitative analysis, numerical values and equations are used to analyze the risk but in qualitative risk management, words and descriptions are used to describe these variables.

RPN (Risk Priority Number) = SEVERITY x OCCURRENCE x DETECTION

These variables are the heart of Qualitative risk management. These are the three dimensions that will need to be analyzed. With these three variables multiplying together, the RPN number will be produced. RPN (Risk Priority Number) is the result from the three variables combined together to analyze the priority of the risk that needs to be taken care of first. By breaking down the equations, RPN number can increase directly proportional to any of the three variables stated, which means no matter which number increases or decreases, the RPN will dynamically changes as well. This is the key to Qualitative Risk Management, to reduce the RPN by trying to use Risk response to handle either one or more of the three key variables.

The variables that are used to calculated RPN number could be determined by using labels. Labels are descriptions used to differentiate the risks severities in the three aspects or variables. Each description is paired with numbers from 0-9, which has to be given a table of labels so the Qualitative risk management. There are standards of labels sets, which are used in different industries or projects. They are not the same and have different descriptions depending on the projects and industries.

Table 2-1. Qualitative Occurrence labels (AS/NZS-4360, 1999; (Loosemore et al., 2006)

Descriptor	**Description**
Rare (1)	This event may occur in exceptional circumstances only
Unlikely (2)	This event is not likely to occur
Possible (3)	This event could occur at some time
Likely (4)	This event has happened before and will probably occur again
Almost certain (5)	This even is common and is expected to occur in most circumstances

These descriptions are the deciding criteria of each ranks of risk (table 2-1). This is only an example to see the how it is done, as told that each projects and industries have different qualitative labels and criteria's. Usually the descriptors are ranked with numbers assigned to them. Then when the description is fully studied and chosen which descriptors will be used in a specific risk; the numbers will then be used in the RPN equation, in this case in the frequency variable. Each variables (Impact, frequency and detection) will have their own label table describing the rank and severities of each risk. After going through three tables of labels assigning the numbers into the risks, then the RPN number can be calculated and recorded into orders to perform the next step of risk management. There are many standards of risk management labels and definitions that companies and organizations have set. Some of them are: (PMI, 1992), (Boothroyd and Emmett, 1996), (ICE, 1998), (Bowden et al., 2001), and (FMA, 2004). These definitions can also distinguish between the risk and opportunity definition, the labels definitions, recommending vocabularies and control systems to handle the correct risk response to the right situations. The labels in this case, will be constructed to fit the purpose of the risk management in this Prefabricated Classical Thai House Construction project.

2.1.3 Risk in many Aspects

In every act in business, there will be uncertainty. In every uncertainty, there will be probability of unpredictable result and in every unpredictable result can be classified into either risk or opportunity. In this logical sense of risk analyzing, it can also be seen that risk must be from uncertain area of management that can cause negative impact to the total outcome. Therefore, if something is known to happen, it is not a risk but just an issue that is to be managed. Another logical understanding is that uncertainties can be interpreted into two sides, risk and opportunities. Opportunities can be something that adds value or adds a positive effect to the total picture, while risk is vice versa.

In the total scope of the dissertation, the areas that will be involved in this risk management are: Construction Operations, Logistics/Supply chain and Production of the prefabricated Classical Thai house. In this section, the productions and logistics/supply chain area will be explained.

Production/Prefabrication

In this risk management scope, production or prefabrication is involved a great deal. It is the managing the parts of the Thai houses locally in the factory, and to generate the best output from the given circumstances. The formation of the factory will be different in each industry. Some industries are able to form production lines, creating a non-customized product, using many different technologies and materials. But some industries, for example the prefabrication of houses with various designs and different customer specifications cannot operate in assembly lines but rather as stations, or functional system. This means the management will be more complex and detailed. There are many factors that are involved in managing a smooth functional production system. Especially in a detailed production like prefabricated houses, the most important factor that is the heart is the information flow and trying to achieve the specifications of the customers. Not to mention the preparation of the materials and the skills of the workers. In the managing the production of Prefabricated Thai house, there can be risk in many steps, which can play very important part in the projects.

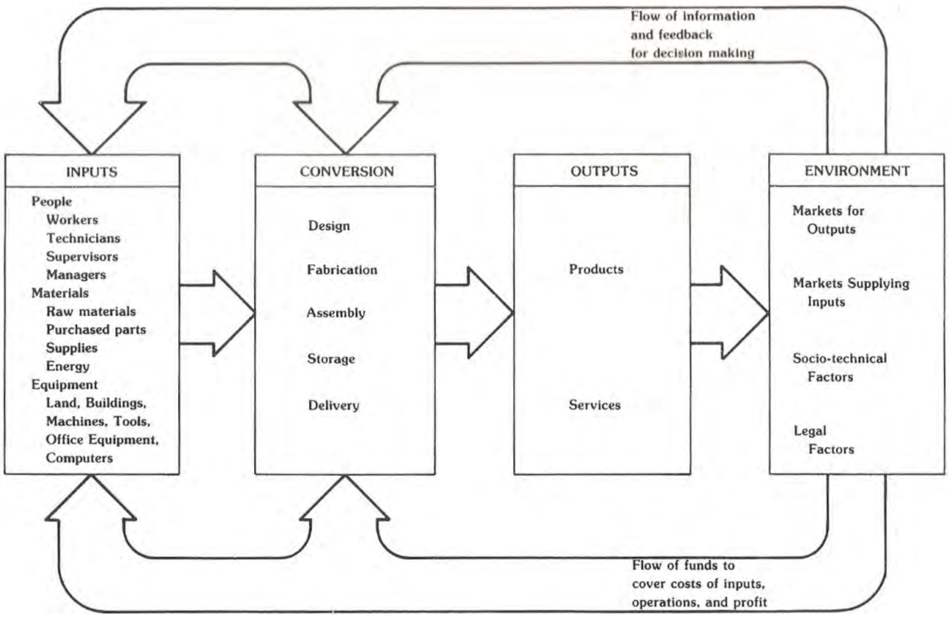


Figure 2-4. The Production Function in General (Fearon et al., 1989)

This is the general diagram (figure 2-4) showing the functions and the involvement topic in production, so the risk can be estimated. There are many factors involved in production; therefore, there are many risk and also managing problems that needs attention.

Logistics/Supply chain

The components combining in the construction project is considered a very wide range. There are many stakeholders involved in both internal and external to the project. The requirements of skills and material including the sub-assemblies is countless, therefore, the supply chain and the logistics of a construction project is vital.

The important logistics and supply chain in the prefabrication house factory, is the flow of material and the inventory. Most of the material is wood, which is ordered from the neighbor countries; therefore, it needs processing and the appropriate storage. Another concern is the transportation of the wood will have to be firmly scheduled and synchronized to the production schedule, to gain maximum result and minimum lag time. The logistics of the production process is another big issue, because the process that wood has to go through complicated with many preparations and finishing, so the lag time management of wood may cause problems.

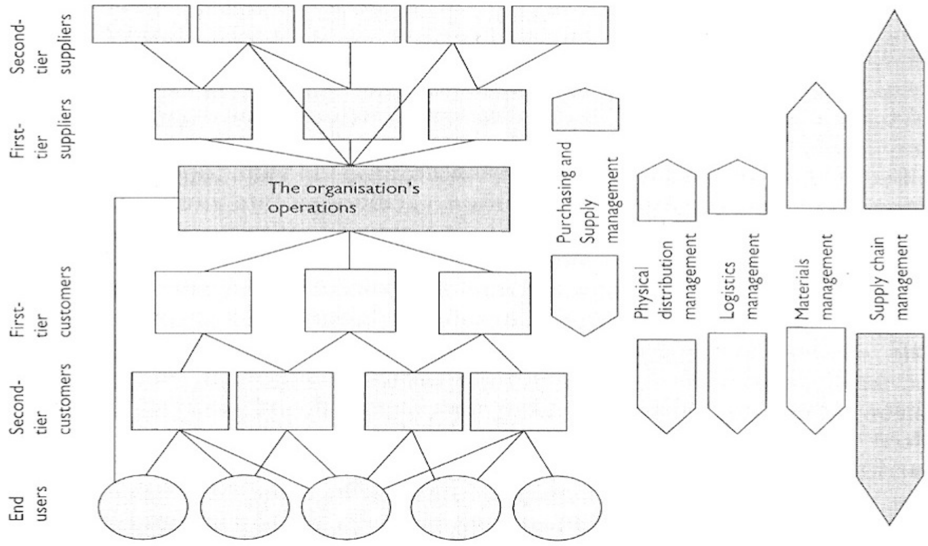


Figure 2-5. Example of a full supply chain. (Fewings, 2005)

The figure 2-5 is showing the complexity of supply chain management. Showing the tiers of suppliers and the customers, and how the organization is connected to them. As it is labeled on the right side, there are many subjects in the supply chain management and therefore, many risks as well. The risk in supply chain is countless considering the supply chain configuration, the supply relationship and supply chain coordination, which will also be coordinated with the production planning that the factory has planned too.

As it is proven that the Risk Management is a very useful topic and it is worthwhile to discuss, however, it is still a balancing act. When looking at Risk Management in an objectifying matter, it is the foreseeing of something that has not occur yet, might not occur and might not be relevant in the future time. This is why Risk Management (RM) is something that must be balanced with the reality and actual possibilities of occurring otherwise it can be treated as wasting of resources.

The Risk management in a project can be measured from the success of the project and how smooth running the project operation was. At the final stage, a contingency plan is built to handle any last minute trouble shooting events.

2.2 Construction Risk Management

Construction projects are one of the most difficult projects to manage due to the various parties that are involved within it. The parties are involved in the project, in both direct and indirectly, which causes it to be very complicated with many tasks being done in the same time. The involved parties can include the landowners, project owners, Designers, Workers, and Tenants, Marketing team or even the neighbors. (WMG Course Note, 2008)

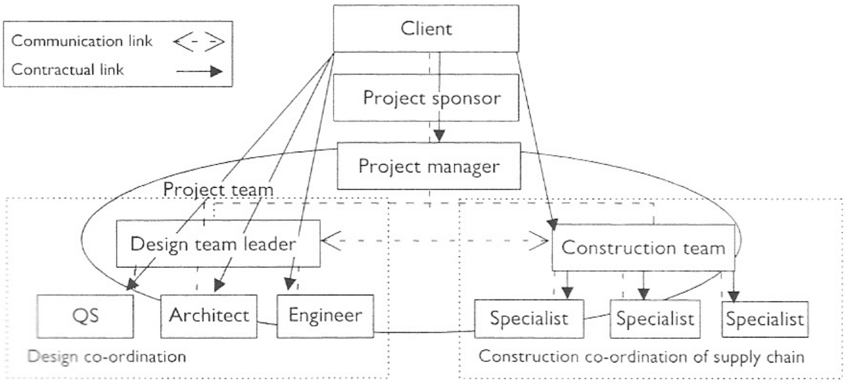


Figure 2-6. Project structure diagram of the executive management model (Fewings, 2005)

The main factor that is the same in every project, no matter what project it is, is that the result must fulfill the customer requirements. Especially in construction projects, the product is unique and always changing designs. With such complex product, without good synchronizing of the design and construction team, the project is nearly impossible (as shown in the communication link in figure 2-6). The two main coordinators are the design manager and the construction manager. The design manager's role is mainly to co-ordinate the design functions and the specialist design when needed. The construction manager will be in charge of tendering specialist packages, set up the site procedures and integrate the construction program and the interfaces between the specialist packages. (Fewings, 2005)

Risks in construction projects are very high, because of many reasons such as it is a high investment business, usually comes with high volume, involves a lot of parties, and require a lot of resources. Due to the very unique product that the project team will have to deliver from a construction project, it is not always easy to be able to focus on meeting the customer’s requirement. There are tools and models built for the risk management, which can be applied into the construction projects as well.

The risk management in both conventional and prefabrication construction is a big subject with a lot of details and complex understanding. The process especially in the prefabrication houses will need attention on the information flow. Construction is a fast changing process and daily problem solving operation with a wide scope and multi- level stakeholder, which have their own sets of requirement and culture of working. It can be considered that construction project management is one of the most complicated and unpredictable types of project to management let alone the risk that it generates. Even though, managers try to minimize and control the project, there are still a lot of unknown and uncontrollable problems that will always be added on in the picture. The best solution to handle risk might not be only to eliminate it, but there are numbers of risks response that can be used to handle the risk to gain highest result with the lowest impact.

Another nature of the construction management is the crisis. Crisis moments are the time when the risk or problem comes to a critical situation. These situations are usually scoped with limited time or wasting cost. It can be the lack of material up to the striking of the labors. Crisis management creates stress and reduces the morale or motivation of the employers, therefore reducing the efficiency of the project staff. Crisis can also be stated as a poorly manage problem or risk that occurs to the project. Therefore, risk management is at least an approach to solve the crisis before it actually initiates.

2.3 Risk Management Procedure

The risk management procedure is a few steps that are created to enable the best result for the risk management. Before elaborating the risk management procedure, it is logical to generate the definition of risk first.

"Risk is the potential for realization of unwanted, negative consequences of an event" **(**Rowe, 1977)

The causative event may be a single event, some combination of events, or a continuing process, and the consequences may affect individuals, group of people, or society and its institution, or they may affect physical and biological systems. The definition of Risk aversion is defined as:

"Risk aversion is the action taken to control risk" **(**Rowe, 1977)

The action taken to reduce risk may be motivated either through direct reduction of uncertainty or by intuitive perception of risk taker. The total risk management can also be scoped into figure 2-7.

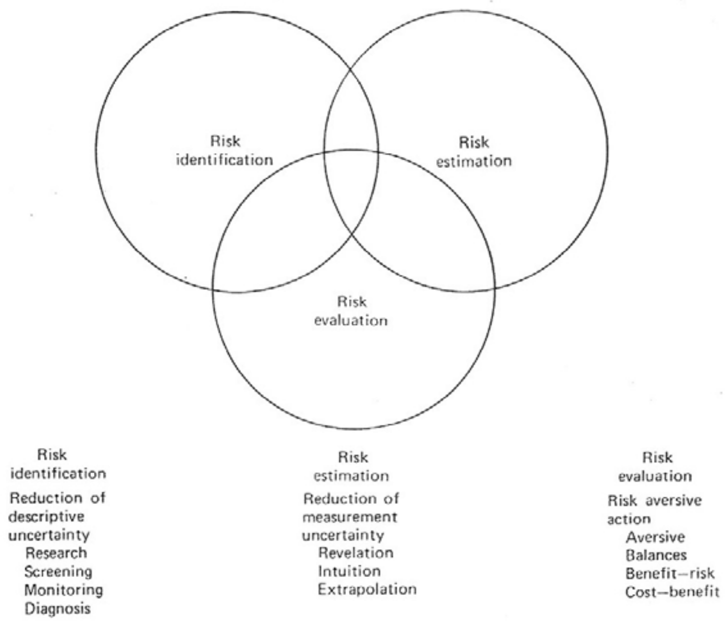


Figure 2-7. Element of risk assessment/management. **(**Rowe, 1977)

There are many approaches to risk management procedure depending on the type and the time given for risk management process. An actual approach of risk management should start with identifying of the decision objective. If the process starts with identifying the risk and opportunity, then there might be no reference of deciding whether the possible situation will be affecting positively or negatively to the total project. Therefore, according to (Loosemore et al., 2006), the risk management preparation should be according to the following procedure:

- Obtain organizational commitment to risk and opportunity management.
- Conduct a stakeholder analysis.
- Consult stakeholders.
- Identify Objectives.
- Identify key performance indicators (KPIs).

The key of this procedure is for the risk managers to understand the objectives in every party and understand the project objectives as well. This will include both stakeholder analysis and objectives analysis.

The more common risk analysis procedure, which might in some cases leave out the procedure above, because of lack of information and no time available; is simplify into 3 or 4 steps. According to (Fewings, 2005), this is how risk management procedure is described:

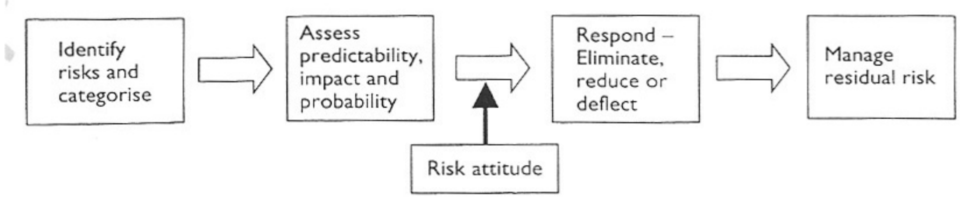


Figure 2-8. The risk management process. (Fewings, 2005)

The risk management process in figure 2-8 is a rather simplified starting with identifying the risk and categorizes it. Then assess the predictability, impact and probability. Risk attitude is how the risk taker will manage the risk, for example; a defensive risk attitude will add risk premium for a response of risk. Then comes the risk response process, where there are a few types of response to try to solve the risk. The management of residual risk is at the end, where the risk is already managed but still leaves residual, which needs to be taken care of.

2.3.1 Risk Identification

As it is self explanatory, risk identification is the identification of all the events that can be a threat / opportunity to the project. (At this point, project risk is only assumed to be a threat to the project, excluding opportunity) Before the risk can be managed, the risk management team will first have to try to forecast the risks that could happen. There are two types of risk foreseeing; proactive and reactive risk identification. There are also numerous sources that risk can be identified from, these sources are: (Akintoye et al., 2003)

- Personal and Corporate Experience

  The personal and corporate experience can help identify the risk by the concept of not repeating the same mistakes and building a firm database of the entire potential negative factor that has happened. At the end, this experience can be used to form checklists and risk matrices.

- Safety Reviews

  Following through from the personal experience is to create a review at the end of a project. This will both create awareness and further forecasting of risk and other important subject that the project team will have to be more delicate about. Looking back to a done deal project can help the project to plan a more effective project plan in the future; helping identify risks.

- Intuition insights

  Intuition is a very complex subject, however, when it comes to identifying risks, it can be very helpful. Some risks cannot be foreseen or quantifiable, some we cannot be curtain of it occurring, therefore; it is also good to trust and use intuition as a tool for risk identifying. Taking a view of the future through the mind.

- Site Visit

  Site visits are one of the oldest risk identifying methods. Sometimes the risk is not clear unless it is seen objectively. By walking at construction site and analyzing the synergy of the project can generate a lot of ideas on what could go wrong. The risk can be seen at the sight due to unpredictability or it can be a false method, which does not work in a practical way.

- The use of Organizational Chart

  One of the easiest ways to find out about a company is to review the organization chart. The organization chart reveals how the company operates and the nature of working in the company, it can also show the quality and competence of personnel within that company. This information can further be assessed into risk identification information.

- Use of Flow Chart

  The process of operation is also vital to risk management. Flow chart is a good tool to use to analyze the process of operation within the project. For example, flow chart can make the analyzing of materials within the site clearer and simpler. It can show the number of workload in the site and allow us the see the labors distribution. Spotting the mistakes and illogical process can be done with the help of flow chart and therefore another source for risk identification.

- Research, Interviews and Surveys

  Research, interviews and surveys are very useful in this process. It can be used to understand and deepen the knowledge of a subject of lacking information such as the construction site; it can be applied to see the customer behavior and possible risk. It can be the direct information from the minds of the buyers to see how things should be done. Interviews with the right person may lead to a very useful source of information and pool of experience. Therefore, this method is highly recommended for all the projects to gain the best benefit from risk identification.

- Analysis of Assumptions

  Revising the assumptions can be a great idea when risk identifying. Assumptions are always required in projects to operate, and sometimes, when other risk identification tools are executed, analyzing of the assumption can generate more because doubting the beginning changes everything.

- Consultation of Experts

  Consultation of experts is an easy and valuable way out to risk identification. Experts are person with theories and experience of the subject at hand, so consulting them can produce many other perspectives that have not been covered yet. The more different fields of expertise consultation, the wider the picture can expand, therefore, more risk covered. The common field of consultation given can be legal, financial, design, environmental or project scheduling and timing. With these experts consultation, risks can be found, handled with before the construction even starts.

These are the basic resources that risk can be identified from. It is possible that one is more suitable than other consider each projects are different. But with these guidelines, risk can be identified and possibly solve them.

There 2 types of risk identification. The first is type is Reactive Risk Identification, and the second is Proactive Risk Identification. For Project Risk Management to be effective, you need to have both of them. (Loosemore et al., 2006) Reactive risk identification can be differentiated from proactive risk management by time. Reactive risks are risks that occur after the decisions have been made. Some may have gone undetected from the proactive risk identification or some can occur from the action take from solving the risks proactively. These are the content of proactive and reactive risks identifications.

Proactive Risk Identification

Imagination is the core to proactive risk identification. Proactive risk identification is the assumption into the future, which is very difficult because the personal interests and thinking methods will be clouding the overall view of the future. Then the judgment and weighting of the ideas are very sensitive; it takes courage and creativity not to mention experience. These are some factors effecting proactive risk identification (Loosemore et al., 2006):

- Creativity of the team
- Organization Characteristics and relationships
- Usage of Tools and Techniques to elicit Ideas

Every company has its own attribute on generating ideas in the risk identification. The first two factors might be difficult to gain in an organization. The creativity of a project team will be depending on the hiring and the skills of people in the team and creativity takes time to build. Organization characters and internal relationship is also a very complex issue that will take a lot of time to create and organize. However, the latter factor is very useful and can be applied instantly.

Ideas Elicitation Techniques

(Loosemore et al., 2006)

- **Checklist** – The simplest of usage of experience forming topics to consider when starting a project. A standard checklist of risks and opportunity for construction is provided in Appendix.
- **Decomposition Techniques** – These are techniques are designed to breakdown or divide an activity into step by step for easier risk identification. It is very useful for the decision-makers to logically approach to total picture again to gain more understanding in the process.
    - Devil's Advocate – This is when an independent person is introduced into the group and as it is self-explanatory, this person will provide different perspective to the project, gaining a two-side argument, which results to more risk identification.
    - Scenario Building – A simple technique on the use of "what if", and with imagination generating a scenario that can help on this process.
    - Attribute Listing – It is when the risk management team assigns a word describing the action such as fast, heavy, clumsy, sharp or dirty. These words will make the risk more clear.
    - Forced Relationship – Forcing relationship is when you pare up two random objects to each other to see the possible risk that can happen between it interacting. For example crane and adjacent building.
    - Synectics – this is for the decision-makers to try to reconstruct what they already know in new ways and to connect seemingly unrelated ideas, objects and process.
- **Forecasting** – A tremendous use to quantify risks and analyze them, there are many forecasting techniques available as well but it is designed for quantitative risk analysis more than qualitative.
- **Soft Systems Analysis –** There are many risk analysis software available. It can assist in identifying the feelings, attitudes and perceptions of

stakeholders, enabling potential conflict between them to be considered (Steward and Fortune, 1995)

- **Brainstorming** – Was developed by (Osborn, 1953) which is a technique that relies on group dynamic of ideas bouncing around. The success of the brainstorming depends on the experience and the perspective of ideas. There are structural steps available to follow and also some of the brainstorming techniques that will need to be use for best practice.
    - Delphi Technique – The Delphi technique is another approach to hold a brainstorm session. It is to eliminate the Asch Effect and the Groupthink effect. The process is done usually with the group members never met. The process starts with the coordinator asking the group members on individual basis for their own opinion about a certain problem, mostly in form of questionnaire. Then the ideas will be revised and then summarized. The summary will conclude all the ideas into a middle ground and then it will be resend again to be further discussed. It is important that all the ideas will have to be accepted and to mesh around. Also, it shall not be that the people will not stick to their own specific research domain. Then once again it will be collected and summarized to be a stabilized idea. When the ideas are stabilized, then the whole team will generate a list of acceptable ideas. This will help minimize many team problems and will also help the coordinator reach better ideas. However, the process takes a lot of preparation and takes a lot of time.
    - Nominal Group Technique – Nominal group technique is a technique that requires a group of people, gathering together to generate ideas on a certain topic. However, it is different from a normal brainstorming because the first part of the session will be done privately. Then all the ideas will be presented to the group. Each of the participants will have equal amount of weighing to each other's idea. At the end, the participant will then rank the risks/idea according to rankings, which this information can then be process further in the risk identification process. This technique is still influenced with the Asch Effect but it is

more structured and controlled, which is easier to do and requires less time than the Delphi Technique.

- **Fishbone Diagram (Ishikawa diagram or influence diagram) –** It is a diagram, which is created to see "How" risks can immerge. It is used after you have used all the other tools of "What" risk can arise, or "When" risks can occur. Figure 2-9 will start with a risk topic that could to happen. Then it is separated into many smaller subjects related to the risk. Such as Cost overrun can be linked with Designs, materials, or industrials relations. Then under each topic, you can create a sub-topic that can cause a reason for the risk to happen. Each sub-topic immerges, the question of "what could cause …(risk)...." Will be asked until it cannot be broken down anymore.

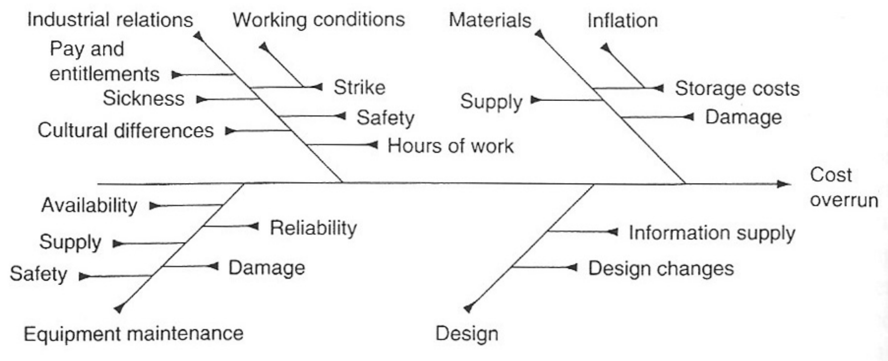


Figure 2-9. A typical fishbone diagram of Cost Overrun. (Loosemore et al., 2006)

- **Fault Tree Analysis –** A similar technique to the influence diagram. It is designed to find the "How" of the risk. The structure is like a decision tree (figure 2-10), but rather in a "possible cause" way. The process starts with identifying the top risk. Then identify a secondary fault, which contributes to the occurrence of the top risk. Then, identify a primary fault, that would contribute to the second fault, and the process goes on and on between 4-16 steps.

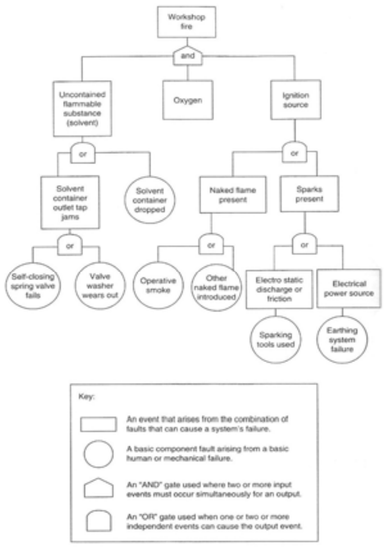


Figure 2-10. A typical Fault Tree Analysis of the risk of workshop fire. (Loosemore et al., 2006)

Reactive Risk Identification Techniques

It is impossible to forecast every single risk, and expect that the project will run smoothly without any risk occurring. Reactive risks are risks that occur after the decisions are made. Therefore, it means that reactive risk will happen in the implementation stage. There are measures to control the reactive risk, which will require the work of all the project team uniting to help. There are numbers of formal techniques to try to handle the reactive risks.

- **Risk Inspection** –By inspecting the workplace, employees and the document frequently, some risks can appear up. Sometimes, the unpredictable risks might not be accumulated from thinking but from investigating and observing.
- **Bug Listing** – The main idea of bug listing is to list out the things that bother the workers and employees in a day-to-day basis. Usually people tend to miss out the little annoying things by focusing on the bug picture. So by doing so, makes the work much smoother with lesser risks and problems.
- **Risk Review Meeting** – It is the meeting of decision stakeholders to come and discuss on the follow topic (Loosemore et al., 2006):

- Discuss the results of regular risk inspections
- Discuss the implementation of a decision with the aim of identifying potential new threats or opportunities.
- Maintain effective communications with decision stakeholders.
- Facilitate cooperation in instigating developing and implementing measures to minimize threats and maximize opportunities.
- Formulate, review and disseminate standards, rules and procedures to ensure that the decision outcomes are achieved, ideally better than planned.

- **Industry Information –** by updating news and information about the industries can be useful. Getting new researches, news, political movement on certain industries and threats can be a good look out to the project.
- **Incident Investigations –** By the term “incident”, in this case is defined as an event that affects the loss or benefit to the business objective. By investigating incidents, lessons can be learnt and not repeat it again.
- **Performance Appraisals –** Performance appraisal should be conducted to prevent a performance drop and to control and identify risks that could happen. It should be appraised using the objective and the KPIs of the risk management, to gain best benefit for preventing and controlling reactive risks.

The Risk identification process uses a lot of creativity and resources to generate. However, it is the most important step in the risk management process, because it is the starting of all other rankings and ratings. If the risks are all identified, then the projects can easier be managed knowing more the unknown. However, too many generated risk can also take too much time in identifying it. Once the risks are all identified, it then comes to assessing the risk.

2.3.2 Assessment of Risk Sensitivity and Sensitivity Allocation

Once the risks are identified, a list of risk will be produced along with some of the reasons why it could occur and how it will occur. The process of risk management will then move on to the assessment of the risk. The assessment of the risks has been discussed earlier, separating the assessment of risk into 2 types, which are quantitative and qualitative risk. The distinguish difference is that quantitative RM uses number, whilst qualitative RM uses workings to describe the severity.

There are many risk assessment tool to use for assessing the risk according their specific types and fields. Each of them has different approach and methods. These are some of the Risk Assessment Tools:

- Portfolio Management
- Investment Analysis
- Decision Analysis
- Failure Mode and Effect Analysis (FMEA)
- Monte Carlo Simulation
- Project evaluation and review technique (PERT)
- Multiple estimate risk analysis technique or Root mean squared

These tools have been presented with the approach ways, and examples of usage in (Fewings, 2005). These tools will require different specific data from the project and the specific type of project for each one.

The main tool for risk assessment of Prefabricated Classical Thai House Construction project will be adapted from FMEA. Failure Mode and Effect Analysis (FMEA) is a powerful tool to analyze and arrange the risks. It is considered to be a qualitative risk management. The process of FMEA is very simple, and was explained in the Qualitative Risk Analysis, the objective is to evaluate and accumulate the RPN (Risk Priority Number). In the FMEA, there are three columns that need information gathering to produce the RPN number. The three factors to create the RPN are Impact, Detection and Frequency. These factors will have a descriptive score assign to it. These score will be created, with description saying the depth of each lever starting from score 1 to score 10. The scoring system will be different in different products and industries. Therefore, the score will have to be original and well balanced so the project risk management team can understand the system and generate an accurate FMEA scoring. Usually this is done in teams of decision-makers and experts.

Risk Priority Numbers (RPNs) of failure modes with highest RPN and RPN after corrective action.

Step[a]	Failure mode	Possible effect	Possible cause	Possible mode of detection	Estimated frequency of occurrence (O)	Estimated frequency of detection (D)	Estimated severity (S)	RPN	Corrective action	RPN after corrective action	Improvement index[b]
10	Mistakenly switching of samples	Wrong result	Inadequate procedure	None	4 (after corrective action: 2)	10	8	320	Number the trays when more than one sample is analyzed	160	2.0
15	Inadequate control by NIR expert	Wrong result	Carelessness	Not timely	4	10 (after corrective action: 3)	8	320	Second control by other NIR expert	96	3.3
12	Lack of experience with chemometrics	Wrong interpretation of result	Incompetence	None	3	10 (after corrective action: 4)	8	240	Second control by NIR expert	96	2.5
18	No qualification of library in letter to commissioner	Wrong interpretation of result	Inadequate communica-tion	None	3	10 (after corrective action: 2)	8	240	Include standard restriction in letter.	48	5.0
9	Wrong measurement parameters of NIR equipment	Unreliable result	Carelessness	Control by NIR expert	4	7 (after corrective action: 3)	8	224	Printing out measurement file	96	2.3
11	Wrong parameters NIR equipment for sample analyzed	Unreliable result	Carelessness	None	3	10 (after corrective action: 2)	5	150	Printing out measurement file	30	5.0

Figure 2-11. An example of FMEA (Van Leeuwen et al., 2009)

As the figure 2-11 is showing, the FMEA is not a complicated process. It starts with describing the risk (Failure Mode) and the possible effect/cause/detection. These probability columns are there for the team to descriptively input the information so the number of three factors. The estimations on the three variables will be filled in and multiply to gain RPN. When the RPN is calculated, the corrective action column is what the risk team will implement to solve the problem. Them RPN is re-calculated to see how much it have improved. Once the serious risks sorted and scored in the FMEA. It is the matter of solving them and creating a back up plan/strategy as known as “Contingency Plan”. It is the protocol to follow to prevent and solve the risk from the project.

There are many types of FMEA to use, for example the process FMEA and design FMEA. The design FMEA is involved in design activities, such as product designs, machines or tooling designs where the components are broken down to smaller steps and identifying the potential failure modes and the cause of each parts. After the potential cause and effect to the end user is determined, the risks can be managed. (Teoh and Case, 2004)

The process FMEA is used more to solve problem due to manufacturing process where the project is moving on step by step (in this case construction). It starts with a process flow chart that represents each of the manufacturing steps (construction steps). Then the potential failure and potential effect will be listed, with the risk and their response to reduce the risk to the production (project team) or end user (owner). (Teoh and Case, 2004)

The steps to implement FMEA are summarized as follow (Johnson, 2002):

1. Reviewing Process.
2. Brainstorming potential failure modes.
3. Listing potential effects of each mode.
4. Assigning a severity rating for each effect.
5. Assigning an occurrence rating for each failure mode.
6. Assigning a detection rating for each failure mode and effect.
7. Calculating the risk priority number (RPN) for each effect.
8. Prioritizing the failure modes for action.
9. Taking action to eliminate or reduce the high-risk failure modes.
10. Calculating the resulting RPN as the failure modes are reduced or eliminated.

The ratings of the Severity, Occurrence and Detection (SOD) is very important to the FMEA because it is the determine factor of the RPN score. The rating of Form Motor Company is attached in Appendix.

The sensitivity allocation of risks is the re-arranging the risks in order, in order to know which risk is more severe and where to cut off. First, it is reasonable to re-arrange the RPN number from the highest to lowest, to see which RPN is highest priority to solve. There is a relationship between the impact and probability of risk. The relationship can show reaction that will need to take place. By looking at this table, you can first allocate the risks in to each category and see what the ranking will be.

Probabilities	*Consequences*				
	Insignificant	*Minor*	*Moderate*	*Major*	*Extraordinary*
Almost certain	Low	Medium	High	High	High
Likely	Low	Medium	Medium	High	High
Possible	Low	Low	Medium	High	High
Unlikely	Low	Low	Low	Medium	Medium
Rare	Low	Low	Low	Medium	Medium

Key

High – are those risks or opportunities with a relatively high likelihood and large impact. They will require close management attention at senior level, detailed research, quantitative analysis if possible and a formal risk action plan. Any management strategy should be developed in close consultation with senior managers and a Risk Manager.

Medium – are risks or opportunities with a medium likelihood and impact. You should decide how they are to be managed in consultation with a Risk Manager who will decide whether senior management attention and further quantitative analysis is necessary. A formal risk action plan is normally needed which clearly allocates responsibilities and timetables for action.

Low – are those risks or opportunities with a relatively low likelihood and impact. They are regarded as acceptable within normal business activities, are managed effectively by routine and standard procedures and can be excluded from further detailed consideration. However, they cannot be ignored because if standard procedures and controls do not work, a minor risk can quickly become a major problem or a potential opportunity may be missed.

Figure 2-12. The relationship between the Severity and the Occurrence (Loosemore et al., 2006)

According to figure 2-12, the risks are allocated into 3 rankings, which are low, medium and high. So, the team can solve the risks with a "high" rank. Another useful tool to allocate the sensitivity and the severity of the risk is to use Pareto Analysis.

Pareto Analysis is a very famous management technique that can be applied to many subjects in management. It is stated "80 percent of the trouble comes from 20 percent of the problems." (Scholtes et al., 1988) It can be explained that 80 percent of the impact (damage) comes from only 20 percent of the risk. This is an excellent way to allocate the risk sensitivity.

2.3.3 Risk Response

The first question that should be asked before any risk response process is whether the risk should be handled or not. There are some risks that do not require managing due to insufficient resource or the risk is worth to manage due to very low RPN number. To mitigate risks, there are countless ways to implement; however it is dependant to the circumstances and the peculiarity of an organization. There are mainly 4 strategies developed to mitigate the risk. (Akintoye et al., 2003)

- Risk Elimination – it can also refer as risk avoidance or risk aborting. It is the total elimination of the risk due to a very high severity possibility. The actions that could need to be done could commonly be drastic measures that require a very high amount of resource to eliminate that risk completely.
- Risk Reduction – Risk reduction is rather softer than risk elimination. The fastest way for risk reduction is to gain information about the risk and solve it in a less drastic method. This is more preferable than risk elimination in the given circumstances that risks are inevitable and needed to be minimized rather than eliminate.
- Risk Transfer – Transferring the risks to the other parties is commonly used in the construction business. There are several partners that are linked to the project and by switching responsibilities or linking the tanks to them, the risk can be shared to another organization that would not suffer much from the impact that the risk can summon. For the effective risk transfer, the risk should be transferred to experts in that specific field.
- Risk Retention – Sometimes known as risk absorption or risk pooling. Risk retention is the last resort strategy to handle risk. The risk can be reduced or transferred, to deal with the residual risk the risk management team will have to absorb it if there is nothing else worth doing. The risks that are most suitable for risk absorption are those with minimal impact to the project.

These are the four main strategies that are used to mitigate risks. There are tools that are design from these strategies to mitigate risk such as Guarantees, Bid

Bonds, Risk Premium, insurance or risk-adjusted discount rate. (Akintoye et al., 2003)

2.4 Contingency Plans and Other Risk Prevention Methods

Contingency plans are back up plans for when the situation are not as it is expected. (Fewings, 2005) When the risk management process is done, it is the duty of the risk management team to create a backup plan to protect and prevent the risk from happening again. There are many ways to prevent it from happen. First the team will have to understand the risk that happens and locate the root cause of the risk. Locating the root cause of the risk means the risk is changed to be a managing problem. Once it is changed into a management problem, then it is the matter of information flow and management to handle it. This is the closing of the Risk Management process.

Checklist is a very good and informative tool to present issues. In the FMEA, when the risks are measured with RPN and solved accordingly presenting the new lowered RPN, the method of solving risks can be simplified to subjects and factors of risks. These factors can be put together to form a checklist. The checklist then will be created to specifically serve a typical type of project, such as a prefabricated Thai House construction project. The checklist can then distribute to all the managers to see how the risks can be solved and where to take caution when implementation.

In the lower rank staff such as labors, other than being supervised on the work from the supervisor, there can be notice boards and safety trainings to the specific risks. Providing tools and techniques in constructions that can assure that risks shall not happen again.

Experience is also another very important tool in the team. If the decision-makers and managers are involved in the risk management process, then they will think about the risk and ways to prevent it. Therefore, the overall risk is automatically reduced from the psychological effect of awareness.

At the end of the process, it is the matter of information flow within the project teams from the top to the bottom. If the high rank staffs are involved and passing the information down to the labors and contractors, then the system is already effective. Bringing in experts, tools or techniques can radically change the outcome of the project if the awareness and is initiated within them.

2.5 Academic Resources and Information Source

In this section, some of the relating literature published about the Risk Management will be reviewed for guidance. After reviewing several literatures, it is found that there are many approaches to try to manage the risk in many countries. Referring to (Wyk et al., 2008) the project risk management in South Africa is a good case to use a guideline for this thesis because it uses risk management to solve a problem of power interruption using models and none “state of the art” techniques similar to the project that is going to be implemented in the southern Thailand. This journal follows the similar step of identifying, analysis, mitigation, monitoring and reporting, back to the company.

The UAE construction was also investigated (El-Sayegh, 2008), the literature mainly focused on identifying the risks from the UAE (United Arab Emirates) based on questionnaires and surveys distributed to the construction experts. This is a great help because it reflexes another expert point of view of the construction industries. The data is further developed by base lining the data of risk in construction from many international countries such as USA, Hong Kong, China and Kuwait. This gives a good wide view of the risks and how to allocate them, giving the big picture of the thesis.

The success factor or criteria of the mass house building projects (MHBPs) in developing countries can be very useful to the focusing objectives in operations of the prefabrication house construction. (Ahadzie et al., 2008) This journal has researched on the success criteria of the mass house building projects in Ghana, where surveys are given to the property developers to determine their success factor. The results of the survey after some statistical analysis shows that the developers have some common success factors that can be minimized to a few criteria such as environmental impact, customers satisfaction, cost and quality and time. These success factors can be given to the construction team for considering the risks and objectives of the total projects.

The decision of the delegation of risks is also important as it is stressed (Lam et al., 2007) in the model created in this literature piece. Risk is quantified into equations and mathematical model, which is then form into a decision model. The model transforms the linguistic principles and experiential expert knowledge into a more usable and systematic quantitative-based analysis. It is a good example of another quantitative risk management, and can be applied into many fields. It also summarized on the risk delegation of the owner and the construction contractor.

Projects are not only about operations; they involve a lot of strategic management. (Naaranoja et al., 2007) Same to business, before starting something, it is important to know where you are going. Vision, mission and strategy are a very good tool that is rarely applied to the project. Project Risk Management can be supported with these tools to help in the decision making process. It is encourage that these simple tools are applied to gain most from the project including risks management.

The scheduling of the prefabricated construction is thoroughly explained (Phatsaphan Charnwasununth, 2006) As it is stated in the thesis that the prefabrication construction is one of the popular techniques that have been applied to housing projects due to the savings of time, costs and quality. However there are also many problems to the need of continuous flow of material and an advanced workload distribution to try to arrange the best schedule. The result is that there is five vital components found that will need to be re-arranged and monitor in the scheduling of construction. They are Materials and tools, prefabricated members installation sequence, activity and sub-activity schedule, troubleshooting and integration schedule. The thesis also explained in both verbally and graphically to give better understanding to the operator. Moreover, it explained on how the machine in sub-activity should be in a scheduled hourly scale and starting time in order to provide more efficiency in machine management as well.

Risks management for SMEs is very much different in both the scale and the approach comparing with the corporate risk management. (Leopoulos et al., 2006) The tools for qualitative risk management for SMEs are explained in this journal. The aim of this specific journal is to show the basic risk management tools a long with their key features. There are as much as sixteen software tools ranked in varieties of aspects. At the end of the journal, some tools are also used to see the result of enhancement of project related operations to reduce risks and costs.

Risk Management is separated into stages, (Raz et al., 2001) and each stage can be approached systematically using tools and techniques. The tools and techniques will help to analyze the stages to gain the highest result. The question is which tool is good for what. In this literature, the tools and techniques are listed and rated according to the experts and it concludes to show what tool can be applied to gain which area of result, usually comparing between project management and risk management field result. It is a very good way for tool and techniques selection with the help of the expert's opinion.

By quantifying the risk sources and consequences, (Carr et al., 2001) you can gain more efficiency on decision-making and success. This journal approached risk management using work breakdown structure, which is a great way to systematically identify the risks. Then the relationship of the risk factors, risks and their consequences are presented on cause and effect diagram. The model of fuzzy quantifying method is proven to enhance the level of risk management and gain better result in the construction industry.

"Systematic risk management is expecting the unexpected", (Mills, 2001) this journal is explaining the systematic ways and approach to risk management from starting at identifying risks to solving and managing the uncontrolled aspects in the construction project. It also discussed the allocation of risks and suggests that risk needs to be identified and managed early in the procurement process. There is also a case study attached with it to gain more clarity. This paper is a very good guideline to this thesis showing almost all the necessary tools and thinking methods.

Prefabricated house have their special characteristics in cost, value and quality. (Liang et al., 2001) This journal is showing the assessment in the characteristics of the prefabricated houses from different stakeholders. The interview focus group consists of developers, contractors, social housing clients, planners, architects, lenders, valuers and housing occupant. This is a great way to know the insight of what weak point the prefabricated house have to different point of view of customers. There are analysis of financial, production and also the costs benefits to types of prefabricated house. It can be a good guideline to understand and evaluate the product to fit the requirement of the customers and construction teams.

The very way that risk identification process is conducted has a direct influence to the result to overall project management. (Chapman, 2001) The realization of the risks that will be done in the identification of the risks by the project team can initiate the awareness and realization of the problem at hand affecting the total outcome of the project management. This journal has examined steps involving the conducting the identification and assessment process and how they may influence the effectiveness of risk analysis. By focusing these issues, the understanding that risk management will improve the project performance may be enhanced.

Scheduling is considered like the master plan of a project (Mulholland et al., 1999) risk management in construction schedule is also a very big topic to be analyzed. The concept is that most projects are bound to a time constrain, which is in one of the statement of problems in this thesis. With limited time constrain and the dynamic environment of the construction project, schedule risk management has to be very intensely investigated. The quantifying method of scheduling will be based on rated risks and estimations of values. This Journal also includes the past experienced of scheduling problems, which can be used for future benefits.

Risk Management as it is abbreviated in this thesis proposal, is a complicated and dynamic process. (Akintoye et al., 1997) This literature expresses the overall picture of the risk analysis and management in construction. At the end of the chain, risk management is to minimize losses and gain more profitability, but it is not possible to perfectly dodge every risk occurred. It is also summarized that the risk management is mainly assumed to be only on intuition, judgment and experience of the manager rather than a technical approach due to lack of knowledge.

There are numeral limitations to the conventional risk management process. (Jirapong Pipattanapiwong, 2004) The conventional RMPs (Risk Management Processes), the risks will be structured and prioritized by the impact and the probability of the risks. However it is not logical for the inexperienced, insufficient, inaccurate, and inapplicable data for it. Therefore, it is the matter of forecasting and relying on the uncertainty. Therefore, there are methods trying to minimize and gaining more accurate data and experienced to overcome these problems.

2.6 Conclusion

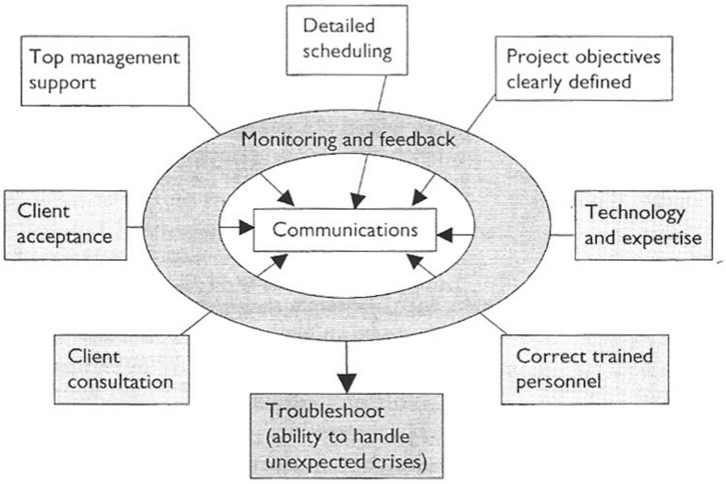


Figure 2-13. Success factors of a project (Fewings, 2005)

The factors to success of a project are countless. It requires good management technique, good personnel, technologies, determination and many more such as clear objective as shown in figure 2-13. No matter how good a project team tries to summon these factors, it is never enough to run a project without risk. Risk Management is no matter what crucial to every project.

Risk management is a procedure, basically to try to look where things might go wrong and as it is explained, there are a few steps to it. Starting with identifying the objective of all the Stakeholders, in order to gain the maximum and getting every staff in the same direction. Risk management starts with risk identification, where risks are being identified from various techniques. Then it is being ranked and analyzed. After analyzing the sensitivity and the severity of the risks, it will be solved and produce a system for the risk information flow within the project team. These processes are universal for every risk management done everywhere. The only different is the method of approach and the tools and techniques used to do them.

Another important issue is the risk culture and how the project team reacts with risks. It is called risk attitude. Some team tackle risk head on without looking out for consequences. Some team takes too much time to analyze the risk but lack in the implementation stage. Therefore, choosing the best tool and techniques for the right risk attitude culture within the project team is also a challenge.

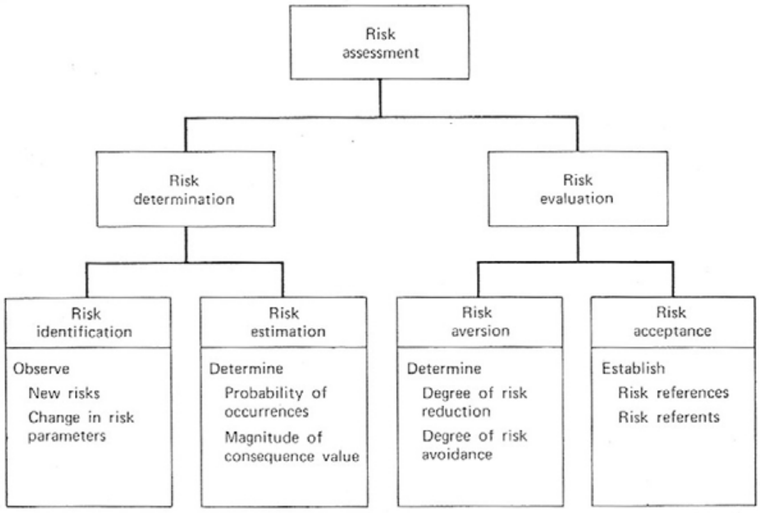


Figure 2-14. The risk management hierarchy diagram. (Fewings, 2005)

As it is showing in figure 2-14, it is the total summary of the risk management process. Risk management is a continuing process; it will always be there until the project or business ends. It is still important to realize that developing risk management culture is something that could not be built over night. It takes time and consistency, not to mention courage to think outside the old traditional and conventional ways.

To sum up the risk management, it is always to remember that risk management is not only designed for project managers or risk management teams but it is for every single stakeholder in the project. Without the participation of all of the stakeholders from the CEO to labor force, the risk management will not be as effective. It requires a lot of effort and participation because risk is everywhere even in the smallest steps. By using the tools and techniques of risk management, many of them can be managed using the different types of risk response. The main goal that an organization can achieve about risk management is the risk managing culture or pro-risk culture, which will benefit an organization in the long term.

Using many of the aspects covered in the literature review chapter, the next chapter will be about the methodology of the risk management of prefabricated house. Many of the company information is given and put to use in the future.

CHAPTER III

PREFABRICATED CLASSICAL THAI HOUSE CONSTRUCTION PROJECT RISK MANAGEMENT INFORMATION AND METHODOLOGY

Chapter three will be the detailed methodology of the thesis, showing the information necessary now and the process that will be done. These are the information that will be included in this chapter.

3.1. ABC Company and Project Information.

3.2. ABC Project Planning Process

3.3. Project Strategies

3.4. Current Risk Management System

3.5. Risk Management Process

3.6. Conclusion

The information given is the information needed to understand the risk management process and to enable processing the risk and its RPN rating. The risk management in practice will be described at the end of the chapter.

3.1 ABC Company and Project Information

ABC Company started the company with casting and machinery operations and has broadened the company operations to prefabrication house. There are some past prefabrication housing projects that were successful but with many errors and many problems in such as PP Island. With the project in Phang-nga in the present time, it is very suitable for a risk management program to be applied and execute for future benefits. Prefabrication house are houses that will be assembled at site. The design of the house is very flexible and has many advantages compared to the conventional construction. The most important and dangerous process will be scheduling. Prefabrication has a reputation of fast speed and very complicated construction process, but it is not well planned, then the project can be a burden to the project manager and the construction team.

There are many styles of houses available from the company, and each house requires different specifications to build and different materials for it. In this Phang-nga project, the house that will be built (figure 3-1) will be built with Shera (Fiber Cement) in the size of approximately 36 m^2 with only small amount of teak wood and hard wood involved. This brings up the advantage of ordering in economics of scale. The factory for prefabricating the Shera wood is located in Bangkok, where the in-house architect will give the information and specifications to the production department. The floor plan of this Shera house will be given in Appendix including the view from different angle.

In the Phang-nga project, the contract that is signed with the customer stated that at the end of January 2010, if the products were not delivered, there would be a 100,000 Baht penalty fee per day of delay. Any defects (leaking/breaking/paint problem) that are spotted within the house, ABC will have to take responsible to fix it, and will have to absorb all costs into ABC penalty fee. Within 45 days after the completion date, everything has to be put in order and ready for usage.

Figure 3-1. Example of Shera house.

The organization chart of ABC Company can be summarized in to the following diagram:

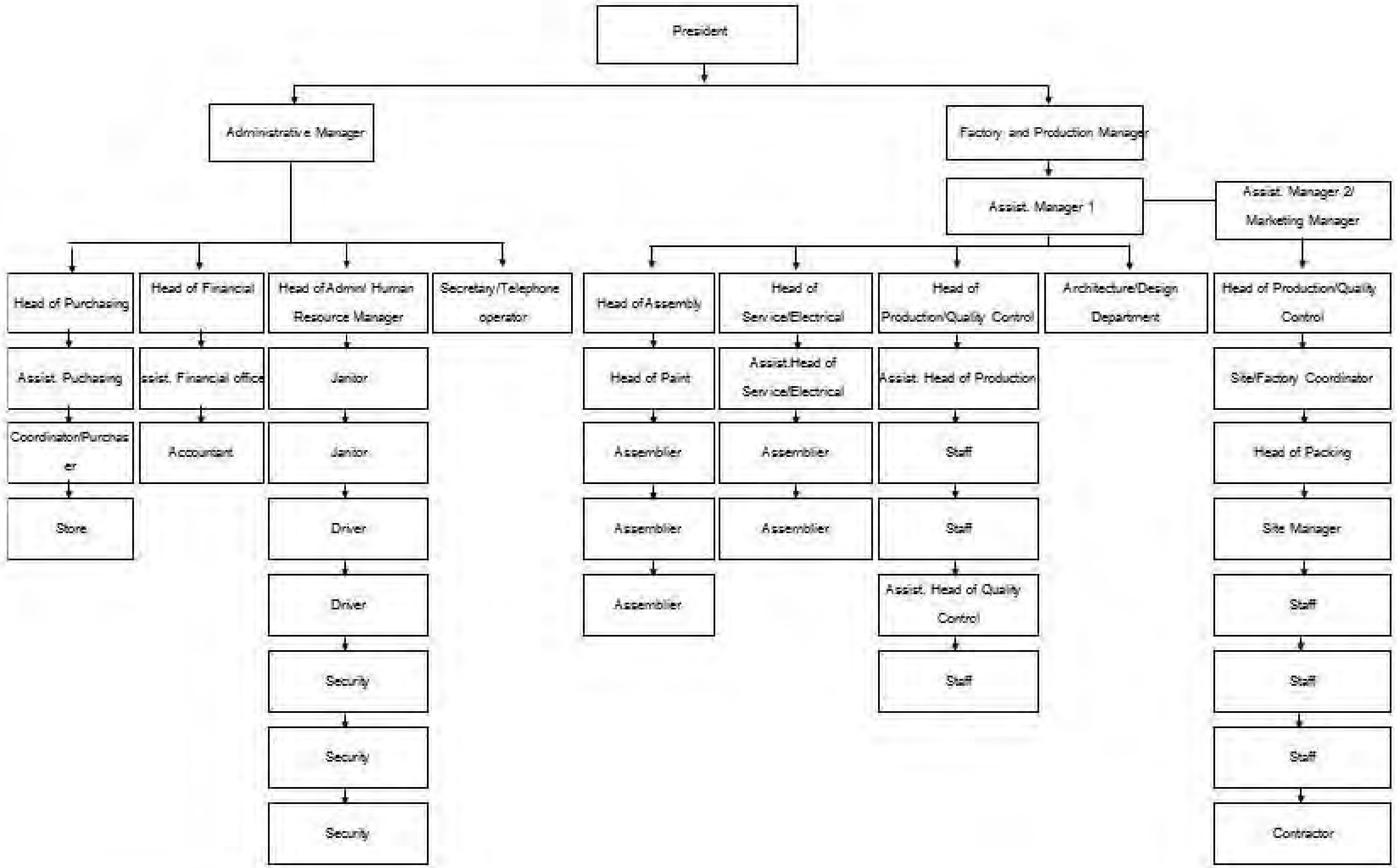


Figure 3-2. ABC Company Organization

The organization chart of ABC Company (figure 3-2) is a Functional type. It is separated into 9 departments where each of them has their own work specification. There are 2 main managers, which are the administrative manager and the factory and production manager. These two managers will coordinate the work between factory and administration work such as documents and contracts. Because construction business depends a lot on the location and site manager, therefore, they have initiated another Coordinating manager at Bangkok base to operate and coordinate all the information between each other.

Because a construction project has countless details and information needed. It is easier to summarize all the information needed into a list. Using these lists, the risk management program can operate easier and with a clearer picture of the project. This is a summary of the information about the project:

- Project Location: Phang-nga (Southern of Thailand
- Production Factory Location: Bangkok, Thailand
- Driving Distance: 782 Kilometers (From Bangkok)
- Driving time: 11-12 Hours (Truck) or 9-9.30 Hours (Sedan Car)
- Total Prefabricated Classical Thai House: 35 Units
- Total construction phase: 3 phase, separate into 11,12,12 house per phase
- Total Labor at Site: Approximately 25-30 person with rotation system.
- Total Labor at Production Unit (Bangkok): 10 People + Fully Equipped Machines
- Total Land: Approximately 15 Rai (1 Rai = 1,600 m^2)
- Total Construction Time: Feb 2009 to End of Jan 2010 = approximately 1 year
- Penalty Fee: 100,000 Baht per one delay day + Responsibility of any cost from Defects and Problems within 45 days.
- Construction Team: ABC Company Limited
- Infrastructure Team: Sub-contractor of ABC (Water, Electric and waste water treatment.

Transportation Information

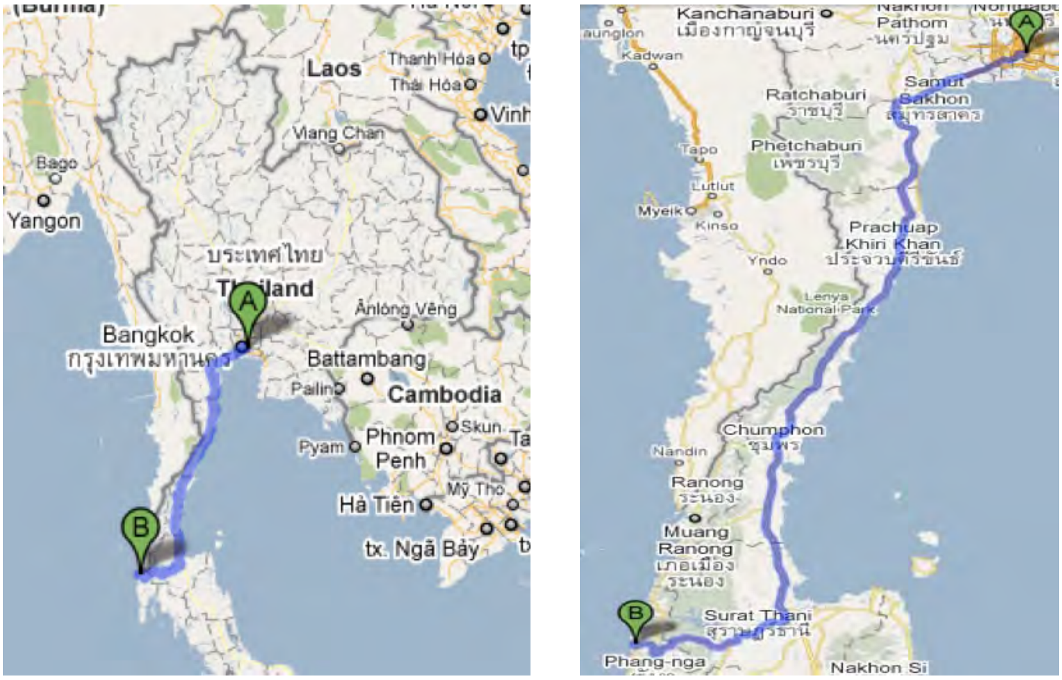


Figure 3-3. Transportation map from Bangkok to Construction Site. (Google Earth)

For a prefabrication construction, the delivery of the parts will be done repeatedly according to the schedule. In the figure 3-3, the map of Phang-nga (marked B) from Bangkok (marked A) is shown. The route that is being used is the best route, which is a bypass avoiding to go into cities along the way. The cities that will have to be driven through are Samun Sakorn, Prachuap Khiri Khan, Chumporn, Surat Thani and then Phang-nga. The total driving distance is approximately 800 Km. The average driving time will be approximately 12 hours by the delivery truck and 8-9 hours using an average Sedan. The time will be slightly different depending on the time of the week and in national holidays.

The best route that is mainly being used is route 31 (51.4 km.), route 35 (81.7 km.), route 4 (378.1 km.) and route 401 (300.4 km.). This is the best route that the transportation will choose to use. The problems of transportation usually will be accidents, over speeding (detected by police), bad traffic, 2-lane road (difficult to overtake), lost directions, passing mountain area (curves and narrow roads) and exploding tires. Accidents are not as common as in-city driving but have a fair chance of happening.

3.2 ABC Project Planning Process

Each company has their own project planning process depending on the objective and the product that shall be produced. In the construction business sector, the project planning will be similar in many companies. In the construction contractor business, the first start of the project will be identifying the objective of the client. The objective of the client is the vision and style direction that the construction team and the architect will have to produce. Therefore, it is the single most important element will be the client information because it will be the consequence of everything else from the project management characteristics to the project team.

After investigating and interviewing the ABC project process, it can be summarize into the following figure 3-4. The diagram presents the total picture of the prefabricated construction process that is being applied and followed in this project. The process is separated into six parts. Each part will have their own objectives and their own tasks. The final product will be the completed projects of prefabricated houses. Following the project process, each step will be broken down into smaller steps and more informative note.

These steps are the process but not regulations to follow by the company. Usually in Thai culture, the process could be skipped and sometimes ignored because of many factors. This process is what the project procedure will be but it is does not define that the company will follow through every single step. Sometimes, the process is mixed up due to technical problems or easier management.

(Figure 3-4 available Next Page)

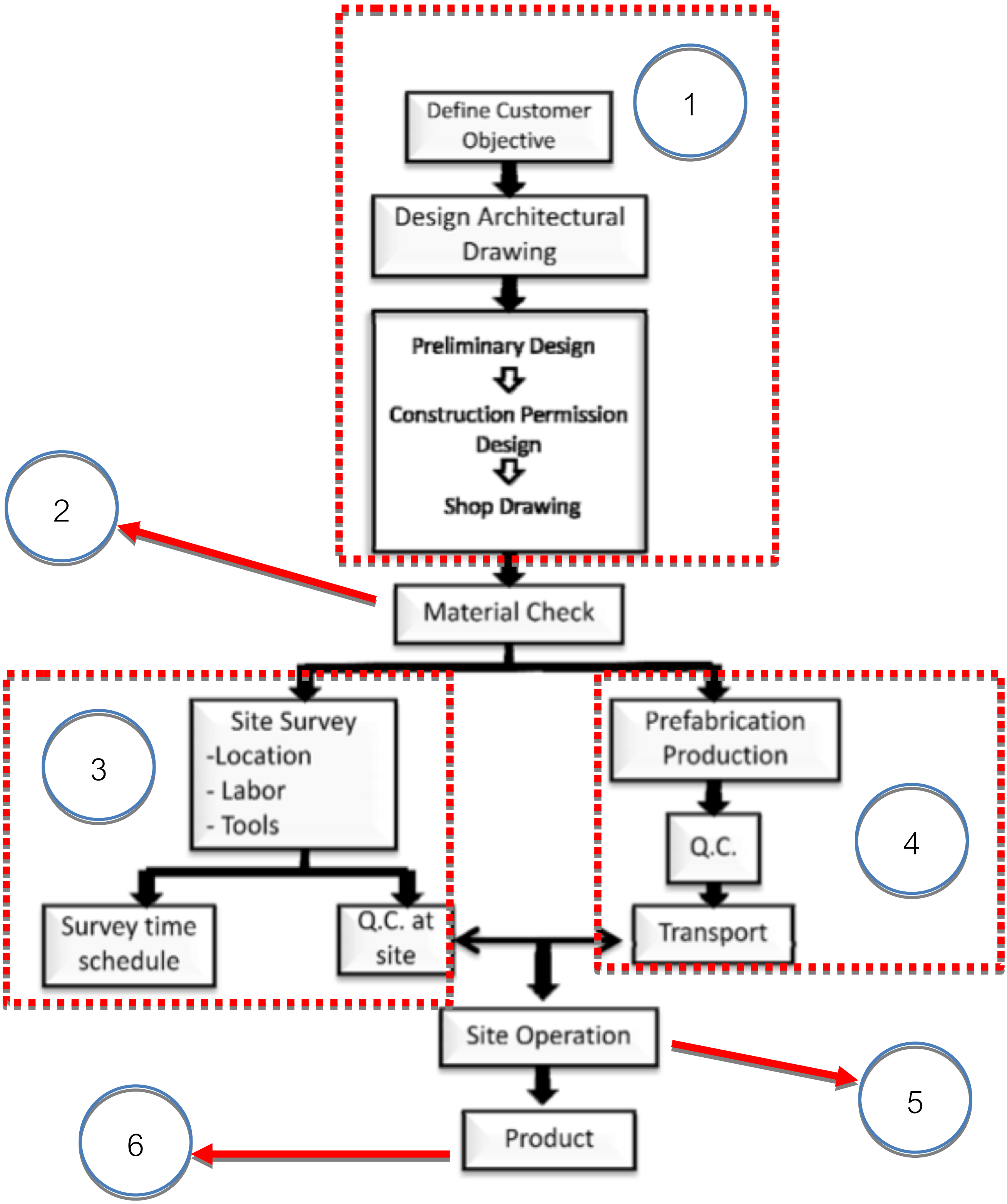


Figure 3-4. ABC Company Prefabrication Construction Project Process.

The process of prefabricated classical Thai house construction (figure 3-4) can be summarizing into the following steps:

1. Define customer objective and Design drawing.
    a. Gathering ideas and information from customer by architects.
    b. Produce a preliminary architectural design to present to the customer and sign contracts.
    c. Produce a construction-permit approval design.
    d. Gather shop drawing and send information to project manager.
2. Material checking and scheduling
    a. Process of breaking down the material list from the architectural designs of the prefabricated houses.
    b. Gather information concerning the material broken down from the design e.g. availability, price, inventory etc.
    c. Produce a material resource plan to order (purchase request) and produce the prefabricated parts and ordered materials.
3. Construction site Preparation.
    a. Construction team surveys the site.
    b. Gather information on location, available resources such as labor and tools.
    c. Set up labor camp and on-site office for synchronization between factory and site.
    d. Summarize total resource and produce a project master plan based material schedule, location information, labors and their requirements, budgets, and other resources in both factory and construction site.
    e. Set up Quality control team on construction site for delivery check.
4. Factory Operations.
    a. Start prefabrication production from the material schedule planning and design requirements.
    b. Quality control team at factory control standards of parts after production
    c. Transport to site via most suitable transportation

5. Construction site operation.
    a. Check quality of prefabricated parts after they arrive at construction camp.
    b. Keep record of the delivered items and stock at site.
    c. Assemble the parts and build the Thai houses.
    d. Supervised by project site manager, supervisors and foreman at site.
6. Finishing Product.
    a. Finishing process of product
    b. Examine for defect in houses
    c. Hand over the products to the clients
    d. End of Project with summary of performance.

The process of the projects are now broken down into six steps and then divided into sub-tasks within the steps. Each steps has their reasons and their specific details. These steps will be broken down as follow:

1. Define customer objectives and Design Drawings is the first step, the main objective is to generate a final master plan of the architectural design based on the idea of the client. The architect will have to gather information from the client, carefully constructing the vision and the objective of the project to generate a house that will fulfill the client's requirement. Once the ideas are gathered, the architect will then generate the architectural drawing of the house, showing the building in many views and showing the draft usage of the building. The customer shall then select the most acceptable design with or without minor changes. The design will then be developed into the suitable design that will be used for construction permit request, enabling the design to be legally built. Once the permit is granted, all the information will be forwarded to the project manager including the shop drawings of past projects (prefabrication houses has the same structural configurations). The floor plans of the house will be attached in Appendix. The steps of architectural design process is:

- Design Specification: Problem recognition and establishing requirements
- Conceptual Design: Finding possible concept that can perform the requirements and functions.
- Embodiment Design: Produce design layout, drafts and layout of design.

- Detail Design: Establish detail engineering drawing (shop drawing)

2. Material checking and scheduling is one of the most important stages for a prefabrication construction project planning because everything is based on this stage. The process is the breaking down of the design that is passed on from the architect into purchase requests and production plan. After the parts are broken down to material lists, now the purchaser can check on the factors involving the material such as prices from different vendors or availability at ordering time. When all the information needed is required, the material resource planning will be drafted and the production plan will be computed. The production plan will be the master plan of production to prefabricated or prepare all the materials at the factory to be sent to the construction site. The plan must synchronize the incoming of materials, the labor force at the time, and the machines in the factory. These productions are all based on the information received from the design specifications and material breakdown.

The materials that will mainly be used in this project are:

- Hard wood (Structuring and framing)
- Shera wood (Wood substitution and fiber cement for walls, floors and roof
- Teak wood (fine work such as windows, doors or traditional Thai art walls)

3. Preparation of the construction site is the gathering information concerning the project from the site and close by areas. The construction team will have to survey to site to first gain information about the construction, doing engineering tests that will affect the construction process and resources such as soil testing and water ways or electricity lines etc. Then the team can settle down on the site to find more information about the nearby area such as construction material store (comparing prices and emergency purchasing), finding labor source at the site for workforce security and find/acquire necessary tools needed. It is normal for a construction project in Thailand to find available local labor rather than moving the whole team to the construction site, the only team that is going to station at the site is the foreman team and the project site manager. The tools that are necessary at the site are hammer, nails, electric drills, handsaw and Arm saw, etc. By stationing at the site, the team can communicate effectively with the factory and the project manager about all the information at the site, which is a very important task. With all the information

gathered from the site and the information about the material at base office. The master schedule plan can be made. The plan will be distributed throughout the project team. The site manager will set up quality control team to control the standard of the delivered parts from the factory at site.

4. The factory operations will include receiving the materials, production of house parts, quality control, packing and transporting. The materials that were ordered are already in the state that can be used immediately. Wood is already processed to gain strength and should be in a quality that can be put to use. If the materials don't pass the quality check, the factory will send them back to the suppliers. The production of parts will follow the production plan produced from step 2 with the information from step 3. The production of the parts will follow the specification of the design breakdown and then it will be checked at QC station. If the product is not a defect, then it will be sent to packing. Finish parts will be transported from the factory to the site using a logistic company. All the parts will be labeled with codes for fast assembly process at site.

5. Construction site operations starts when the materials arrived at the site where it will first have to be quality checked. All items will be recorded and then stored in a suitable place. The site manager will report the base office on the delivered material and then it will be put to use in the site. While construction, the site will have to be supervised by a foreman and a supervisor. The labors that are hired might or might not be skilled in construction depending on the available resource in step 3. The foreman team will have to control the process of assembling the parts. The construction will be carried out until the houses are completed.

6. At the end in the Finishing Product, there will be some finishing work to be done and then inspection of defects within the house such as leaking, or painting problem. As it is stated in the contract, if there are delays in the cause of what so ever, the contractor (ABC) will have to pay penalty of 100,000 (One hundred thousand) Thai Baht per one day of delay. If there is any defect or problems with the houses, ABC will have to take total responsibility. After all of those problems are fixed, the houses will be handed over to the client ending with a performance review of the total project.

The processes given are the detailed step that ABC will follow. These processed will be discussed within the risk management team to generate risk from them as well as using their expertise and experience. In the risk management process, some risk will effect a certain step, where using this procedure (figure 3-4), the risk can be traced back to the origin of it and solve it at the starting point.

3.3 Project Strategies

3.3.1 Stakeholder Responsibilities

For the risk management process, it is important to state a clear responsibility positioning within each stakeholders in the project. This responsibility of each stakeholder will be different in every project. The main factor that decides the responsibilities of each stakeholder is the budget and working culture. So, stating the roles and responsibilities of each stakeholder will help the risk management program to understand the source of risk and the optimum solution.

Table 3-1. Stakeholder Responsibility in different stages in the project.

Stakeholders	Project Stages / Responsibilities		
	Design Process	**Manufacture Process**	**Construction Process**
Architect	Design Proposal + Consultation	-	Monitor + Consultation
Owner	Vision +Objective + Requirement +Decision	-	Monitor + Requirement + Decision
ABC Manufacturing Team	Breakdown Material + Purchasing + Inventory + Quality Check	Production + Quality Check	Packing + Delivery
ABC Construction Team	-	Communication of site information + Resource finding	Construction (assembly) +On site management + Supervise labor + Quality Check
Infrastructure sub-Contractor	Contract Signing	Site survey + Resource preparation	Construction (Infrastructure)

The stakeholders in this project are slightly different from the other projects. It is because prefabrication houses need production unit and it relies very much on that department, which is what other construction project does not have. The stakeholders include (table 3-1) Architect, Owner, ABC Manufacturing Team, ABC Construction Team, and Infrastructure contractor.

The Architect will be in charge with the designing process starting with the preliminary design to the final design that will be used in actual construction. The architect will be consulting the customer (Owner) through the project about the details and the site surveying information. A good architect would first survey the site for information like weather, waterway, wind direction or the sun light direction in different time of the day.

The Owner will be the decision maker on the design and architectural work. The most important task of the owner is the project the vision of the project and the usage to the houses to the architect. The customer, as a SME business owner will be monitoring and coordinating the project with all the partners unlike a corporate business owner's nature would do.

The ABC manufacturing team (after receiving the material list and final designs) will be in charge of producing the parts (walls) and purchasing the parts according to the specification. The manufacturing team will remain inactive at the designing stage due to lack of working information. The most important task of the team is to coordinate the information between the factory and the construction site. After the quality check, the team can pack the parts for transportation protection and deliver to the site.

The Construction team most important task is the site survey and coordinating this information to the architect and the manufacturing team. After that, the team's only task is to assemble the houses and to control the quality of the house.

The Contractor team will be responsible of all the infrastructure of the site such as water piping, electrical system and wastewater treatment. The contract will logically be signed after the design is approved and the Project Manager already breaks down the project. The contractor team will have to synchronize with the construction team because they rely on each other to operate most efficiently.

3.3.2 Construction Operation Schedule

The construction operation plan is also very important. Prefabrication houses are fast constructing product type; therefore after understanding the method and assembly process, the construction team can start to replicate such act very fast. The plan of operation at site will determine which house to build first and in what order will the houses be done, the distribution of the work force in the construction site and sequence of what part will be done first by which team. The construction plan will also link with the production plan. The production plan of the prefabricated parts must lead the construction plan and transport to the site in time for assembly process.

Table 3-2. Construction Operation Schedule.

Cluster	**Months**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1												
2												
3												

The construction operation plan (Table 3-2) is separated into 3 parts. Each part will consist of 11-12 houses. Therefore, 3 cluster with 11,12,12 houses will be in total of 35 units. The RED zones are the construction and assembly period.

The method of construction of the will be a rotation system. This means the process of the construction will be in phases. The rotation system means the rotation of labor for lesser cost on manpower. The rotation system will rotate the labor into groups, where each group will be responsible for a single phase such as Cement Foundation phase. In this phase, a group of labor will be separated out to construct the cement foundation house after house until all of them are finish, while the other labor group starts the structuring of the house. This working system, where labor handle each task separately will make them gain more experience and able to finish the task faster with time. Only with this system, the construction will be able to finish within the time limit.

The process of building a prefabrication house will be stated in steps, where each steps will be assigned to a group of labor team to manage it. While the labors are constructing and assembling the house, the foreman and project site manager will be checking and controlling the total process for lesser errors and more efficient workers.

Table 3-3. Rotation System of phases in different months.

Phase	Months			
	1	2	3	4
Cement Foundation				
Wooden Structure and Roof				
Architectural Details				

There are 3 phases to build one house (as shown in table 3-3). The first phase is the cement foundation phase. The second phase is to construct the wooden structure of the house using hard wood and construct the roof to enable internal working. The last phase is the architectural work such as bamboo Parquet floors, door and windows, paintings and internal infrastructures such as light fixtures.

As the table 3-3 shows, the work will be overlapping between months representing that each phase can start right after one phase of one house finishes. When house 1 finishes the foundation, the structuring team can instantly start on that house. The approximate time of the cement foundation will be around 1.5 months. The steps are to dig holes setting iron core of poles and then constructing cement poles to elevate the house. The wooden structure will take the longest time within the 3 phases. When a house foundation finishes, the structure team will start right away. First they would measurement and angulations, structure the main beams, add on details of house, construct roof structure, lay Shera plates roof and install in walls. In the final step (architectural work) all the walls and roof will already be completed. The details that must be done are paintings, internal infrastructure work (restroom piping and electrical installations). After the 3rd phase is finished, the house is completed and can be handover to further development such as furnishing (excluded from project time frame). The process is shown in figure 3-5.

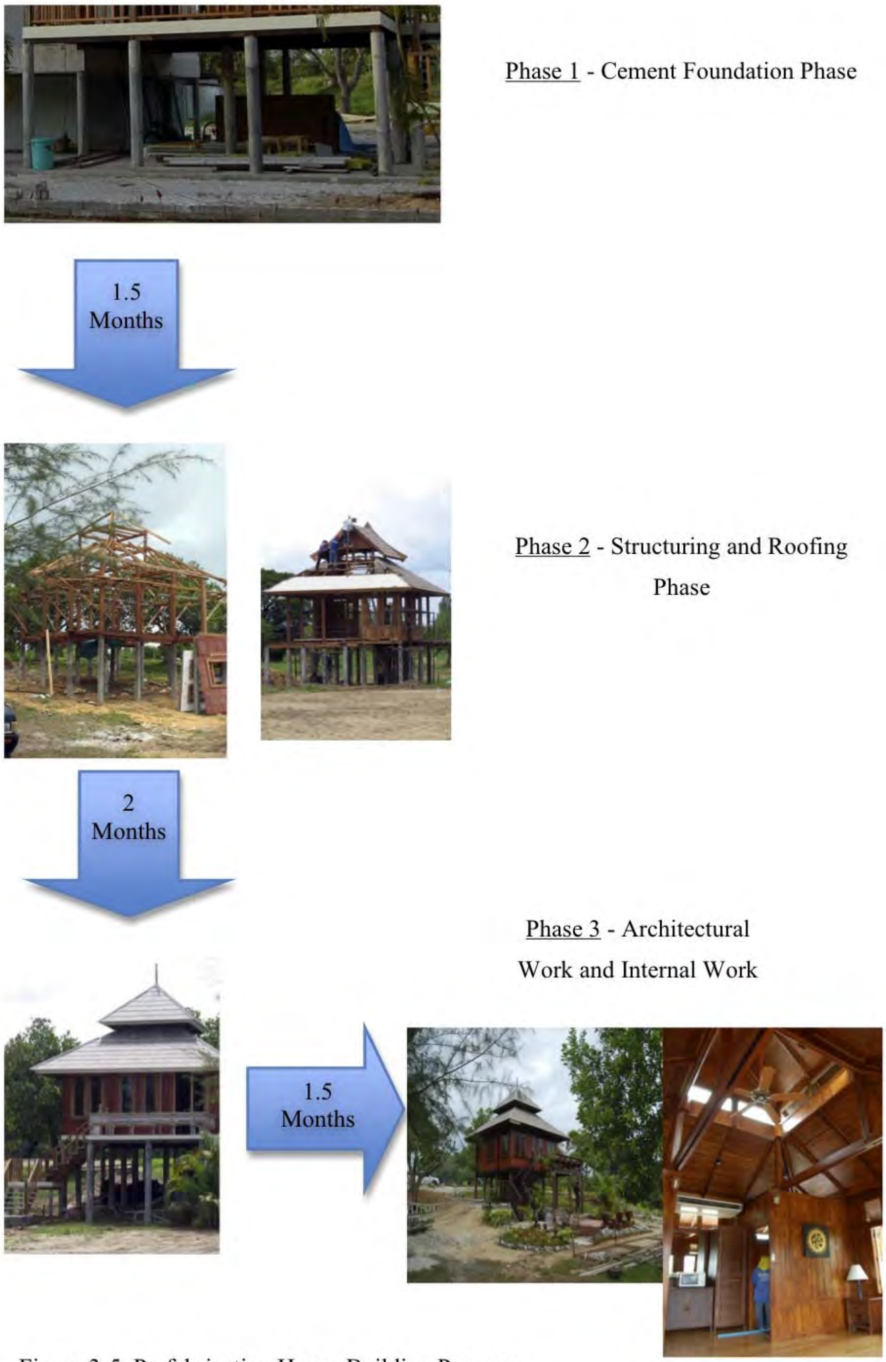


Figure 3-5. Prefabrication House Building Process.

3.3.3 Worker Information

A vital resource to the construction team is the worker/labor; the labor information is the information of the combination of employees and their skills. In order to be able to forecast risks, this piece of information cannot be underestimated.

There are 2 teams of workforce, the first is the construction team based at construction site and the second team is the manufacturing team based in Bangkok.

Table 3-4. Construction workforce information.

Worker Team	**Number of teams**	**Skills**			**Total (Person)**
		Labor	**Skill Labor**	**Expertise worker**	
Construction Team	1	15-20	6-11	4	25-35

The construction team consists of 3 sub-groups (table 3-4) divided by their experience and skills. The total number of employees will approximately be 30 people (this factor will be linked to the delaying of construction project, the longer the delay, the more labor hired) the labor team (15 persons) are the people that is not yet skilled but has done construction work before. The skilled labors are the labor that can apply the knowledge and experience to the work such as woodworking or cement work. The expertise workers are the foreman and mid-level management (Project Site Manager). They will be controlling and leading the construction team, teaching them in technical subjects related to the prefabricated housing construction.

Table 3-5. Production workforce information.

Worker Team	**Number of teams**	**Skills**					**Total**
		Unskilled Labor	**Carpenter**	**Quality Control**	**Design**	**Stock**	
Production Team	1	4	3	1	1	1	10

There are only 10 people at the factory manufacturing the parts of the houses (table 3-5). This team will be supplying the parts to the construction site, theoretically on time and with the correct part. There is only 1 team and it contains 4 unskilled labors that does not have any training on specific skills but are able to help around when following the orders of the carpenters. The carpenters are the main worker in the factory; they take order from the design (Architect) department and the project manager. Quality control unit is the person controlling the standard of the production team and the product (house parts). The design department (Architect) will be monitoring both the construction team and the production team, while coordinating with the project manager. Finally, the stock (Inventory) unit is the unit controlling the flow of material, purchasing and sending the material out to the production team to edit to specification. The project manager and the production manager will monitor all of the information within the production unit.

In a prefabrication production factory, not only will adequate work force be insufficient but also the equipments are very crucial. Fortunately, ABC Company is already a machine manufacturer; therefore their machines are very accurate and are in-house products. Therefore, they have sufficient machinery.

The machineries available at ABC Company are:

Table 3-6. The machineries in ABC production floor

Machines	**Quantity (Unit)**
Cutters	3
Drills	2
Fine Cutting Tools	2
Automatic Planer	2
Polisher	3
Total	**12**

These lists of machines are designed for woodwork only (table 3-6). The machines can be put to use for the Thai wooden walls, the hardwood structure, and the inner fine architect works such as window linings. The machine that is most frequently used is the cutter machine (Arm-Saw).

3.3.4 Production Process

The policy of ABC Company production process (figure 3-6) since the company is still unconfident about contracting a larger number of housing project, they have ruled out that if the parts can be bought in local market, the purchaser would rather choose to buy rather than to produce due to time saving. (Taking this project as a test run for the future with less profit) So the production floor will try to keep it at minimal cutting of wood. The part that will require a lot of editing of materials are the Thai "Prakon" walls, which are not flat walls but requires patterns and requires time to produce it. The most used machine will be the Arm saw for cutting the materials in shape. The fine architectural machine will be used only for small details parts. The hardwood and the Shera component will be ordered to their exact shape and size for time saving and easy management.

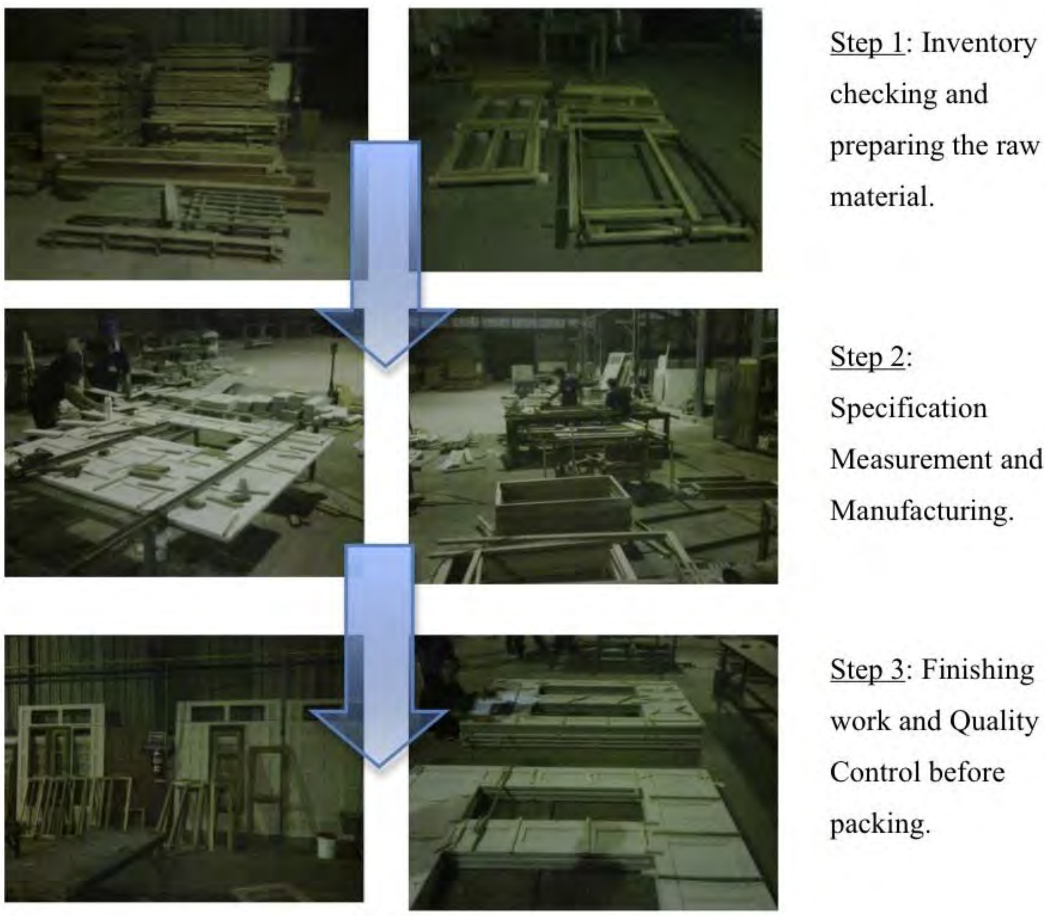


Figure 3-6. Production process at factory.

3.3.5 Single House Schedule

Table 3-7. Schedule Summary for one prefabrication house construction

Scheduling Process	Number of Days	Number of Process
Construction Part (ABC)	**19**	**3**
Foundation Construction	12	5
Floor Construction	3	4
Roof Construction	7	14
Architectural Part (ABC)	**29**	**6**
Floor Part	9	6
Wall Part	14	2
Door/Window	9	5
Attic Ceiling Part	8	6
Sanitary Part	2	1
Painting Part	3	4
Electrical Part (sub-contract)	**3**	**3**
Sanitary System Part (sub-contract)	**3**	**3**
TOTAL (ABC company only)	**48**	**9**

The schedule summary is the list of task that will be done for a single house separated into parts (table 3-7). The presenting figures are the number of days and the number of processes that needed to be done in the part. It must be stated that the number of days cannot be accumulated because many tasks are performed in overlapping or at the same time. Therefore, the number of days is the number of days for the task but not the number of days in sequential. The actual schedule of building one single house is given at Appendix. However, the numbers of days in the actual construction will not be in table 3-7 because it is a rotation working system, so houses will be built process by process in bulk.

3.4 Current risk management system

The current risk management system in ABC construction system is very simple. There are no systematic approaches to it and the risk management itself is also a risk for the Company. The current risk management system of Company ABC is separated into 2 processes:

1. Quality Control

Company ABC is using the quality control to be a risk inspector. The quality control agent is located in two positions in the project process. The first quality control is at the factory controlling the materials and the products that are flowing in and out of the factory. The second quality control check is at the site controlling the quality of the parts and the quality of the construction team.

This system itself is considered a risk because quality control department does not use any forms or document to control the risk but rather personal judgments and experiences as the standard. To many customers, this process is not acceptable and many of the have hired a consultant team to cross check the quality of the product.

2. Project Monitoring and Control

The monitoring and control of the project is probably the easiest way of managing the risk that could happen. However, it is not so effective. The monitoring and controlling of the total project will be done mainly by 3 persons, which are the owner, the project manager and the architect. These 3 key people will be controlling the details of the construction in all aspect.

This technique of controlling risk is the simplest form of risk management, which can control the risk, can have a high detection rate. This means the risk can be seen or thought of easily by generally monitoring the project. The risk that is difficult to detect would likely not to be managed with this technique.

Another benefit of this technique is the risk response of it. With the monitoring and controlling of the project, if there is any problem (impact from risk) then the three coordinators can immediately response to them and bringing the project from crisis state back to the normal state. However, these crises might cause too much damage.

3.5 Risk Management Process

The risk management process for this project will be in the style of meetings and discussing. The team members in different departments will be gathered together Location of meeting: Bangkok Office and Factory

The risk management process will usually be at the end of a meeting; it is the only time when all of the participants are gathered together. Before starting anything, the objective of risk management is first explained to all risk management members.

Risk Management Objective: To identify and solve the critical risk that could impact the project Time and Quality of the Product, therefore not experiencing the penalty of delay and suffer from defects responsibilities.

The FMEA that will be used in this process will be the process FMEA because the process FMEA is more suitable for construction project. The Design FMEA is very useful in the early stage of construction (Step 1 in figure 3-4) but due to the structure and design of the prefabrication house is limited and it does not require such analysis. Therefore, the designing of the house is considered as a risk but it is summarized using the Process FMEA.

The core of FMEA, which determines whether this FMEA is effective or not, will be the FMEA evaluating team. FMEA is based on the discussion of the people within the risk management team, relying on their experience and judgment. With an ineffective team, the FMEA can turn into a process that produces inaccurate information and low integrity of information. Another concern point of FMEA is that the expertise must be spread around within all areas that the project will cover especially in a construction project in this. Therefore, the process of choosing the team is the most important process for a FMEA risk analysis.

3.5.1 Risk Management Team Profile

Before getting into the method of procurement of the risk management in practical. The stakeholders that are involved in the risk management program will first be stated. These stakeholders hold some decision making task in many parts of the project in both office Bangkok and at the construction site.

Table 3-8. Risk management team members.

Bangkok Base	**Construction Site base**
Architect	Project Site Manager
Owner	Junior Site Supervisor
ABC project manager	Foreman x2
Engineer	
ABC Production Manager	The author

The risk management team in this project (table 3-8) is carefully selected to cover all the angles that can have an impact in this project. The team consists of 2 groups; the first group is the office-based staffs, which are project manager, production manager, owner, architect and the engineer. The second group is the site-based staffs consist of the project site manager, junior site supervisor, and the two foremen. This team is selected so the risk that is produced and evaluate is most complete and is most realistic. This is the background review of each member:

Architect: The architect in this project graduated first as a Bachelor of Civil Engineering but has begun interests in Architecture and begun to practice architecture. He has been practicing architecture for more than 5 years in many types of project. His main responsibility is to design house and give consultation to the owner. He has direct control to the decision of the owner and the style of the house.

Owner: The owner of this project is involved in some construction projects but is not considered an expert. The owner has worked in many fields and is experienced in management in general. The owner has vision to open a resort on this land and has chosen this prefabricated house to be the house choice. The main responsibilities are to coordinate and help manage the on-site construction, give ideas and function design of the houses and decision maker in many fields.

ABC Project Manager: The project manager of this project has graduated in Mechanical Engineering but has been managing projects for more than 10 years. There are many projects in both production and construction that is managed by this project manager. The project manager is very familiar to the prefabrication houses and woodwork. The responsibility of the project manager will be to schedule the project and control the movement of the project, including problem solving.

Engineer: The engineer of this project has graduated Bachelor degree in Civil Engineering. He had just started consulting ABC Company for a few years but had been working in the field of construction for 4.5 years as foreman and engineering consults. His responsibility is to calculate and control the load of the designed houses from the architect. He has the most insight in the technical subject in the project.

ABC Production Manager: The production manager graduated Bachelor degree in Finance but he worked as a production manager for 8 years in ABC Company. He had some training of risk management and showed some very valuable information in risk management. He is responsible to supervise and plan the production of the house at factory. He has direct control to the staff at factory.

Project Site Manager: The project site manager is an Electrical engineer as a base occupation but he had been working in construction projects for over 10 years and gains a lot of expertise in the field. He is able to supervise to whole crew and manage the day-by-day problems. He is responsible to coordinate the two workplaces and troubleshooter the foremen. He has direct control to all labor and staff at site.

Junior Site Supervisor and Foremen: The Junior site supervisor and the foremen are all very familiar to the construction project from experience. They have not worked together but are participated in this risk management program for on-site information and problems.

3.5.2 Implementation method

The implementation of the risk management will be in the third phase of the project. The risk management process will be carried out within the first and second project time. There will be in total of 6 meetings where each meeting will have different objective set. The meetings for this project are set every two weeks. The starting week of the first risk meeting will be in April 2009. The third phase of construction will be in October 2010 until February 2010. This is the period where the risk can be implemented and to see the improving the result. The schedule of actual implementation is shown in figure 3-7.

3.5.3 Risk Identification Process

The main tool that will be used in this step is brainstorming. To minimize the "Groupthink" effect, where the ideas are not creative and the group is being invaded with one strong-minded person, the nominal group method is applied in this step. The nominal brainstorming method requires that the group will have to generate the ideas individually and then present it to the group first, and then it can be discussed later with a good control of the group leader. So these are the steps of risk identification will be practically carry out follow these steps:

Meeting 1

1.1 Give all participants risk management resources: The risk team is given checklist and risk management program explanation to gain more insight of the risk management process.

1.2 Individual risk generation: The participants were asked to generate a list of risk in their point of view to the project, requesting of collection at the next project meeting. Any private discussions were only allowed to the group leader.

1.3 Generation of FMEA ranking criteria: Discussions with the risk team to generating the RPN criteria for FMEA scoring consist of Severity, Occurrence and Detection based on their experience and past projects information's. Generate the RPN criteria. (RPN criteria is generated before risk identification as a guideline and a scope for the risk identification process)

Meeting 2

2.1 Risk identification presentation: Asking each member to present their ideas out loud in the room without other comments. Take in all notes after presentation.

2.2 Risk identified gathering: Gather all identified risks into account and summarize.

2.3 Identified risk discussion and summary: Discuss each risk to the point of agreement of each member, any additional risk or comments will all be noted. Use tools and techniques to analyze for more ideas within the room.

3.5.4 Risk Assessment Process

To assess the risk, the tool FMEA will be used. FMEA is a good tool to assess the risk using the RPN (Risk Priority Number) and analyzing the scores. At the start of the meeting, a blank table of FMEA and the RPN score criteria will be given to all members. All the risk are listed and all the score (Impact, Frequency and Detection) are left empty to be filled by the members, this is the step of risk assessment:

Meeting 3

3.1 FMEA introduction: Distribute the blank FMEA table to all members with the RPN score key. The risk listed is separated into processes in the project.

3.2 FMEA scoring process: Request all the members to fill the table at their private time according to their experience and their estimations. Collect the Table at the next meeting

Meeting 4

4.1 FMEA score collection and discussion: Collect the scored FMEA table from each member and open chance for discussion of any problems.

4.2 Calculation of RPN: After the FMEA table is filled and all the scored were agreed and discussed, the FMEA table will then be collected for the calculation of RPN.

3.5.5 Risk Responses and Contingency Plan Process

The risk list that is generated in risk assessment will be digesting into the source of the risk for example inadequate communication, human error or carelessness. Then all the risk response approach will be given and explain to them. (Risk Elimination, Risk Reduction, Risk Transfer and Risk absorption) These are the steps of Risk responses and contingency planning process:

Meeting 5

5.1 Critical RPN risk evaluation: Process the FMEA data and produce the Critical Risks list using Pareto Analysis.

5.2 Critical risk introduction: Distribute out the major risk with their RPN number explaining that the risk presented are the critical risk that will need the team's attention first.

5.3 Discuss risk response for each critical risk: Discuss the Suitable risk response to each of the Risk in the list using tools and experience of each group member to find the source of the risk and how to response to it.

5.4 Summary of critical risk prevention: Summarize and note down all critical risk preventive actions to be filled into the FMEA table.

5.5 New RPN scoring after risk prevention**:** Discuss the changing factor of the RPN and ask the members to give their new scoring of RPN to the critical risk.

Meeting 6

6.1 Gathering of new RPN score: Gather the new score of the critical risk after the preventive actions.

6.2 Discussion on Implementation of preventive actions: After the risk response of the critical risk are discussed and summarized, the team shall discuss the implementation of the risk prevention method.

This is the end of the risk management process involving the risk management team. The result of the implementation will be inspected along the project progress.

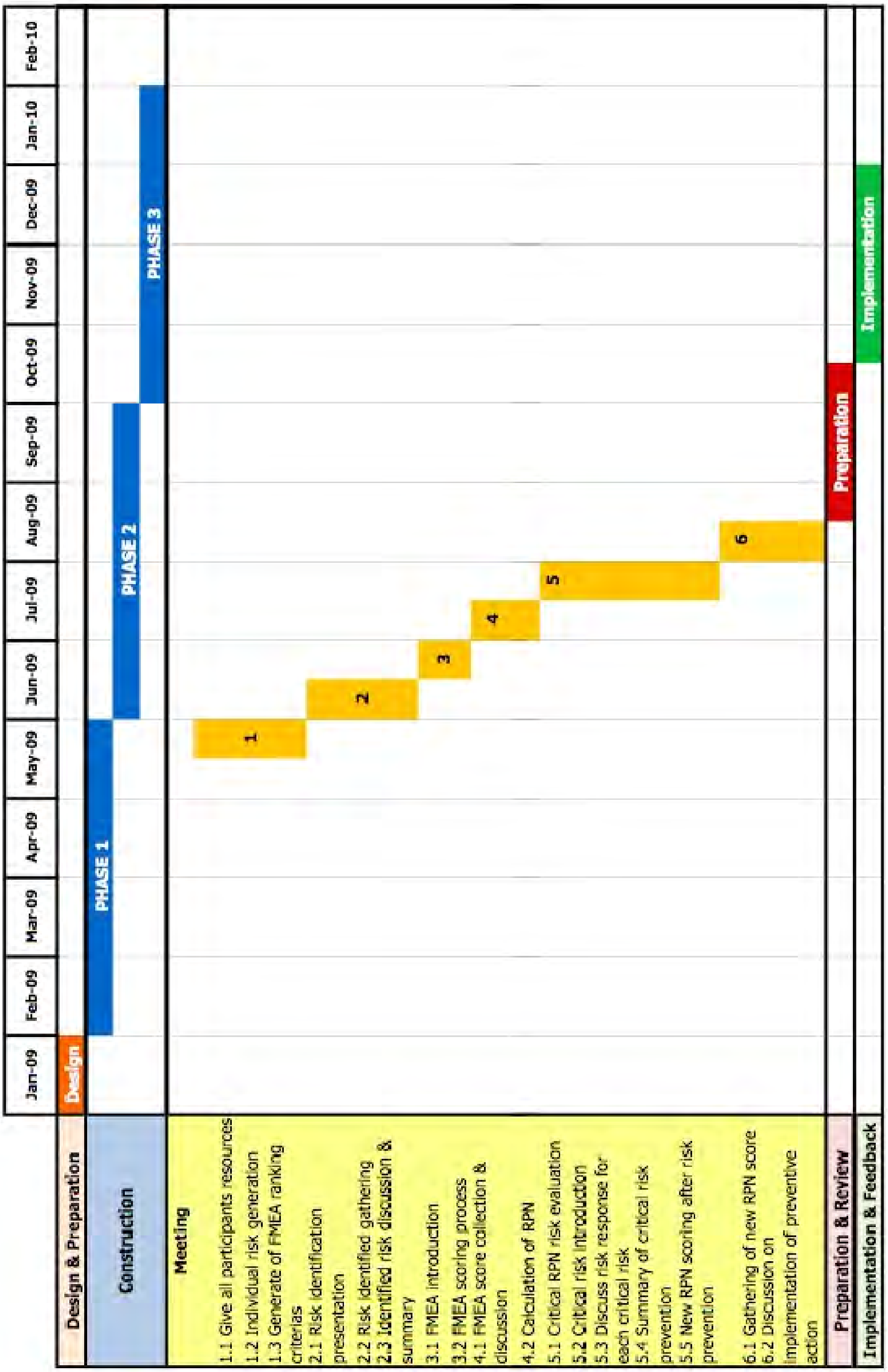


Figure 3-7: Schedule for Risk Management Meetings & Implementation

3.6 Conclusion

From the information given, the risk management team can use it to combine with their vision and experience to generate an effective FMEA to try to response to the risk. The construction of the prefabrication house is already been broken down into smaller steps for better understanding. The information about the labor, machines, the strategies of house building and labor usage, summary of schedule and the number of processes and the current risk management system; the risk management program can be conducted. The steps of risk management are already been presented to show how the risk management program can be implemented in real life using some tools and techniques to gain effectiveness. To generate FMEA table, the risk management team will have to discuss and work together to evaluate the project for risk.

Since all the information about the project is summarized and presented in this chapter, the next chapter will be the actual risk management result and analysis. It will show the result step by step of how the FMEA risk management table is generated and what information can be taken from it.

CHAPTER IV

PROJECT RISK MANAGEMENT RESULT AND ANALYSIS

In this chapter, the risk management analysis will be carried out and shown. Using the theories and literature reviews in the second chapter to combine the prefabricated housing project information in the third chapter, the risk management team will evaluate the risk within the project according to the procedure given in the last chapter and the result and analysis will be shown in the following chapter. This following information will be presented in this chapter:

4.1. FMEA rating scale and criteria
4.2. Risk identification process
4.3. Risk analysis using FMEA
4.4. Critical risks evaluation
4.5. Preventive Actions and Risk Response
4.6. Conclusion

This chapter will be showing the result of the risk management in this project for the further analysis of risk prevention and improvement future projects.

4.1 FMEA rating scale and criteria

The FMEA rating scale and criteria is the descriptive score of the FMEA for ranking and evaluating the risks into categories. In the beginning of the risk management meeting, the team is asked to discuss about the FMEA scoring criteria and the rating scale. This task is done in the beginning of the risk management process because this task is the most crucial step for FMEA risk management. By determining the criteria of scoring will automatically set the limiting range of risk into the wanted scope. This is the reason why this process is put to the first step.

This FMEA is based on 3 main factors as stated earlier, which are severity of the risk, the detection and controlling of the risk and finally the occurrence of the risk. These three factors will be measuring and scoping the risk.

Severity

The severity of the risk is also called impact or damage done (by risk). It is the measurement or estimation of what level of severity could the risk (identified) harm the project. The measurement scheme can be any vital factor to the project but usually severity is measured by time, cost or quality. In this case, time and quality will be used to rate the severity of the risk. The severity rating scale is rated from the score of 1-10, where 1 is the least severe and 10 is the most severe case.

The risk management team has discussed the ranking of the severity rating and first assigned the name to the risk in order to gain more scope to the topic. The severity ranking score of 10 will be assigned to “Hazardous effect” while the severity ranking of 1 is assigned to “No effect”. The criteria of the risk severity will then be split into 2 factor of measurement. The first severity measurement will be the impact on project time in the perspective of ABC company project time. The project time criteria will measure the severity starting from 1 day or less damage to the maximum of 12 months of more project time delay. The second factor will be the customer quality and injury effect criteria. This column will measure the severity in terms of quality of operations of product and the injuries of the concerning person. The criteria start with “the effect is not notice by customer” in ranking 1 and ends with “failure occurs without warning; life threatening risk”. The severity rating criteria that is discussed and produced is presented in table 4-1.

Occurrence

Occurrence is the measure of the frequency of the risk happening in a specific period of time. It is to see how often the risk could happen. The occurrence criteria can be measured descriptively and also in percentage. The ranking score of occurrence is assigned as 1 to be the extremely low occurrence and 10 to be the extremely high occurrence risk.

First, the risk management team decided to start same method as the severity, which is the descriptively assign the wording to the occurrence rating. The scoring of 10 is assigned to be “extremely high” and 1 to be “extremely remote” occurrence.

Then the next column is the percentage of possibility of failure. The possibility of failure is ranged from less than 1% to more than 35%, distributed equally from 1 – 10. The occurrence rating criteria is presented in table 4-2.

Detection

The detection of failure mode (risk) is the method of "how" to detect the risk and whether it is easy to detect of not. The detection rate can be measured by many methods such as using the method of control, using the responsibility of personnel etc. The detection ranking score is arranged that 1 is the risk easily detectable and 10 is the risk almost impossible to detect.

The detection criterion is separated into 2 sides, which are the manufacturing criteria and the construction criteria. The risk management team foreseen that the detection method in these two sites are not the same and cannot use the same scale to measure the detection and control of risk. In the manufacturing side, risk is controlled by the involvement of quality control, documentation, and personnel's responsibilities. The risk in the manufacturing side can be detected by the flowing of work from station to station rather than visual inspection. The risk in the construction side will be controlled mostly by visual inspection. Starting with visual inspection of anyone in the site up to the point of inspection from experiments/consultation/experts. The detection rating criteria is presented in the table 4-3.

The failure rating criteria specification such as the scale of severity (1 day to 12 months+), the occurrence (1% - 35%+) or the detection (control using personnel and visual inspection) is the result of a discussion from the risk management team. The criteria used are derived from some past projects such as construction project in PP Island and the experience of working in the construction field and manufacturing field from each member combining with the point of view of each stakeholder. Each factor is combined and applying using the Ford design institute FMEA criteria (2004) as a guideline, which is presented in Appendix. The rating from Ford motors is used for car manufacturing process FMEA but it is used as a guideline to apply in the construction project of prefabrication house, where the characteristics is that there are both manufacturing and construction involved in the same project. This is why the FMEA ranking scale cannot use the same rating criteria as a normal production process FMEA to evaluate the failure mode in each process.

Table 4-1. Severity rating criteria.

Severity Effects	Project Time effect Criteria	Customer Quality and injury effect Criteria	Score
Hazardous effect	Effect cause 12 months or more delay	Failure occurs without warning; life threatening risk	**10**
Serious effect	Effect cause 9-12 months delay	Complete system shutdown; safty risk	**9**
Very high effect	Effect cause 6-9 months delay	System may not be operatable and safty problems; may cause severe injuries	**8**
High effect	Effect cause 4-6 months delay	System may not be operatable; elicit customer complaints; may cause serious injuries	**7**
Moderate effect	Effect cause 2-4 months delay	Cause customer dissatisfaction; may violate regulations or design code; cause injuries	**6**
Low effect	Effect cause 4-8 weeks delay	Customer require imidiate service; some small injuries	**5**
Very low effect	Effect cause 2-4 weeks delay	Customer may return product for service	**4**
Minor effect	Effect cause 7-14 days delay	Cause customer annoyance, but they do not seek service	**3**
Very Minor effect	Effect cause 1-7 days delay	Very minor effect notice by customers, does not annoy or inconvenience customer	**2**
No effect	Effect cause 1 day or less delays	The effect is not notice by customer	**1**

Table 4-2. Occurrence rating criteria.

Occurrence rate	**Approx. Probability of Failure (one process)**	**Criteria**	**Score**
Extremely high	More than 35%	Extremely high number of failure in process	**10**
Very High	31% - 35%	Very high number of failure in process	**9**
High	26% - 30%	High number of failure in process	**8**
Frequent	21% - 25%	Frequent failure in process	**7**
Moderate	16% - 20%	Moderate number of failure in process	**6**
Occasional	12% - 15%	Occasional failure in process	**5**
Slight chance	8% - 11%	Slight chance of failure in process	**4**
Very slight	5% - 7%	Very few failure in process	**3**
Remote	2% - 4%	Remote number of failure in process	**2**
Extremely remote	Less than 1%	Failure is very unlikely	**1**

Table 4-3. Detection rating criteria.

Detection Rate	**Manufacturing Criteria**	**Construction Criteria**	**Score**
Almost Impossible	No known controls to detect	No known controls available to detect the failure	**10**
Very Remote	Detectable from inspection by Experts/Consultation	Detect from Thorough inspection by experiments/consultation/experts	**9**
Remote	Detectable from visual inspection by upper management (production manager/Project Manager/Architect)	Detectable by Experts and Consultation	**8**
Very low	Detectable from visual inspection by Skilled labor and quality control	Detectable by upper management staff (Owner/Architect/Project Manager)	**7**
Low	Detectable from Visual inspection by labor	Detectable by Quality Control	**6**
Moderate	Detectable from errors by sub-sequent work station/unable to perform the next process	Detectable by skilled labor/middle management (foreman)	**5**
Moderately high	Detectable from resources (raw material/machines) by quality control/production manager	Detectable by Labor	**4**
High	Detectable from resource (raw material/machines) by labors	Detectable by anyone in the site area	**3**
Very high	Detectable by failure search from documentations	Detect from reports of working difficulty/from documents and architect plans	**2**
Almost certain	Detectable by any means of control	Detectable by any means of control	**1**

4.2 Risk identification process

The risk identification process started since the first meeting, where each member was asked to think and brainstorm about the risk, where they shall present it to the group. Then the risk can be further discussed to the point of agreement. The risk identification process is done in the meeting 1 and 2. In the end of meeting two, all the risk identified was summarized.

In the second meeting where members presented out their risk, there were some discussions of whether some of the risks are appropriate or whether it can be summarized into a topic of risk. There were some adjustments of risk list and also identified some new risk along the process. The total count of risk identified and summarized is up to 83 risks spread out in each process. The number of risk in each process can be summarized and presented as follow:

Table 4-4. Summary of risk identified in each process.

Process number	Process name	Number of risks identified
Process 1	Define customer objective and design drawing	9
Process 2	Material check and scheduling	9
Process 3	Construction site preparation	8
Process 4	Factory operations	13
Process 5	Construction site operations	31
Process 6	Finishing product	4
Process 7	Overall process	9
Total		**83**

The total number of risk identified (table 4-4) is summarized into 83 risks. The process 7 is not listed in the construction process but the risk team decided that there is one more category needed to be able to identify all the risk. The process 7 is called “overall process” it is the process showing the risk that can happen to all the processes and is also the linking mechanics of each processes.

The risks that have been identified are discussed on why it should be a risk and what the causes and effects of the risks are. In this section, the risks that were identified will be explained individually to gain better picture of each of them. By doing so, the score of FMEA rating will be more effective.

Process 1: Define customer objective and design drawing

1. Unstable decision of owner over design and function

   The design derived from the customer objective and vision is the most vital part of construction, if the customer is not clear on their ideas, it can cause a lot of confusion and risk to all the operations. It will also affect the way the architect works.

2. Lack of information gathered by architect on the total project direction

   For the architect to produce a design, he/she will have to survey and gather the information for the total project. This information will be the key to generate ideas and structural setting for the whole project. The prefabrication house will require much more planning and information than usual construction.

3. Lack of information gathered by engineer on technical issues and functions

   Same as the architect, the engineer of the project will also need to understand and gather information about the site and the project; the engineer's calculation will affect the structural and load distribution of the house. The calculation will be applied to all houses and the risk of inaccurate calculation is unbearable.

4. Lack of control over design process

   The design process is a process that requires a lot of monitoring because it can easily be mislead from the customer ideas and functional needs. The time is also very crucial.

5. Ineffective communication in design process

   Communication is the key to a good design, if the Architect or the customer does not communicate effectively, then the design might not be effective. It can lead to many problems in the design process.

6. Mismatch between design and functional objectives

In the design process, the architect can easily carry away in the designing process and miss out the functionality of the houses. This will be a big problem and causes a lot of disappointment for the customer in actual implementation.

7. Unclear contract agreement between major stakeholders (Customer - Contractor)

In the contract agreement between the customer and the contractor (ABC company limited), there are many details that will lead to confusion in working together and finally conflict. The contract agreement of construction work will have to be very detailed and specific description in each process including the quality issue.

8. Corruption in construction permission requesting process

The Thai corrupted culture is deep in the Thai working culture. The corruption of the construction permission request will require some bribery or some negotiation, which might cause some risk such as delay or difficult working condition.

9. Inaccurate shop drawing produced and gathered

The contractor produces the shop drawing, it is the detail design drawing of how exactly to produce the house, and usually the contractor will have the shop drawing from past projects. If the show drawing is unreliable or inaccurate, then there can be some risk on the construction of the parts. The shop drawing of the prefabrication house must be very accurate.

Process 2: Material check and scheduling

1. Unclear architectural design for material breakdown

The architectural design of the houses will have to be clear in order to breakdown the material listing. With unclear architecture details of the material and the structural/design of the house, the purchaser and material checking process will be difficult.

2. Different material quality standard between contractor and customer

The customer and the contractor will have to agree on the quality standard or else there will be conflict of quality standard.

3. Mistake in material list breakdown from architect plan

A single prefabrication house consist of a huge amount of detail, with an in-experienced purchasing department or of carelessness, there can be mistakes in the material breakdown of the architect plan, which cause other problems following after. The material list of prefabrication houses is the heart to it.

4. Unavailable material in the market

There is a possibility that the design from the architect is involved with unprocurable materials in the current market situation. This is a problem that the purchase will need to communicate to the architect.

5. Inaccurate inventory information and storage system

To produce the material resource schedule, the purchaser will need to have good information of the inventory and story system. So it is possible form a master schedule of material management. Without it, the material resource plan might not be accurate which will cause a lot of problem in the future.

6. Poor material resource plan

Material resource plan is a very vital part of planning process in the prefabrication house project. If the planner is not skilled, unclear or careless in the material resource plan, the project will be a disaster.

7. Material ordering mistake

When ordering a long list of material, where each material has their specific requirement, the purchaser might order the wrong specifications or material. The prefabrication house material is much higher in volume comparing to the conventional construction, therefore more risk.

8. Long lead time of material shipment to factory

Some material that is required in the prefabrication house might require a long lead-time to the shipment. This lead-time may cause delay to the construction process and manufacturing process if it is a vital key material.

9. Poor information gathering from site and production factory to create master schedule of production and construction synchronization

After the site survey, all the information will have to be sent back to form the master schedule. The prefabrication construction is different to the conventional construction because it requires the synchronization of both prefabrication and production, therefore if there is any mismatch between it, then the whole project will be in risk.

Process 3: Construction site preparation

1. Unavailable resources at site (all relating issue with Labor, tools and material)

Each local construction site will have different resource available. The site in Phang-nga is a site located in Thai rural area. Therefore, there is a chance of not able to gather enough resources for the construction.

2. Site location unfit for construction e.g. Mountain area, dangerous grounds etc.

Some construction site are not fit for construction such as not enough ground foundation support the house near a lake or mountain area, these location will require more supporting foundation work.

3. Poor technical information survey such as weather, ground inspection, water level etc.

In extreme weather area such as the south of Thailand, the natural surrounding and technical information survey is very important. It will affect the quality of the product when being delivered to the customer and the also the construction process. The extreme weather can impact the technical designing and survey.

4. Inaccurate survey on environmental information (weather, ground support, natural resource available etc.)

The environment and weather will have direct effect to the working progress of the construction site. Many processes and many materials are very vulnerable to the environmental information around the site such as wood storing in a wet place or pouring cement in rainy season.

5. Unavailable basic infrastructures and tools needed for basic construction initiation

To initiate the construction site, there will need to be some basic infrastructure to start the construction process such as fresh water and electricity. Without it, the construction site will need to procure it as soon as possible.

6. Poor labor welfare and accommodation available

The labor force is the most important asset on the construction site, if the welfare and the accommodation are not satisfied to them, it will cause a chain of problem that can affect the project.

7. Lack of appropriate communication method available

Some construction sites can have difficulties in connecting with the factory base. It can be a problem because the prefabrication construction will need the cooperating of both sides to be effective.

8. Imprecise quality checking team for material delivery

The quality checking team is the department responsible for all the defects sent to the site. If the defect is sent to the site, then there will be further risks coming. The quality checking team is the key to controlling the standard of the quality delivered to the customer.

Process 4: Factory operations

1. Delay in material delivery from supplier to factory

The delay of material delivered from the supplier to the factory can cause by many things. The material can be in shortage, the factory might change the specification often or the supplier can be unreliable.

2. Under standard quality of material from supplier

The material from the supplier is expected to be up to the standard that the contractor and the customer have agreed on. This standard of controlling the quality of material will have to come from the supplier.

3. Wrong material specifications produced

In the prefabrication house, the range of material and its specifications is very wide. A house requires a lot of detailed work and therefore there are rooms for defects and wrong material specification produced.

4. Poor Inventory management system for raw material (wood, Shera wood etc.) and finished goods

The flow of production for the prefabrication construction is very crucial. If the factory is trying to achieve a good flow of production process, then the inventory system for storing the raw material will have to be tightly design, with no rooms of errors allowed.

5. Poor Inventory storage at factory for raw material (wood, Shera wood etc.) and finished goods

The materials required for prefabricated house construction are mostly Shera and wood. These two materials will require some care in storage; else it will be damaged and unusable.

6. Insufficient skilled labors (carpenters, painters and general wood working skills)

The skilled labor at factory is the team producing a good flow of material from the factory transported to the construction site. If the skilled labors are in shortage, then the effect can accumulate up to the finishing product.

7. Unclear production process provided for staff

With many processes required to prepare the parts to assembly at construction site, the factory will need to provide a lot of accurate information about the production process and how to prepare the best prefabrication house part to the construction site.

8. Inaccurate in design details and specification of product

The design details and design specifications to build a assembled house will be accurate down to the millimeters. The size, shape and the function of the specific piece will need to be precise and if there are errors in the information of these details, the errors will carry on straight to the construction site and cause problems.

9. achine breakdown in production process

In the producion process, if the machines are overused, misused or lack of maintenance, then it might breakdown and cause delays.

10. Under standard quality control (Q.C.)

The quality control at the factory will need to be strict to the standard of quality to the parts produce. If the quality control department is not up to standard, the customer will not be satisfied.

11. Delay in Transportation arrival to factory

In the delivery of the transportation to the factory, if the construction site is in a tight schedule, then the transportation will need to arrive in time to deliver goods to the site.

12. Problem with loading finished product to transportation truck

The parts of a prefabricated house come with different sizes and shapes. It is possible that these parts do not fit to the transportation truck.

13. Finished product packaging and labeling problems

The labeling system of the finished good at the factory will need to be in-sync with the system at the site. There are many parts and many details that need to be labeled and systematically order it so that the parts are well sorted and recognize at the site.

Process 5: Construction site operations

1. Transportation delay to construction site

The transportation truck delaying to the construction site can be caused by many things such as the truck can get into some accidents, discomfort in traffic or the truck simply lost the way to the site, which can affect the scheduling of the construction.

2. Damage of parts/products from transportation

The products that are not well packed and organized in the truck is at risk to be broken and needed to be repaired or return to the factory. This can cause delay in the working process.

3. Ineffective inventory organizing system at site of raw material and parts

The assembly parts and the raw material at the site will need to be organized using an effective system unless the inventory system will not be ready for continuous workflow.

4. Poor inventory storage for storing assembly parts and raw material (wood, Shera etc.)

The inventory storage condition at site could cause damage to the material stored in it. Especially in raining season or dry season, the weather impact or insects can cause defect materials, which delays the construction process.

5. Thefts (raw material, tools etc)

In the site construction where there are numerous people involved, there can be some stolen items and missing pieces from the storage room or in houses. The missing items could mean reordering from the factory or repurchase the item again.

6. Vandalism (raw material and house)

It is in the nature of some local people to vandalize objects just for the fun of it. This can cause many disturbances and could delay the construction.

7. Poor waste management at site (disposal of waste)

The waste management at site can be a subject difficult to handle. A construction site will naturally generate a huge amount of waste and if it is not well organized then it can be a problem to the working process.

8. Internal personal conflict

With human interacting together, conflict is risk to happen. Conflict is another way of saying that the vision of doing a task, which can easily be found in a construction project.

9. Lack of skilled labors (carpenter, foundation work labor, structuring work labor, fine architecture work labor)

Skilled labor is the biggest asset a construction project can have. The skilled labor is the labor experienced in the work field, and if they are not presented, then the project is risk to delay from training, defects and low quality work.

10. Absent of staff and labor

The local labor and some staff are sometimes not able to stay the whole project due to personal reasons. If the labor or staff leaves the project, then the project will be in short of staff and labor, which means the project will be delay for recruitment and training.

11. Lack of supervision in cement foundation

The cement foundation is the base of the Thai house, which requires accuracy on load sharing and construction technique to make a strong foundation. This part of house construction requires techniques and guidance from the foremen.

12. Lack of supervision in wooden structure

After the cement foundation, the structure of the Thai house will be constructed. The structure is the part where the angles and the joint will have to be done correctly and will require guidance from the foremen.

13. Lack of supervision in roofing

Roofing is the part where the tiles and the roof structure will be constructed. The roof construction is a delicate process where the tile piling formation and the treatment to different material will change the way of constructing the roof. This part will need supervision from the foremen.

14. Lack of supervision of wall assembly and wooden floor

The walls and wooden floor assembly is the part that requires accuracy and material care because these are the structural beauty of the Thai house. Therefore this part will require supervision from the foremen.

15. Lack of supervision in fine architectural work (painting, built-in decoration, wooden details)

The fine architect works are the inner charm decorations and paintings of wood. Paint experts will do this part with the guide of foremen or else it could be a difficult part.

16. Lack of supervision in labor management (rotation system)

The rotation system of the labor is the approach of how the construction will construct the houses. The labor will separate into teams and they will hold different responsibilities of construction. This requires management skills and foremen supervision.

17. Inaccurate in working details

Thai house are houses will a lot of details requires for it. The details of building Thai houses require skills and care, which is possibly what the labor doesn't possess.

18. Labor strike

When the project requires a lot of labor working within it, it can create a lot of problems. If there is a conflict between the manager team and the labor group, then it can cause labor strike.

19. Force Majeure (Natural Disaster)

Force Majeure is the natural disasters that are not control able such as Tsunami, forest fire, instant flooding, earthquake etc. These forces are major risk to the project. Phang-nga is also located in Tsunami danger zone.

20. Lack of contingency plans and problem solving

Construction projects are a project, which requires a lot of crisis management within its project nature. The manager team will need to solve problems spontaneously and on dad-by-dad basis to be effective. The prefabricated house construction project can be seen as a more complicated project because it requires the total synchronization of both prefabrication production and the assembling at the construction site, therefore this skill is needed.

21. Local protest to construction activities

In the construction area that is set near a village or local town. If there were some construction activity that interrupts that living habit of the local resident, then they would protest to shutdown such activity.

22. Internal corruptions

Internal corruption is common in the Thai construction project. The corruption can sometimes require investigations or cause problems within the company.

23. Inappropriate construction sequences

Prefabricated house construction requires more precision than conventional construction and takes longer time to repair any defects because it is prefabricated at the factory, which is not near by the construction site. If the labors have mistaken the construction sequences, then it takes time to fix the defects.

24. Impact from extreme weather (Rain/Wind/Sun) to material

The material used and stored for the wooden house building might be affected from the extreme weather at the construction site. The parts that could be affected by the weather are roofing material, walls material, wood in storage etc.

25. Impact from extreme weather (Rain/Wind/Sun) to working progress

The impacts to the working process of the prefabrication house by extreme weather are such as cement drying process, the roofing process, the structuring of the house process etc. These processes will have difficulties to execute if the weather timing is improper.

26. Inappropriate tools used

The use of inappropriate tools is damage many parties involved depending on the tool types and the surrounding. The damages are such as broken tools, injuries of labors, material defects etc.

27. Change of design by owner

The owner of any construction projects has the tendencies to change their mind about the designs and functions of the house, which can cause a lot of delays in the construction process. In the prefabrication houses, this will cause severe effects because the changed information will have to be sent back for production unit and return to the site for assembly.

28. Incomplete infrastructure for construction process

The basic infrastructure for the construction process are water, electric and waste water treatment. If they are not available in the site or in the area that requires them, then the construction process might not be able to progress.

29. Unclear contract with sub-contractor

Sub-contractors and the company ABC are bound with a contract agreement of constructing the infrastructure. An unclear contract on the time, cost, quality and working methods can cause conflicts and delay for the project.

30. Under standard quality control

Quality control is the control of the quality standard of the products. If the quality control is not up to standard, then there will be problems with the customer and repairing of defects, which leads to a lot of unnecessary work.

31. Unacceptable quality from sub-contractor

The sub-contractor quality standard will be a burden to the Company ABC because at the end of the project, ABC will have to pass the project to the owner. If there is any dysfunctional quality or defects by the sub-contractor, ABC will be responsible for it.

Process 6: Finishing product

1. Lack of Maintenance of finished house

The maintenance of the finish houses is vital because the construction period is separated into 3 phases. If the houses in the first phase are completed, then it will be left untouched for another 8 months. In that time, these houses need maintenance.

2. Inaccurate finishing process from labor

At the end of the construction process, the work left are finish work such as paint, detail work etc. These works are considered very fine and detail. The labor might not reach the level of accuracy to complete it.

3. Poor House inspection of function

A long construction project, the customer might change the function or the design many times. This means that the house will need to adapt according to the changes. If some houses are left out or unable to perform the required function in the finishing process, then the customer will be unsatisfied.

4. Shortage of fine tools and resources

The fine tools such as brushes and fine paint are sometimes rare in the local area. This means it is difficult to procure in the surrounding area, therefore it takes some time to send it from the factory to the site.

Process 7: Overall process

1. Unclear roles and responsibilities

In a construction project, coordination and responsibilities are the most important factor. There are many parties involved and many of them need to work together.

With unclear roles and responsibilities, it is very difficult to function together because it is the heart to coordination and working progress.

2. Poor documentation

Documentation and database is like a tool for improvement and risk prevention. The documentation of a project shows how the project is managed. With poor documentation, the information flow and coordination within the project will be a disaster.

3. Low efficiency in information Flow and coordination

The information flow and coordination in a project depends on many factor such as the working culture, the clarity of stating information, poor documentation, or poor project management skills. A prefabrication construction project requires higher coordination because it is a fast building process.

4. Ineffective Meetings

The meetings within the project (once in two weeks) will have to be effective and clear so the work can move on to the next step. An ineffective meeting only cause conflicts and delays to the project and should be avoid.

5. Low efficiency in Manager team

The manager team is the heart of the project. The managers and high-level staff are the driving force that pushes the project forward and solves the problem that comes along. If the manager team is not functional or low in efficiency in working, then the project is highly at risk.

6. Careless working culture

Working culture of Thailand cannot be compared to the working culture of the western. Thailand labor and staff are much more careless in details and are usually in lack of motivation. This affects the project directly and can lead to bad project outcome.

7. Lack of supervision

Because the construction of prefabricated house is still a new construction method to the group and the labor force. This means the labors will need supervision and guidance from the staff and higher-level managers. The lack of supervision in every process shows lack of leadership and poor human resource management.

8. Corruption

Corruption is a problem to every project. It is the cause for conflict and delays. Unfortunately corruption is deep in the root of Thai working habit. Corruption can be hidden in any process and could affect many working process in both quality and time.

9. Lack of efficiency in project monitoring and control

Project monitoring and control is a difficult task for an inexperienced project team. However, to monitor and control project is the only way to a smooth project. If there is not enough monitoring and controlling of the project, then the total project could collapse.

These are the risks that were identified by the risk management team for the project of 35 units Thai prefabricated house construction. Another topic that had been discussed is the risk that could occur in a single unit of prefabricated Thai house construction. The conclusion is as follow:

- All of the risk in process 7 (overall process) will be too minimal to be accounted as a risk, therefore if a single house is built, the risks in the process 7 will be excluded.
- No local protest due to small-scale construction (process 5)
- No labor rotation management and labor strike due to small-scale house.
- The location will be determining the weather and natural disaster such as Force Majeure (Natural Disaster, process 5) and extreme weather (process 5)
- No finished house maintenance because of small-scale construction project
- The total severity of all process will drop due to small-scale construction.

This is the end of the list of identified risks with the short explanation of what it involves in this project. After all the risks are identified, the members were also asked to discuss about the possible cause and effect of the risk. The possible cause and effect of the risk can help the members score the FMEA to see the SOD (severity, occurrence and detection) of the risk in a clearer way. The table 4-5, 4-6, 4-7, 4-8, 4-9, 4-10 and 4-11 is the summary of risk and its possible cause and effect of each risk in each process.

Table 4-5. Summary of risk from Process 1 (define customer objective and design drawing).

No.	Failure Mode (Risk)	Possible Effect	Possible Cause
1	Unstable decision of owner over design and function	Difficulties with architect, delay in design process, unclear architect plan, effect total project outcome.	External factor of owner sides such as unclear company objective, stress.
2	Lack of information gathered by architect on the total project direction	Poor design function, unsuitable design, delay in designing process, error in foundation process, effect total project outcome.	Lack of time leading to faulty assumptions, low motivation, carelessness, architect in-experienced.
3	Lack of information gathered by engineer on technical issues and functions	Danger to house structure and loading system, unable to pass construction permission	Carelessness, in-experienced engineer, low motivation.
4	Lack of control over design process	Lower detection on risk, low problem solving ability and information, inefficient design function, poor time management.	Carelessness, in-experience in project management, poor project management system.
5	Ineffective communication in design process	Poor house function and design, unqualified function in the house, avalanche effect of changes in other process, personal conflicts.	Low motivation, over-confidence, poor communication skills, poor communication channel.
6	Mismatch between design and functional objectives	Re-construction of faulty parts, personal conflicts between designer and owner.	In-experienced architect, insufficient explanation from customer, over-complex house function.

7	Unclear contract agreement between major stakeholders (Customer - Contractor)	Conflicts between stakeholders, Project delay, unclear roles and responsibilities.	Carelessness in contract approving, poor contract drafting from lawyer, in-experience working culture from either side, hidden agenda of pushing responsibilities.
8	Corruption in construction permission requesting process	Project delay, personal conflict, stress in negotiation.	Thailand corruption culture.
9	Inaccurate shop drawing produced and gathered	Difficulties in construction, difficulties in production, project delay, a lot of construction correction and problem with process.	Poor database system from past project, insufficient skill, lack of information, carelessness, in-experience.

Table 4-6. Summary of risk from Process 2 (Material check).

No.	Failure Mode (Risk)	Possible Effect	Possible Cause
1	Unclear architectural design for material breakdown	Unable to breakdown Bill of Quantity, poor production schedule and planning, project delay, House assembly problem at site.	Carelessness from architect, over-complex details in house required from customer, in-experience architect.
2	Different material quality standard between contractor and customer	Personal conflicts, re-ordering of materials, project delay.	Unclear contract, unclear architectural design and presentation of materials used, carelessness of inspection of customer
3	Mistake in material list breakdown from architect plans	Material procurement and purchasing delay, backlog in production process.	Carelessness, unclear material lists from architect, over-complexity of design.
4	Unavailable material in the market	Revise material used with architect, project delay, and design change.	Rare material to procure, unavailability of certain material in market
5	Inaccurate inventory information and storage system	Poor material resource plan and production plan, mistake in purchasing of materials, difficulties in production work, project delay.	Ineffective or bad inventory organizing system and record, poor inventory database.
6	Poor material resource plan	Production and construction process delay causing project delay, difficulties and confusion in work, unproductive labor use at site and at factory.	In-experience in planning process, carelessness, lack of material information, lack of contact to supplier, inaccurate inventory information, ineffective communication with supplier.

7	Material ordering mistake	Production and construction process delay causing project delay, re-ordering material, waste of material, increase in inventory storage.	Carelessness, in-experience with material type, unclear architect plans, ineffective communication with supplier.
8	Long lead time of material shipment to factory	Production and construction process delay causing project delay, swapping of production order causing delay in construction process.	Difficult process of material preparation by supplier, long distance delivery, undersupply of material in the market causing waiting list, order in large batch, poor material resource plan causing free float.
9	Poor information gathering from site and production factory to create master schedule of production and construction synchronization	Project delay in construction and production process, conflicts from misunderstandings, stress from delaying and confusion, lower motivation, disrupt the work flow in both site and factory, cause for re-organizing total project management issue, cause a lot of problems in both daily basis and long-term.	Carelessness, no system of information gathering, in-experience survey team, lack of information flow, ineffective communication.

Table 4-7. Summary of risk from Process 3 (Construction site preparation).

No.	Failure Mode (Risk)	Possible Effect	Possible Cause
1	Unavailable resources at site (all relating issue with Labor, tools and material)	Request resource from base office, delay in resource shipment time, difficult to operate at site due to lack of tools and material, stress, personal conflicts from stress, labor not motivated.	Rural construction location, construction site surrounding area is under developed
2	Site location unfit for construction e.g. Mountain area, dangerous grounds etc.	Project delay from site development, contract revision on completion date, in need of instant resource for site development, Project re-design	Rural undeveloped location, abandon piece of land, construction site in danger grounds such as mountains or island.
3	Poor technical information survey such as weather, ground inspection, water level etc.	Failure in house construction, project delay and cause damage, waste of resource, unable to proceed further in construction, re-calculate engineering part, re-survey site location.	Carelessness, in-experience survey person, over complex technical issue.
4	Inaccurate survey on environmental information (weather, ground support, natural resource available etc.)	Delay in construction, unused opportunity for construction advancement, damage to house from unclear ground support information, architect and engineer redesign, project delay	Carelessness, in-experience, unrecognizable problem, difficult to survey from time of the day/month/year factor.
5	Unavailable basic infrastructures and tools needed for basic construction initiation	Infrastructure construction request to government unit, connect site location	Rural undeveloped site, hard to reach location, lack of technical support.

		to any possible resource of basic infrastructure, project delay.	
6	Poor labor welfare and accommodation available	Labor protest, low motivation, project delay, welfare and accommodation transport to camp.	Rural undeveloped site, poor labor camp, lack of store for labor basic needs item.
7	Lack of appropriate communication method available	Low information flow, difficulties in site operations, poor synchronization of construction site and factory, project delay, stress, poor decision making due to lack of information, unable to connect to factory for vital decisions and information.	Rural undeveloped site, lack of technical support, unavailable communication resource at site.
8	Imprecise quality checking team for material delivery	Poor quality standard to customer, conflicts, re-construction and repair, house damaged from poor quality parts, project delay.	In-experience quality control team, carelessness, lack of knowledge over material, lack of time, poor quality standard judgment.

Table 4-8. Summary of risk from Process 4 (Factory operations).

No.	Failure Mode (Risk)	Possible Effect	Possible Cause
1	Delay in material delivery from supplier to factory	Production delay, inventory storage and backlog problems, conflict in supply chain.	High volume, wrong purchasing order, transportation problems, unreliability of suppliers.
2	Under standard quality of material from supplier	Production delay, Increasing of defect rate, conflict in supply chain, Reordering of material.	Unreliable quality of suppliers, lack of material specification, Ineffective communication of supplies.
3	Wrong material specifications produced	Waste, Delay in repairing process.	Unclear documents, ineffective communication, misuse of tools, lack of skills.
4	Poor Inventory management system for raw material (wood, Shera wood etc.) and finished goods	Confusion of material storage, ineffective usage of inventory, waste, production delays from material preparation.	Carelessness, in-experience in inventory management, poor inventory record, lack of information flow, inappropriate technology and tools, ineffective labeling system.
5	Poor Inventory storage at factory for raw material (wood, Shera wood etc.) and finished goods	Raw material defects, high defect rate, production delay, reordering of material.	Carelessness, low storage capacity, inappropriate storage area, inappropriate technology, unskilled labors.
6	Insufficient skilled labors (carpenters, painters and general wood working skills)	High defect rate, misuse of tools, low quality products, production delay, internal conflict, delay caused by training.	Lack of training, unavailable skilled labor at factory area, low motivation.

7	Unclear production process provided for staff	Confusion in production process, production delay, high defect rate, delay caused by process correction, waste, conflict between staff.	Carelessness, inexperience production manager, lack of information flow, ineffective documentation,
8	Inaccurate in design details and specification of product	Production delay, waste, unacceptable product quality.	Ineffective documentation, ineffective communication, in-experience labors, low quality control standard.
9	Machine breakdown in production process	High defect rate, production delay, and injuries.	Low maintenance, misuse of machine, unskilled labors.
10	Under standard quality control (Q.C.)	Highly defect products delivered to construction site, conflict with customers, Delay caused by training.	Low motivation, ineffective documentation, in-experience quality control team, poor quality standard judgment.
11	Delay in Transportation arrival to factory	Delay in delivery to construction site, conflict with transportation company.	Unreliable transportation outsources, factory location difficult to access.
12	Problem with loading finished product to transportation truck	Material breakdown, transportation delay, conflict with transportation company.	Carelessness, unskilled labor, ineffective loading system, inappropriate package size.
13	Finished product packaging and labeling problems	Material breakdown, transportation delay, confusion at construction site.	Carelessness, ineffective packing and labeling system, unskilled labors, inappropriate packaging tools, ineffective monitoring and control over packaging and labeling process.

Table 4-9. Summary of risk from Process 5 (Construction site Operations).

No.	Failure Mode (Risk)	Possible Effect	Possible Cause
1	Transportation delay to construction site	Construction delay, conflict, construction backlog.	Unclear directions given, difficult transportation route, unreliable transportation company.
2	Damage of parts/products from transportation	Defects, construction delay through corrective actions, re-procure of raw material, delay cause from reordering parts/products.	Ineffective packaging, carelessness, difficulty in transport route, ineffective package arrangement in truck.
3	Ineffective inventory organizing system at site of raw material and parts	Confusion, construction delay, delays in material preparation, multiple purchase of same material, conflict.	In-experience in organizing inventory, unskilled staff, ineffective labeling system, misused of technology, ineffective documentation, and ineffective information flow.
4	Poor inventory storage for storing assembly parts and raw material (wood, Shera etc.)	Defects, project delay, waste, material shortage, re-ordering material from factory.	Poor labeling system, poor storage area condition, insufficient warehouse space, ineffective documentation.
5	Thefts (raw material, tools etc)	Shortage of material and tools, conflict, labor loses moral, re-ordering material from factory, re-purchase missing tools.	Ineffective security, local residence habit, ineffective controlling and monitoring system.

6	Vandalism (raw material and house)	Defect, rework, re-purchase.	Local residence habit, conflict, carelessness.
7	Poor waste management at site (disposal of waste)	Harmful to environment and community, difficult to operate, conflict with government and community.	Lack of waste management system, neglect of importance, carelessness.
8	Internal personal conflict	Labor strike, low quality, delay in decision-making, lower motivation, injuries.	Misunderstanding, ineffective communication, unclear organization responsibilities and ranking.
9	Lack of skilled labors (carpenter, foundation work labor, structuring work labor, fine architecture work labor)	Construction delay, increasing of defect, low quality, increase of workload in quality control department, stress to foreman.	Unavailable skill labor in local area, insufficient training.
10	Absent of staff and labor	Project delay, shortage of staff, lack of monitoring and control, confusion in construction process.	Unavailability of staff and labor in local area, low motivation, external personal factors, unclear contract.
11	Lack of supervision in cement foundation	Damaging to foundation of house, project delay from re-work, project delay because unable to progress to other process, endanger risk of house collapse.	

12	Lack of supervision in wooden structure	Project delay from re-work, project delay because unable to progress to other process, distorted house angle, difficult in roofing structure.	Carelessness, lack of leadership, lack of understanding in process, lack of communication, over-work of foreman, in-experience in process, low motivation, over-complicated process, unskilled foreman and managers.
13	Lack of supervision in roofing	Leakage, delay from re-work, damage inner area of house.	
14	Lack of supervision of wall assembly and wooden floor	Delay from rework, leakage, waste of wood, damage walls and floors and delay from re-ordering from factory, unable to progress to other process.	
15	Lack of supervision in fine architectural work (painting, built-in decoration, wooden details)	Delay from re-work of detail work, parts damage, re-ordering from factory.	
16	Lack of supervision in labor management (rotation system)	Delay from confusion, wrong distribution of labor, distortion of working process, distort integrity of schedule, lower quality construction due to lack of labor at specific process.	
17	Inaccurate in working details	High workload of quality control, defects, delay caused from rework, penalty.	Unskilled labors, ineffective documentation, ineffective communication, insufficient leadership, carelessness, low monitoring and control of quality.

18	Labor strike	Project delay, possible vandalism, and penalty.	Conflicts, unsatisfied welfare and accommodation, over workload, lack of communication.
19	Force Majeure (Natural Disaster)	Project delay, project termination, penalty, total lost and injuries.	Natural disasters.
20	Lack of contingency plans and problem solving	Construction delay, defects, low quality.	Low monitoring and control, lack of experience, neglect of importance, poor problem solving skills.
21	Local protest to construction activities	Construction delay, construction termination, shortage of labors, vandalism.	Inappropriate acts to local community, lack of communication, hidden agenda of local citizens.
22	Internal corruptions	Construction delay, internal conflicts.	Personal benefits, Thai corruption culture, unsatisfied welfare.
23	Inappropriate construction sequences	Project delay, defects, delay from rework, and waste of resources.	Lack of information flow, lack of leadership and guidance, ineffective documentation, lack of skills, carelessness, ineffective monitoring and control.

24	Impact from extreme weather (Rain/Wind/Sun) to material	Construction delay, reordering of material, low material quality.	Natural causes, inappropriate storing method.
25	Impact from extreme weather (Rain/Wind/Sun) to working progress	Construction delay, high maintenance of completed house, defects, injuries.	Natural causes.
26	Inappropriate tools used	Tool breakdown, defects, injuries, construction delay, and waste of resources.	Unskilled labors, lack of monitoring and control, ineffective usage method provided to users.
27	Change of design by owner	Construction delay, delay caused from redesign and rework, waste of material and resources, conflicts.	Lack of communication, unforeseen problems in design process, change in objectives of designed functions, shortage of resources, external factors.
28	Incomplete infrastructure for construction process	Construction delay, conflicts.	Unclear specifications, ineffective documentation, unreliable sub contractor, change in schedules.

29	Unclear contract with sub-contractor	Conflicts, project delay, unclear responsibilities and tasks.	Ineffective communication, carelessness, unclear documentation, lack of laws consults.
30	Under standard quality control	Low product quality, customer's disappointment, delay caused from training and rework.	Unclear standard setting, lack of training, carelessness, ineffective documentation, unskilled staff, lack of monitoring and control.
31	Unacceptable quality from sub-contractor	Low product quality, construction delay, conflicts, unable to use basic infrastructure in-house.	Ineffective communication, unclear specification, unclear contract agreement, unreliable sub-contractor.

Table 4-10. Summary of risk from Process 6 (Finish product).

No.	Failure Mode (Risk)	Possible Effect	Possible Cause
1	Lack of Maintenance of finished house	Finished house defects, customer disappointment, suffer from penalty, project delay due to corrective action required.	Carelessness, insufficient resource, unforeseen problem, neglected task.
2	Inaccurate finishing process from labor	Customer disappointment, suffer from penalty, project delay due to corrective action required.	Carelessness, lack of control, ineffective communication.
3	Poor House inspection of function	Customer disappointment, suffer from penalty, project delay due to corrective action required.	Ineffective quality control, ineffective design, carelessness, unclear customer's objectives of functions, ineffective communication.
4	Shortage of fine tools and resources	Low house quality in detail, delay in transportation of tools, customer's disappointment.	Misuse of tools, unable to procure in local area, rare tools required, theft.

Table 4-11. Summary of risk from Process 7 (Overall process)

No.	Failure Mode (Risk)	Possible Effect	Possible Cause
1	Unclear roles and responsibilities	Project delay, confusion in responsibilities, confusion in internal staff position ranking, internal conflict, same jobs done multiple times.	Carelessness, unclear contract agreement, internal conflict, ineffective communication
2	Poor documentation	Confusion in any process, conflicts in any process, project delay.	Carelessness, ineffective documentation system, insufficient documentation organizing skills, Neglect importance of good documentation system and recordings.
3	Low efficiency in information Flow and coordination	Confusion in any process, conflicts in any process, project delay,	Unclear organization position and ranking, in-experience, carelessness, ineffective information flow system, misuse of technology, non-information sharing cultures, corruption.
4	Ineffective Meetings	Confusion in any process, conflicts in any process, project delay, delays in decision making, ineffective problem solving.	Carelessness, unclear organization responsibilities and ranking, unable to admit to mistake and defects, poor meeting records and documentation.

5	Low efficiency in Manager team	Confusion in any process, conflicts in any process, project delay, delay in decision making, ineffective problem solving, project termination.	Stress, corruption, carelessness, low motivation, in-experience, internal conflicts, lost of project direction, ineffective communication, personal problem.
6	Careless working culture	Defects in every process, difficult to monitor and control, project delay from various factor, customer dissatisfaction.	Lack of motivation, Thai working culture, under estimating workload, no discipline.
7	Lack of supervision	Project delay from confusion and lack of leadership from upper and middle management, high defect rate, low motivation, lack of monitoring and control,	Carelessness, lack of leadership, lack of understanding in process, lack of communication, over-work of foreman, in-experience in process, low motivation, over-complicated process, unskilled foreman and managers.
8	Corruption	Project delay, conflicts in any process, stress.	Thai corruption culture.
9	Lack of efficiency in project monitoring and control	Project delay, high defect rate, confusion in any progress, conflict in any progress, low efficiency in total project, low problem solving ability, and low detection of problems.	Carelessness, ineffective communication, in-experience, misuse of technology, neglect of importance.

The tables 4-5 – 4-11 are the summary results in the risk identification including the risk identified and the possible cause and effect. The causes and effects are presented as key words on how the risk can occur and what could be the following effects of it. After the critical risks are analyzed, the in-depth analysis of possible cause and effects of the critical risk will be done again.

4.2.1 Risk identification meetings

During the meeting, there are some resources and tools that were used to gain better picture of the project (tools for risk identification are introduced in chapter 2). These are the list of resources used to discuss and to gain more perspective of the project.

- Personal and corporate experience of each member
- Intuitions and insights of each member
- Site visit and inspections
- The use of organization charts and role and responsibilities analysis
- Flow chart of process
- Analysis of assumptions and decisions
- Consultation of Experts at site and in factory.

These resources used for risk generation and identification were brought up to discuss from each member. Member's argument tends to show the knowledge in their area of expertise and some comments are based on their comments. These comments and discussion are encouraged in the group because it will lead to better and more in-depth analysis of risk.

The risk identification meetings (as clarified in chapter 3) is designed trying to avoid the groupthink effect. That is why the team will have to generate the risk individually first before gathering together in a group. By doing this, all the members can state their opinion without getting beaten down by other members. This way all the members will participate and identify the risk that they think would be valid. After the presenting risk, all the risk are collected and then a group discussion of the reason and suitability is encourage. In this stage, some more risks were identified as well. The tools that were used in this stage consist of:

- Checklist (shown in Appendix)
- Scenario building (the “what if” technique)
- Nominal group technique (brainstorming)
- Risk inspection (inspection of factory and at construction site)
- Bug listing (inspecting the little things that annoyed the workers such as insufficient tools, labor welfare, weather, working condition or work process)
- Risk review meetings and implementation

The tools used to identify risk did help the member to gain more perspective to the risk identification process. The tools such as checklist, brainstorming and risk inspection are the major tools used. The other tools like scenario building, bug listings are the tools used only when the group ran out of ideas or does not have answer to some explanations.

4.3 Risk analysis using FMEA

In the third meeting, FMEA is introduced to the group. The FMEA table that is given to all the group is a blank table with the risk listed, the risk were translated to Thai language so all members in the group were able to understand (English-Thai blank FMEA translation is attached in Appendix) The FMEA table were distributed with the expectations to return it in the next meeting. This is done with the same reason as the risk identification process, to reduce the groupthink effect. This is why the FMEA will be done in private first and then discussion later.

The risks and their score will be presented in process with some explanation of what the discussion and the decisions of major scorings of some risks.

Table 4-12. Summary of risk analysis in process 1 (define customer objective and design drawing).

No.	**Failure Mode (Risk)**	**Estimated Severity (S)**	**Estimated frequency of Occurrence (O)**	**Estimated Detection (D)**	**RPN**
1	Unstable decision of owner over design and function	5	3	1	15
2	Lack of information gathered by architect on the total project direction	7	8	8	448
3	Lack of information gathered by engineer on technical issues and functions	5	4	2	40
4	Lack of control over design process	3	4	7	84
5	Ineffective communication in design process	4	4	2	32
6	Mismatch between design and functional objectives	5	4	2	40

7	Unclear contract agreement between major stakeholders (Customer - Contractor)	8	5	2	80
8	Corruption in construction permission requesting process	3	3	1	9
9	Inaccurate shop drawing produced and gathered	9	6	8	432

The risk in the first process (table 4-12) is a difficult process to analyze. The process of design and defining the customer objective is a process that could affect the whole project and the severity could be very high.

The risks that the members concerned about were the risk about the architectural information and the inaccurate shop drawing. The reason these two risks were given such a high RPN score is because these two risks are considered high damage to the project and very difficult to detect. The occurrence of these risks happening in this project is also high. Therefore, the member gave many of them in high score and came to the same conclusion that these risks can lead to a lot of more problems in the construction and prefabrication process.

Table 4-13. Summary of risk analysis in process 2 (Material Checking).

No.	Failure Mode (Risk)	Estimated Severity (S)	Estimated frequency of Occurrence (O)	Estimated Detection (D)	RPN
1	Unclear architectural design for material breakdown	7	7	8	392
2	Different material quality standard between contractor and customer	3	4	4	48
3	Mistake in material list breakdown from architect plans	6	6	2	72
4	Unavailable material in the market	3	2	8	48
5	Inaccurate inventory information and storage system	3	3	6	54
6	Poor material resource plan	7	5	9	315
7	Material ordering mistake	5	4	5	100
8	Long lead time of material shipment to factory	2	1	7	14

9	Poor information gathering from site and production factory to create master schedule of production and construction synchronization	7	3	6	126

In the second process, the team have discussed on the impact that could occur to the construction part and the prefabrication part of the project. Many members suggested that the construction part could only function well if the manufacturing team prefabricating the house provides a steady flow of assembly parts and supportive functions to the construction.

The risks that were concentrated on consist of 2 risks, which are risk number 1 and 6. These risks were rated high because it involved in preparing the material for the factory and construction site. In this stage, the team finalized that anything that could affect the factory operations and the flow of material is much more severe than the construction problems.

Table 4-14. Summary of risk analysis in process 3 (Construction site preparation).

No.	Failure Mode (Risk)	Estimated Severity (S)	Estimated frequency of Occurrence (O)	Estimated Detection (D)	RPN
1	Unavailable resources at site (all relating issue with Labor, tools and material)	2	4	1	8
2	Site location unfit for construction e.g. mountain area, dangerous grounds etc.	3	1	1	3
3	Poor technical information survey such as weather, ground inspection, water level etc.	3	1	3	9
4	Inaccurate survey on environmental information (weather, ground support, natural resource available etc.)	2	2	3	12
5	Unavailable basic infrastructures and tools needed for basic construction initiation	5	2	1	10
6	Poor labor welfare and accommodation available	3	2	3	18

7	Lack of appropriate communication method available	6	3	1	18
8	Imprecise quality checking team for material delivery	4	3	6	72

The RPN in the process of construction site preparation (table 4-14) shows that there are no high scored risks in this process. The reason is because the risk management team discussed about the condition of the site and concluded that with the technology and communication method nowadays, there is not much to worry about in this process. Most of the problems in this process can be solve quickly, can be detected with a reasonable method/personnel, and there is not much occurrence within this project and the pass projects.

Table 4-15. Summary of risk analysis in process 4 (Factory operations).

No.	Failure Mode (Risk)	Estimated Severity (S)	Estimated frequency of Occurrence (O)	Estimated Detection (D)	RPN
1	Delay in material delivery from supplier to factory	3	2	2	12
2	Under standard quality of material from supplier	3	5	6	90
3	Wrong material specifications produced	3	4	2	24
4	Poor Inventory management system for raw material (wood, Shera wood etc.) and finished goods	2	3	3	18
5	Poor Inventory storage at factory for raw material (wood, Shera wood etc.) and finished goods	2	1	5	10
6	Insufficient skilled labors (carpenters, painters and general wood working skills)	8	8	7	448
7	Unclear production process provided for staff	3	2	3	18
8	Inaccurate in design details and specification of product	4	3	2	24
9	Machine breakdown in production process	3	2	1	6
10	Under standard quality control (Q.C.) at factory	7	8	9	504
11	Delay in Transportation arrival to factory	2	1	2	4
12	Problem with loading finished product to transportation truck	2	1	2	4

13	Finished product packaging and labeling problems	1	1	2	2

The RPN score for the process 4 (table 4-15) shows that there are 2 main risks in this stage to be aware of. The first risk is about the skill of the labor at the factory, the factory manager team had stated that this is a very big risk and would cause a lot of problems. The second problem is the quality control at the factory may not be up to standard. There were some discussions about the quality of production at the factory and concluded that this is one of the keys to the success of the prefabricated house construction.

Table 4-16. Summary of risk analysis in process 5 (Construction site operation).

No.	**Failure Mode (Risk)**	**Estimated Severity (S)**	**Estimated frequency of Occurrence (O)**	**Estimated Detection (D)**	**RPN**
1	Transportation delay to construction site	2	2	1	4
2	Damage of parts/products from transportation	4	4	2	32
3	Ineffective inventory organizing system at site of raw material and parts	2	3	2	12
4	Poor inventory storage for storing assembly parts and raw material (wood, Shera etc.)	2	3	2	12
5	Thefts (raw material, tools etc)	2	3	2	12
6	Vandalism (raw material and house)	2	1	1	2
7	Poor waste management at site (disposal of waste)	2	2	2	8

8	Internal personal conflict	1	1	2	2
9	Lack of skilled labors (carpenter, foundation work labor, structuring work labor, fine architecture work labor)	8	10	6	480
10	Absent of staff and labor	3	3	1	9
11	Lack of supervision in cement foundation	6	2	5	60
12	Lack of supervision in wooden structure	4	5	5	100
13	Lack of supervision in roofing	3	6	5	90
14	Lack of supervision of wall assembly and wooden floor	3	3	5	45
15	Lack of supervision in fine architectural work (painting, built-in decoration, wooden details)	2	3	5	30
16	Lack of supervision in labor management (rotation system)	5	3	3	45
17	Inaccurate in working details	6	8	6	288
18	Labor strike	1	2	1	2
19	Force Majeure (Natural Disaster)	10	1	10	100

20	Lack of contingency plans and problem solving	2	2	6	24
21	Local protest to construction activities	1	2	2	4
22	Internal corruptions	2	3	2	12
23	Inappropriate construction sequences	5	2	3	30
24	Impact from extreme weather (Rain/Wind/Sun) to material	4	4	1	16
25	Impact from extreme weather (Rain/Wind/Sun) to working progress	3	3	5	45
26	Inappropriate tools used	3	4	5	60
27	Change of design by owner	4	1	1	4
28	Incomplete infrastructure for construction process	5	2	1	10
29	Unclear contract with sub-contractor	3	4	2	24
30	Under standard quality control at site	6	9	7	378
31	Unacceptable quality from sub-contractor	4	2	3	24

The RPN score for the process 5 (table 4-16) shows 3 highly scored risks. There are many discussions during the scoring process of process 3. Most of them are the severity and the occurrence of the construction process. In summary, the team member agreed that most of the problems that occurs in the construction process is caused by the factory, not the construction site operations. The problems on the construction site are narrowed down to 3 risks, which the score of each members submitted were rating high commonly in these 3 risks as well. The two of the three critical risks are about labor and their skills and accuracy in working. The other risk is about quality control standard at the factory.

Table 4-17. Summary of risk analysis in process 6 (Finishing product).

No.	Failure Mode (Risk)	Estimated Severity (S)	Estimated frequency of Occurrence (O)	Estimated Detection (D)	RPN
1	Lack of Maintenance of finished house	4	4	5	80
2	Inaccurate finishing process from labor	3	2	5	30
3	Poor House inspection of function	4	3	2	24
4	Shortage of fine tools and resources	2	3	5	30

In this process, there are no highly scored risk because the members discussed that the in this process, there are no major tasks that could damage or delay the project. These tasks will take small amount of time to fix and could be handled with without having major difficulties. This is why the RPN score of this process is commonly low from every member.

Table 4-18. Summary of risk analysis in process 7 (Overall process).

No.	Failure Mode (Risk)	Estimated Severity (S)	Estimated frequency of Occurrence (O)	Estimated Detection (D)	RPN
1	Unclear roles and responsibilities	7	8	8	448
2	Poor documentation	7	8	7	392
3	Low efficiency in information Flow and coordination	8	6	8	384
4	Ineffective Meetings	3	2	1	6
5	Low efficiency in Manager team	7	6	8	336
6	Careless working culture	7	7	7	343
7	Lack of supervision	7	8	8	448
8	Corruption	2	2	1	4
9	Lack of efficiency in project monitoring and control	8	6	8	384

The RPN score for process 7 (table 4-18) is the process with highest number of highly scored risk. There are in total of 7 highly scored risks showed in this process because this process is the risk that can occur overall the process. The members had difficulties discussing about the risks in this process and agreed that if these risks were not managed, then the project efficiency shall drop. This is why most of the members have scored highly in this process and many risks.

This is the end of the risk analysis using FMEA. The RPN score are shown in each process and there are many risks that were highly scored and discussed about. In the next step, all the risk will be allocated based on sensitivity of the RPN score. Pareto analysis will be used to separate out the critical risks in order to response to them.

4.4 Critical risk evaluation

The risks that were identified and analyzed using the FMEA scoring system will be evaluated and allocated in this section. The tool that will be used to separate these risks is the Pareto analysis (80-20 rule). In this case, the Pareto analysis can be applied to "80% of the total RPN will be 20% of the number of risks" In order to do Pareto analysis, these steps will have to be carried out.

1. Reorder the RPN of all risks from highest to lowest.
2. Calculate the total cumulative RPN of all risks
3. Determine 80% of the total cumulative RPN.
4. Determine the specific total number of risk that means 80% against the total number of risks, which should meet 20%.
5. Determine the RPN score accumulating down of the risk that matches 80% of the total cumulative RPN (cross checking of 20%)
6. The risks that are within that 80% of the accumulative will be 20% of the total number of risks, and these risks will be the critical risks that needed to be managed.

Using this method of evaluating the sensitivity of the RPN of the risk, the critical risks can be determined and therefore can be managed accordingly. The Pareto analysis method might not be exactly 80% to 20% because the number of samples in this case might be too small. The actual number of the Pareto analysis might be an approximate of the actually theoretical 80-20 number but with a small-scale sample size, it is considered acceptable.

4.4.1 Pareto Analysis

The Pareto analysis of the risks will be carried out in this section. The calculation and the critical risks will be determined at the end of this section. The result of Pareto analysis is presented in figure 4-1 and figure 4-2.

1. All the risks in every process reordered from the highest to the lowest of RPN
2. The cumulative RPN of all the risks is: 8536
3. 80% of the cumulative RPN (8536) is: approx. 6828
4. The total number of risk is 83, 20% of the total number of risk is: 16.6 ≈ 17.

5. The accumulating score cross checking of both 80% and 20%:
    a. At risk number 17, the accumulative RPN at that point is: 6546
    b. 6546/6828 = 76.68% ≈ 80%
6. The risks that will need to be managed or so called "critical risks" will be from number 1-17, which is approximately 20% of the total risk and is approximately 80% of the total RPN.

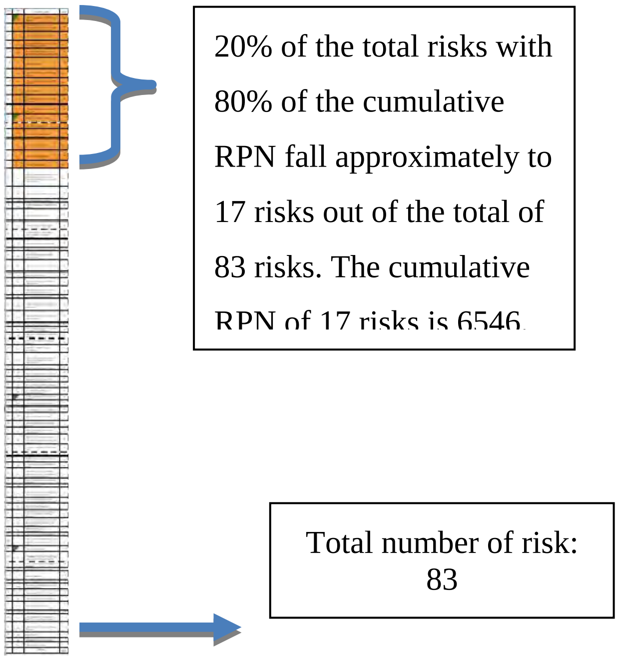


Figure 4-1. Pareto analysis of critical risks.

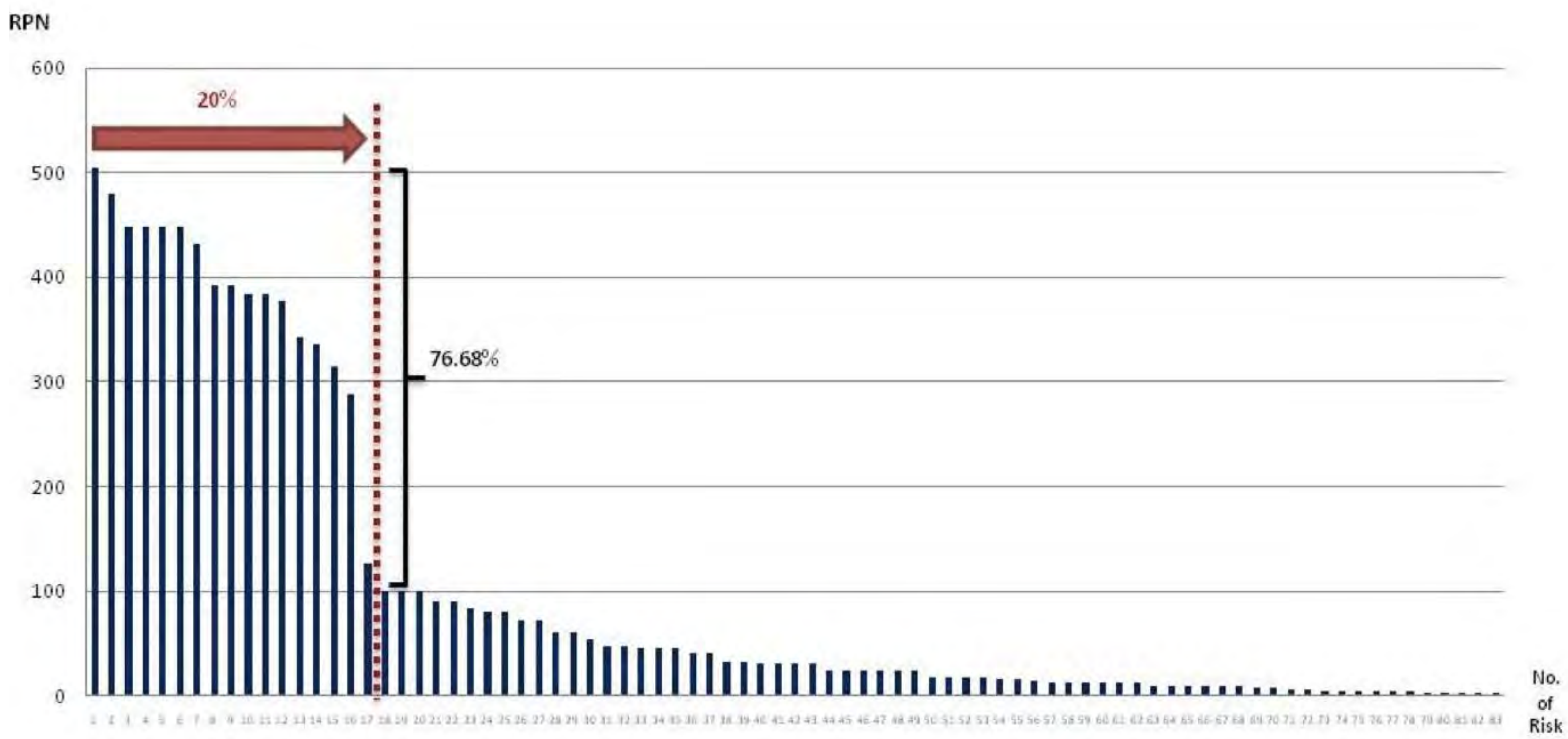


Figure 4-2. Pareto analysis of RPN and number of risks.

4.4.2 Critical Risks

After the Pareto Analysis, the critical risks are determined. The total number of critical risks is 17, which is summarizing as follow:

Table 4-19. Critical risks from Pareto analysis.

Risk NO.	Risk from process	Failure Mode (Risk)	RPN
1	4.10	Under standard quality control (Q.C.) at factory	504
2	5.9	Lack of skilled labors (carpenter, foundation work labor, structuring work labor, fine architecture work labor)	480
3	7.1	Unclear roles and responsibilities	448
4	1.2	Lack of information gathered by architect on the total project direction	448
5	4.6	Insufficient skilled labors (carpenters, painters and general wood working skills)	448
6	7.7	Lack of supervision	448
7	1.9	Inaccurate shop drawing produced and gathered	432
8	2.1	Unclear architectural design for material breakdown	392
9	7.2	Poor documentation	392

10	7.3	Low efficiency in information Flow and coordination	384
11	7.9	Lack of efficiency in project monitoring and control	384
12	5.30	Under standard quality control at site	378
13	7.6	Careless working culture	343
14	7.5	Low efficiency in Manager team	336
15	2.6	Poor material resource plan	315
16	5.17	Inaccurate in working details	288
17	2.9	Poor information gathering from site and production factory to create master schedule of production and construction synchronization	126

The column of "risk from process" is the information showing which process the specific risk came from. Therefore knowing which process has the most critical risks in it. The summary of the critical risks process:

- Process 1 = 2 critical risks
- Process 2 = 3 critical risks
- Process 3 = 0 critical risk
- Process 4 = 2 critical risks
- Process 5 = 3 critical risks

- Process 6 = 0 critical risk
- Process 7 = 7 critical risks

The summary of the processes of critical risks shows that process 7 contains the highest risks can is the risks that involve the overall process. The highest score of RPN is from process 4 (factory operations) with 504 and the lowest score of RPN is from process 2 (material checking) with 126.

These critical risks will be brought up to solve in meeting number 5. Then the RPN will be recalculated for improvement. After that, the implementation of the risk response will be done.

4.5 Preventive Actions and Risk Response

In meeting 5, the team is asked to discuss about the critical risks. The approach that the team decided to manage these risks is to break the critical risks down to the root cause and then solve it. As the team discussed about the critical risks, a linkage between them were found. The linking of cause and effect that puts all the critical risks into a relationship, the chain reaction of one risk after another causing a disaster to the project. In this section, the linkage, the root cause and the preventive actions will be shown and at the end, a new RPN score will be calculated.

4.5.1 Linking critical risk

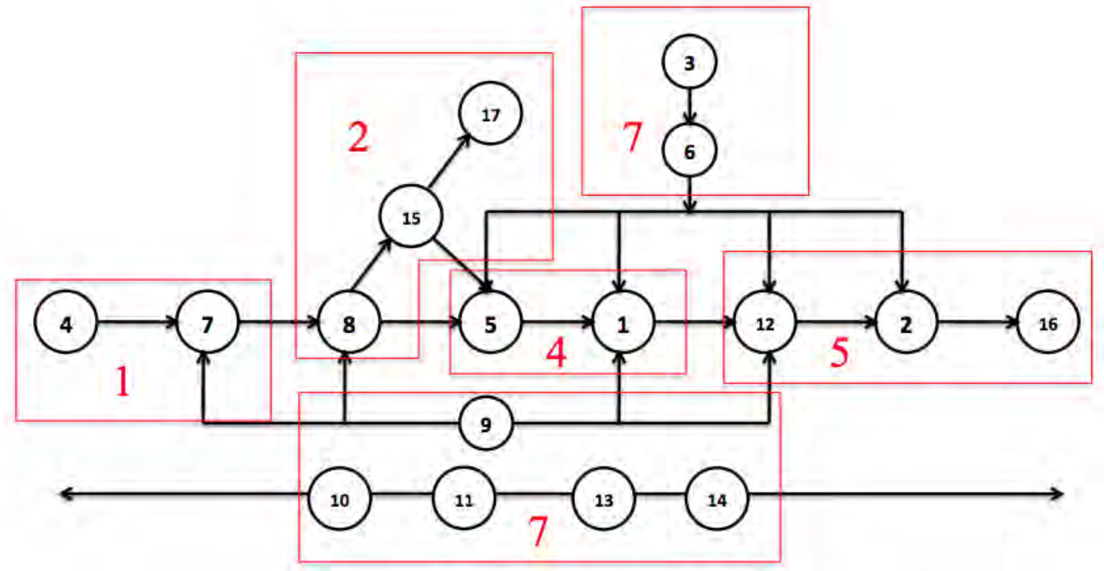


Figure 4-3. The linkage of the sequence and consequence of the critical risks.

The linkage of the critical risks (figure 4-3) the linking events of the risks from the beginning to the end of the project. The numbers are the number of risks that that is assigned to the critical risks as shown in table 4-19 and the number in red is the process that the risks are in.

The linking sequence and consequence of the critical risks starts with number 4 (Lack of information gathered by architect on the total project direction" where the architect understands the objective of the customer and will need to gather information about the project from various places and sources such as the design, the surveying of the location etc. From this risk, the consequence will carry out to be risk number 7, which is "Inaccurate shop drawing produced and gathered". The shop drawing is the result from poor documentation of show drawing from the previous designs and projects, and also the lack of information gathered by the architect. The inaccurate shop drawing will then result to unclear architectural plan for material breakdown or risk number 8. The risk number 8 will then result to risk number 15 (Poor material resource plan), where an unclear material resource plan will then be the root cause for risk 17 (Poor information gathering from site and production factory to create master schedule of production and construction synchronization) as well. From risk number 15, the critical risk will move to the risks in process 4 (factory operations). In this process, risk number 5 (Insufficient skilled labors) and risk number 1 (Under standard quality control (Q.C.) at factory) will be the process that follows each other. Then in the risk number 12 (Under standard quality control at site), 2 (Lack of skilled labors) and 16 (Inaccurate in working details) are from the process 5 (construction site operations. Each risk is the sequences of each other and has more or less effect to each other. Risk number 5 and number 1 will combine together creating a bigger risk at risk number 12. Risk number 12 and risk number 2 will be a part of the result of risk number 5.

The critical risks from process 7 (overall process) are the risks that affect many other risks in many processes at the same time. Risk number 3 (Unclear roles and responsibilities**)** one of the root cause of risk number 6 (Lack of supervision). In the same way, the risk number 9 (Poor documentation), number 10 (Low efficiency in information Flow and coordination), number 11 (Lack of efficiency in project monitoring and control), number 13 (Careless working culture) and number 14 (Low efficiency in Manager team) are affecting the other critical risks in various processes. This is how all the critical risks are linked together to create a chain of effect.

4.5.2 Identifying root cause

To identify the root cause, the suggestion of using fish bone analysis (quoted in chapter 2 as influence diagram or Ishikawa diagram) and fault tree analysis is suggested to them. Influence diagram is a useful tool to find the cause of the problem and an easy way to look at them and fault tree analysis can develop the causes to find deeper and more analytical causes of the critical risks. The team decided to break all the risks into these diagrams first so all of them can be prevented correctly and to the right source and right root cause.

Risk number 1: Under standard quality control (Q.C.) at factory

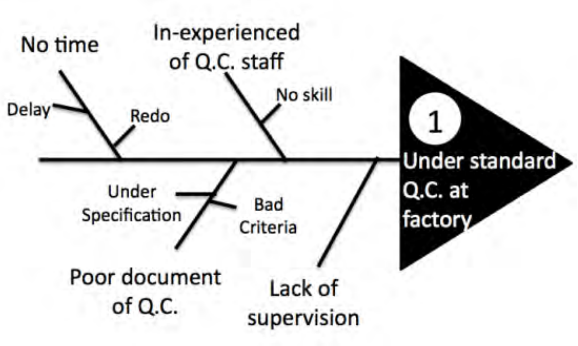


Figure 4-4. Fish bone analysis of critical risk number 1.

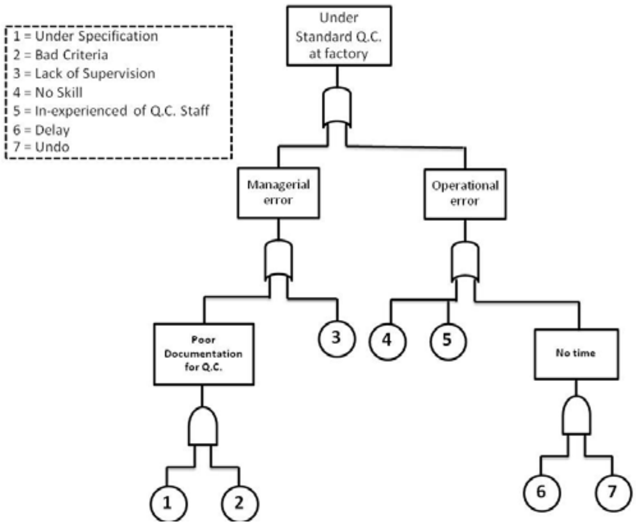


Figure 4-5. Fault tree analysis of critical risk number 1.

There are four main causes to the risks number 1(figure 4-4 and 4-5). The discussion about this risk has concluded that the risk would not occur if it is properly documented and properly controlled and supervised. The team has concluded that the control of quality of the production unit cannot be relied by a single staff but should be bind with documents and supervisions.

Risk number 2: Lack of skilled labors (carpenter, foundation work labor, structuring work labor, fine architecture work labor)

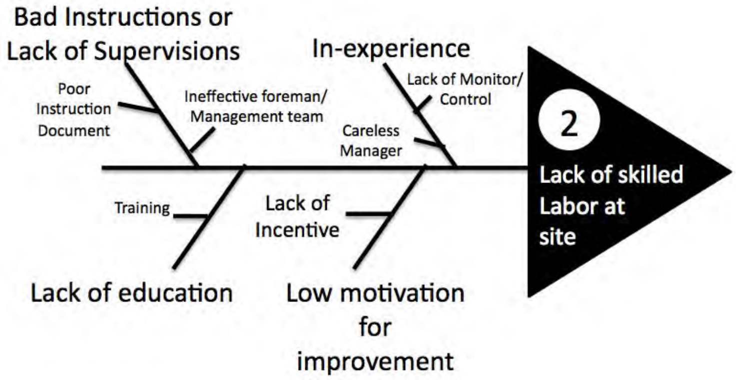


Figure 4-6. Fish bone analysis of critical risk number 2.

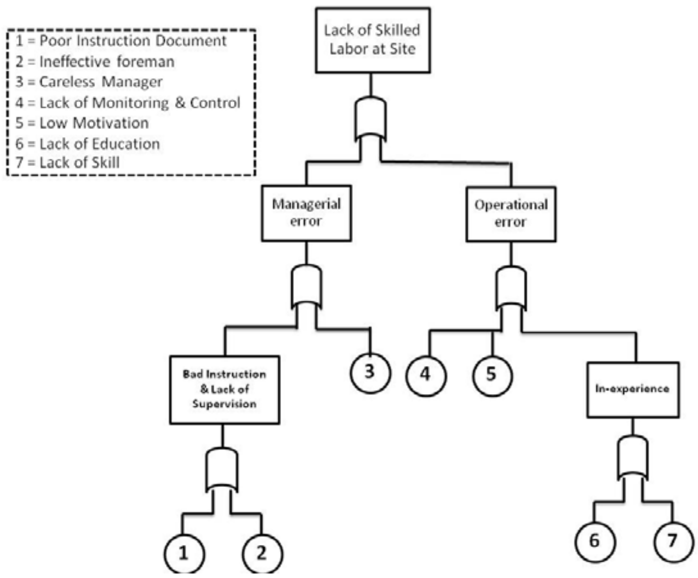


Figure 4-7. Fault tree analysis of critical risk number 2.

The discussion about the skill of labors at the site from the risk team concluded (figure 4-6 and 4-7) that because the prefabricated house construction is still very new for most of the Thai labors. It is not expected that the labor can perform as the manager expects them to be. Therefore, the team suggested that the risk root cause should link with the lack of supervision, low motivation and poor documentation.

Risk number 3: Unclear roles and responsibilities

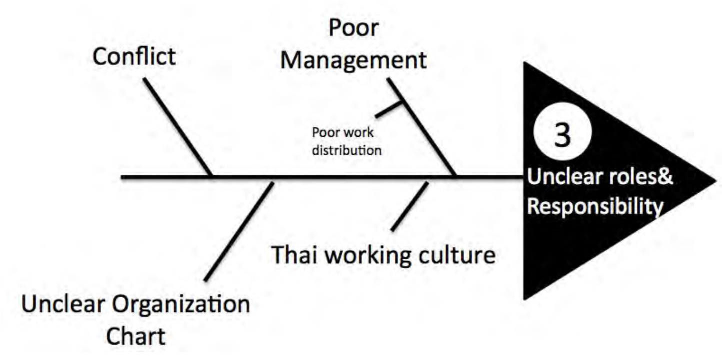


Figure 4-8. Fish bone analysis of critical risk number 3.

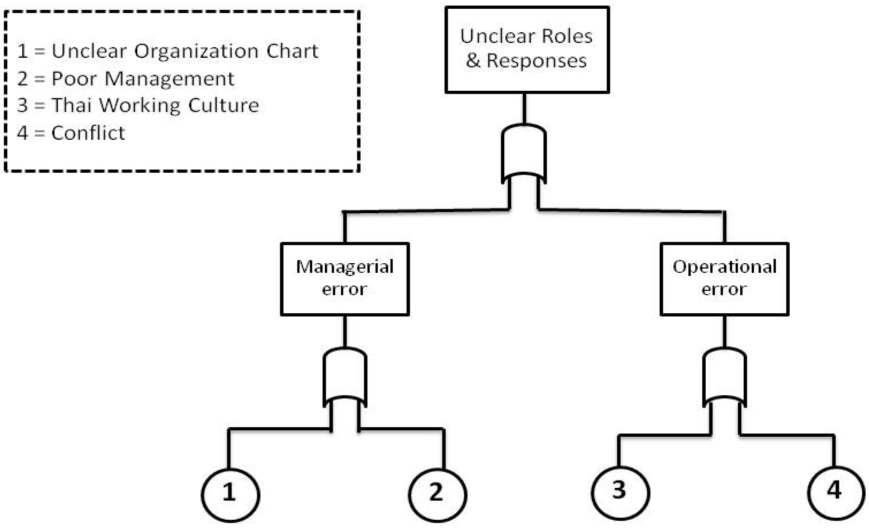


Figure 4-9. Fault tree analysis of critical risk number 3.

The root cause of this risk can be summarized (figure 4-8 and 4-9) into 4 causes but the main cause that the risk team suggested that should be managed, is the cause from unclear organization chart and poor management. Conflict and Thai working culture is something uncontrollable but can be improved in long term. To improve the clearness in roles and responsibilities, the risk team decided to improve the organization chart to a more effective one.

Risk number 4: Lack of information gathered by architect on the total project direction

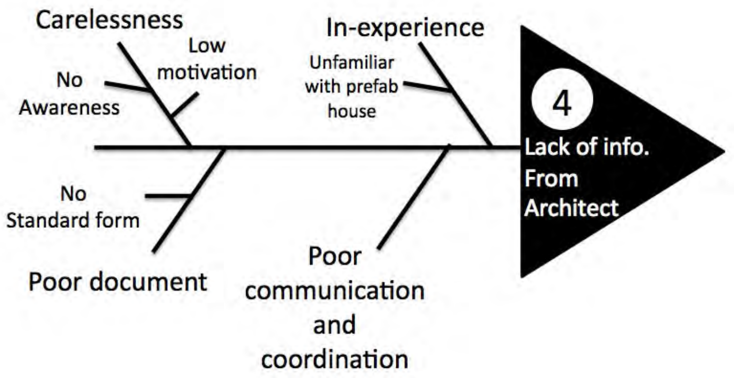


Figure 4-10. Fish bone analysis of critical risk number 4.

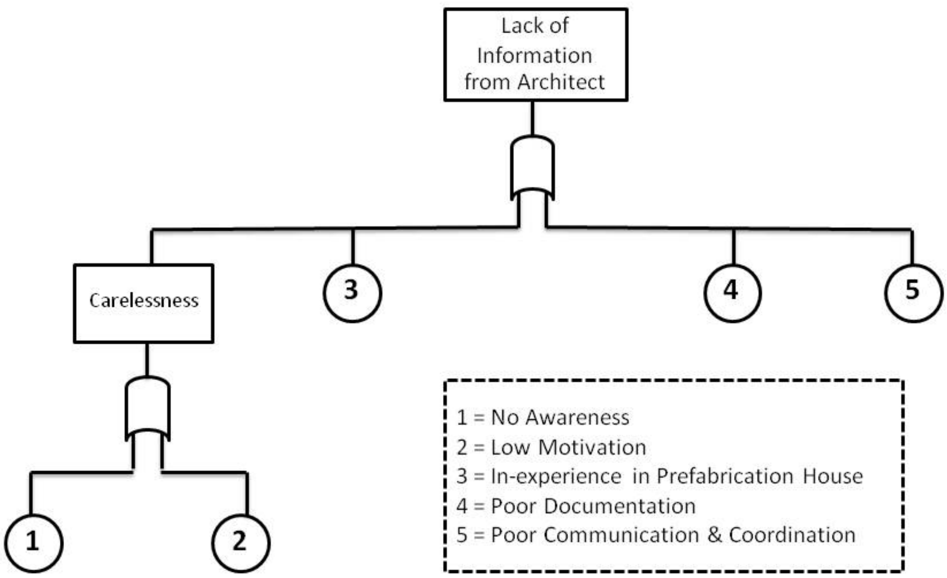


Figure 4-11. Fault tree analysis of critical risk number 4.

The risk number 4 is mainly about the information that the architect gathered about the project (figure 4-10 and 4-11); therefore the root cause will be about the lack of information by various methods such as poor documentation, poor communication and coordination, or careless. The team discussed about this and decided that the document will be the root cause for this risk.

Risk number 5: Insufficient skilled labors (carpenters, painters and general wood working skills)

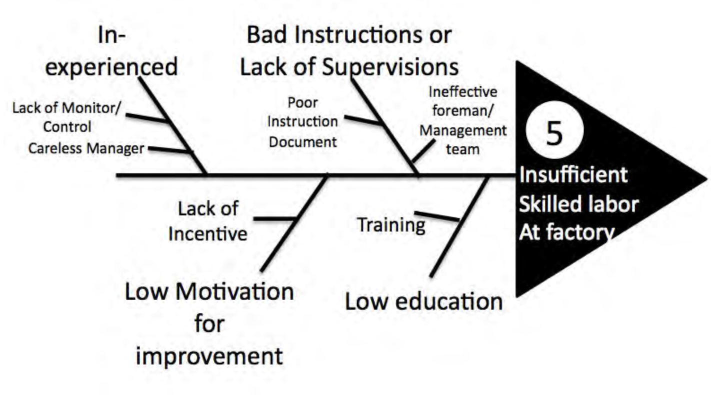


Figure 4-12. Fish bone analysis of critical risk number 5.

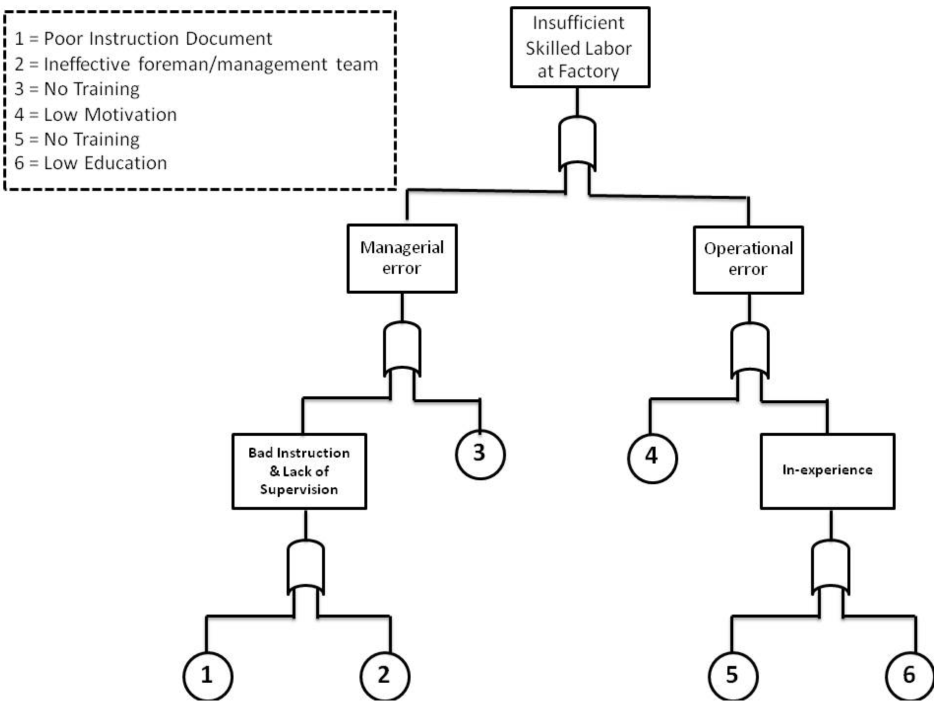


Figure 4-13. Fault tree analysis of critical risk number 5.

Finding the root cause of risk number 5 (figure 4-12 and 4-13) is similar to the risk number 2. The labor issue is linked to the controlling and supervising aspects of the managers. There are many issues that could cause the problem but for the risk management team, they concluded that the root cause is to control them. Some managers suggested that another solution is to increase motivation.

Risk number 6: Lack of supervision

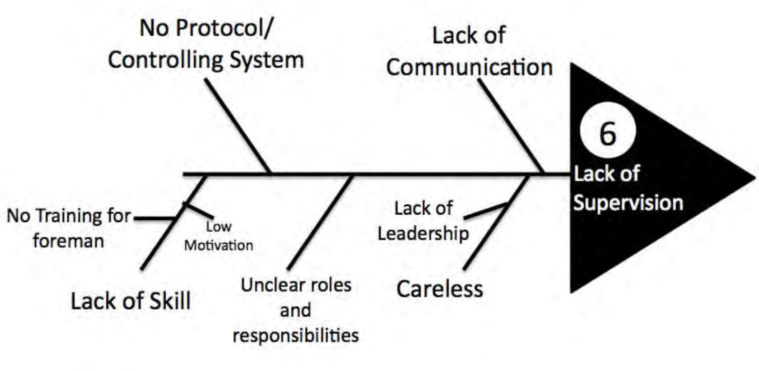


Figure 4-14. Fish bone analysis of critical risk number 6.

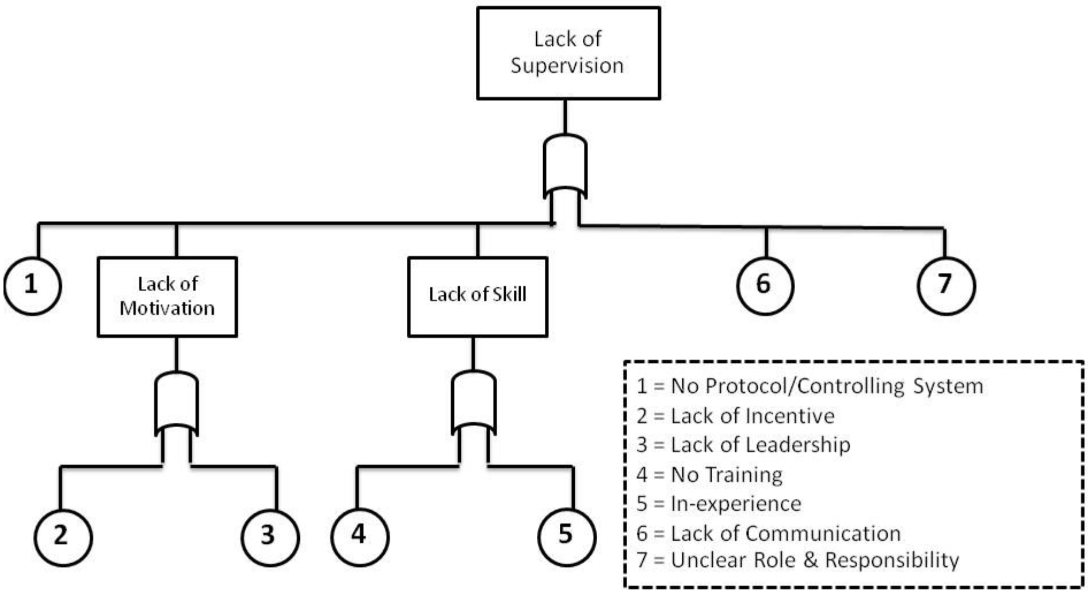


Figure 4-15. Fault tree analysis of critical risk number 6.

The major root cause for risk number 6 (figure 4-14 and 4.15) is summarized by the team that it narrows down to unclear roles and responsibilities and no protocol/ controlling system of the staff. There are many other root causes that can cause the critical risk such as lack of leadership or low motivation. However, there is no structural way to prove or test such cause, therefore the team decided to use the root cause of something controllable.

Risk number 7: Inaccurate shop drawing produced and gathered

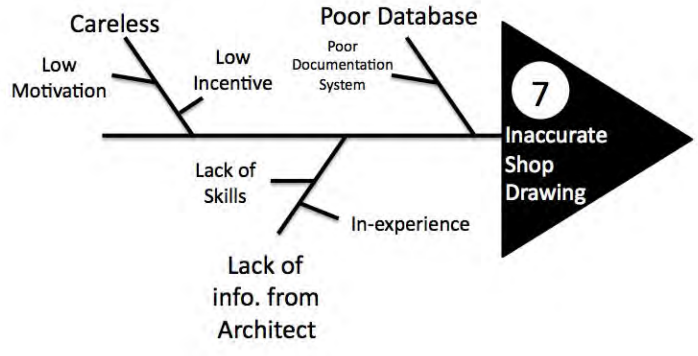


Figure 4-16. Fish bone analysis of critical risk number 7.

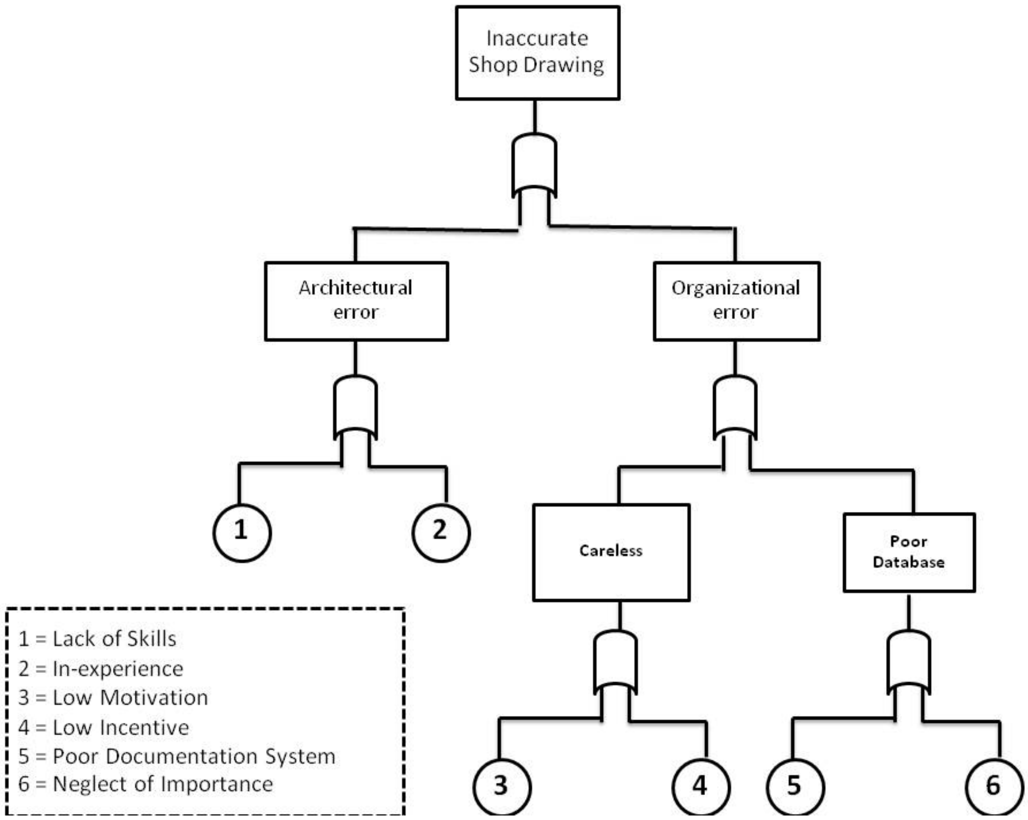


Figure 4-17. Fault tree analysis of critical risk number 7.

The root cause for the inaccurate shop drawing can be dissected into 3 main branches (figure 4-16 and 4-17). It can come from the lack of information from architect, poor database or carelessness. The poor database means that the show drawing collected from previous projects is not accurate. The team concludes the root cause to this risk that the architect is the key root to this risk.

Risk number 8: Unclear architectural design for material breakdown

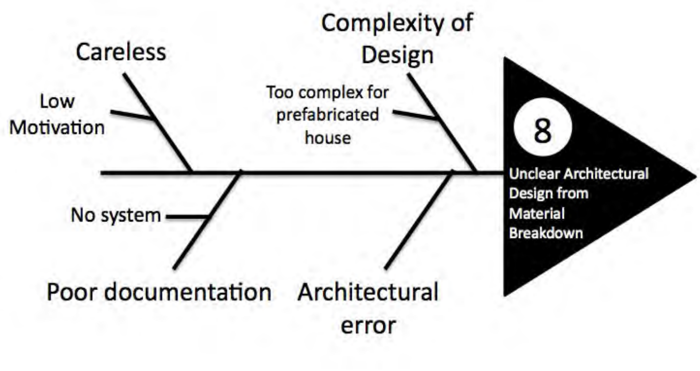


Figure 4-18. Fish bone analysis of critical risk number 8.

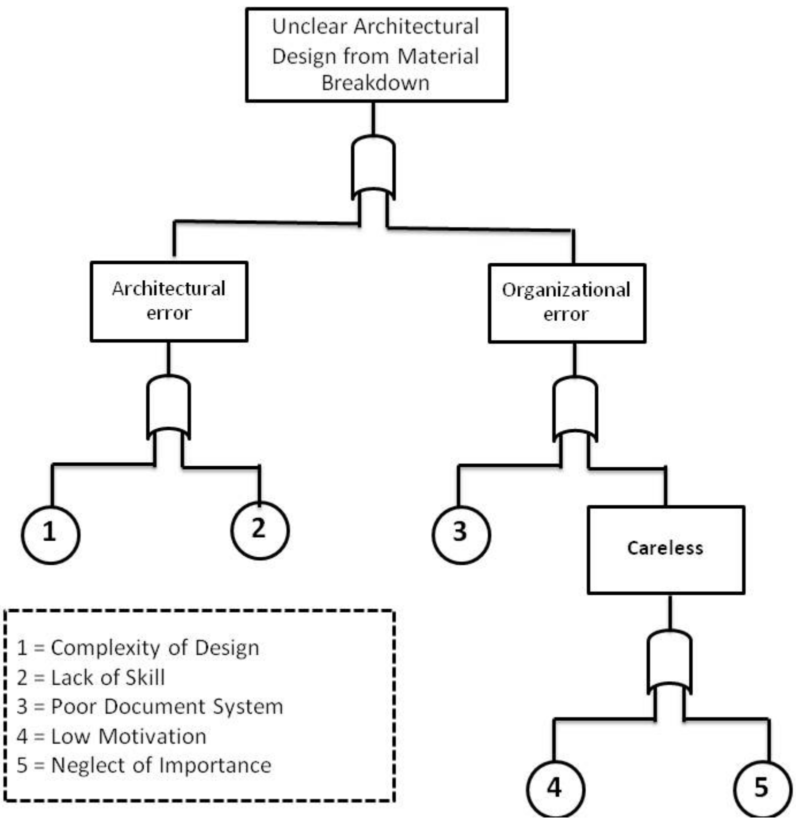


Figure 4-19. Fault tree analysis of critical risk number 8.

For this critical risk, the team did not take a long time to see that the problem comes from two sources, the architect or the documentation (figure 4-18 and 4-19). Either one of these problems will be the root cause for this risk.

Risk number 9: Poor documentation

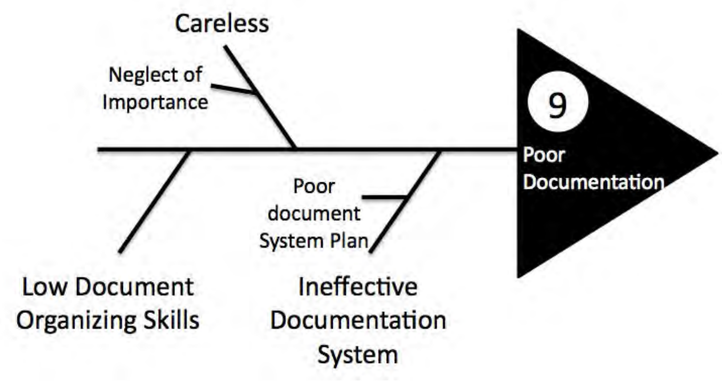


Figure 4-20. Fish bone analysis of critical risk number 9.

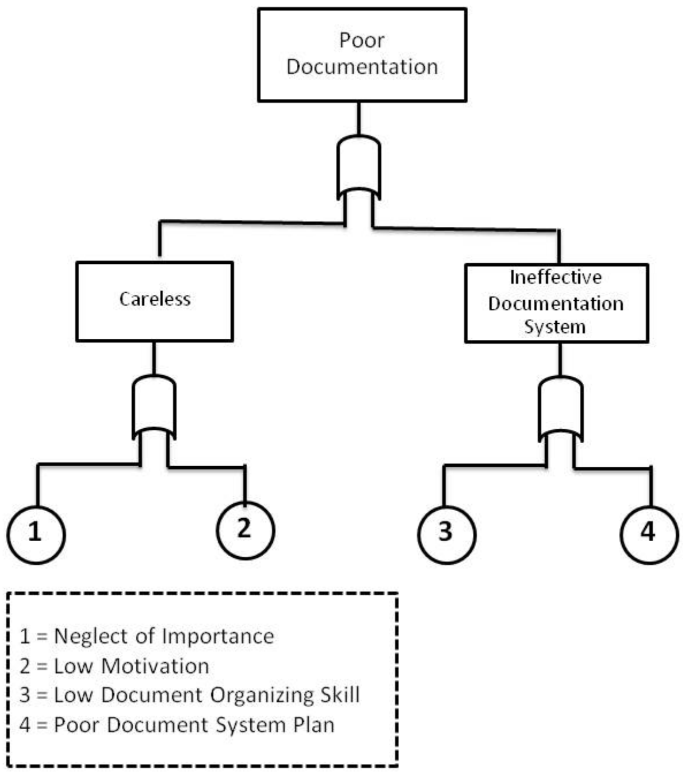


Figure 4-21. Fault tree analysis of critical risk number 9.

This risk from poor documentation (figure 4-20 and 4-21) is one of the critical risks that the team is concern on. The team feels that this risk is the many root cause to the other risks therefore should put to variety of to solve it because the solving this risk helps lower the RPN to the other critical risks too.

Risk number 10: Low efficiency in information Flow and coordination

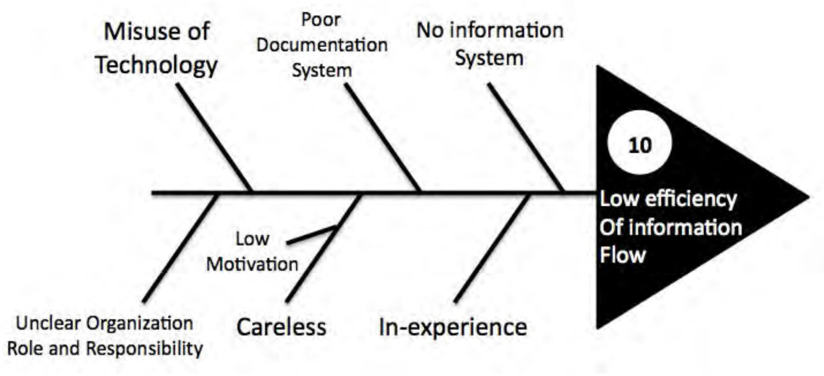


Figure 4-22. Fish bone analysis of critical risk number 10.

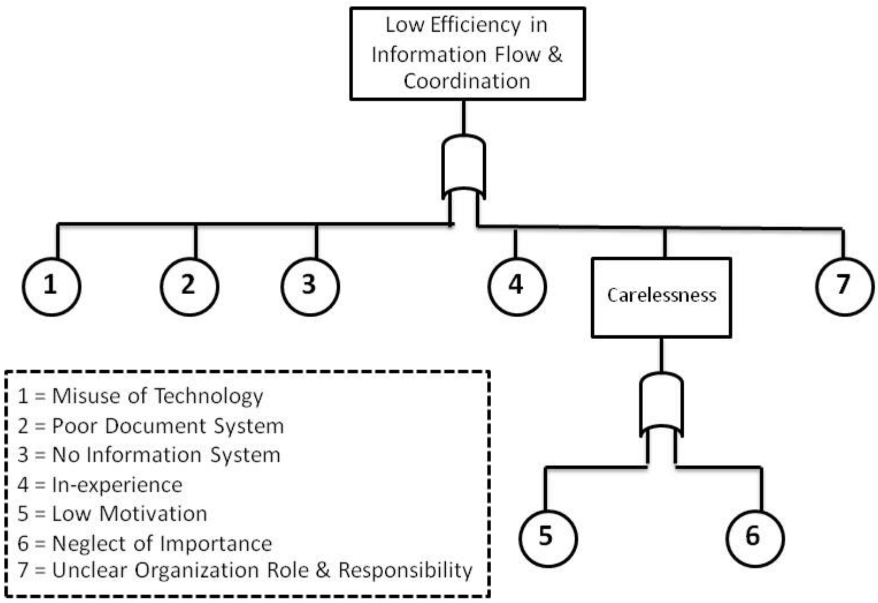


Figure 4-23. Fault tree analysis of critical risk number 10.

In this critical risk (figure 4-22 and 4-23), there are discussions concerning that a construction project cannot be accomplished without a good information flow. There are many root causes to this problem, where each root cause will need good approach to solve them. The team concentrated on discussing about the “poor documentation system” for the main cause.

Risk number 11: Lack of efficiency in project monitoring and control

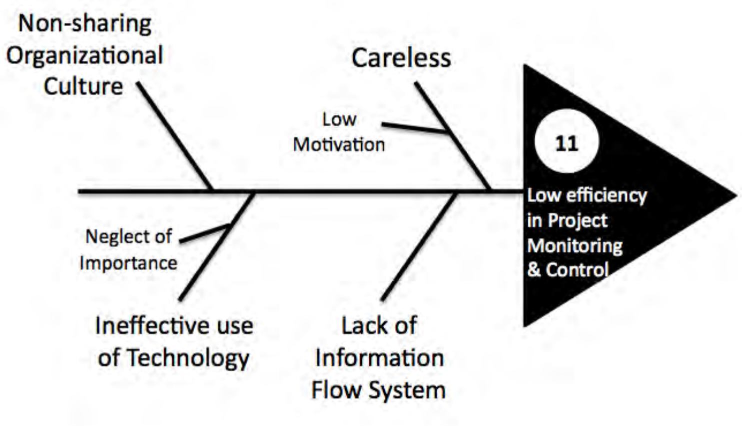


Figure 4-24. Fish bone analysis of critical risk number 11.

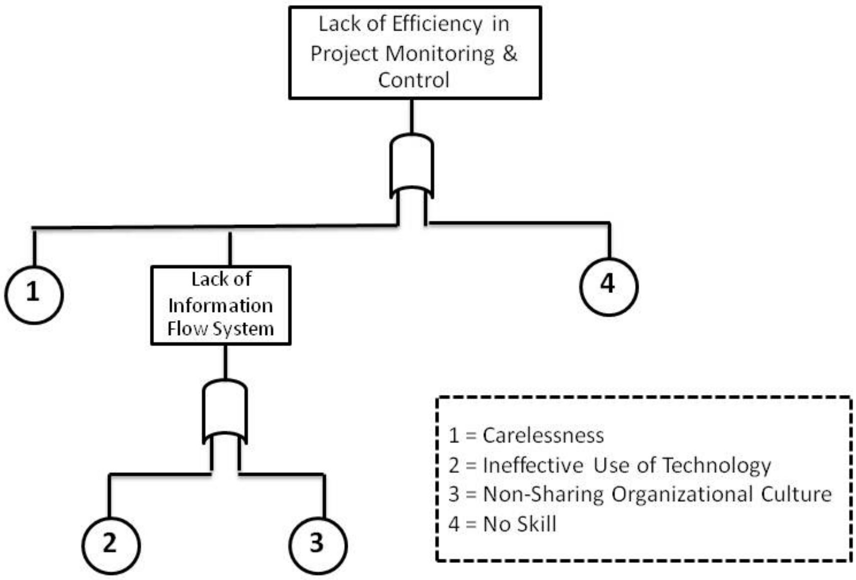


Figure 4-25. Fault tree analysis of critical risk number 11.

Company ABC is a SME business; therefore the project monitoring and control that requires project management skills might not be available in both skills and technologies. Therefore, the major root cause for this risk (figure 4-24 and 4-25) is because the company does not have the system to support project monitoring and controlling.

Risk number 12: Under standard quality control at site

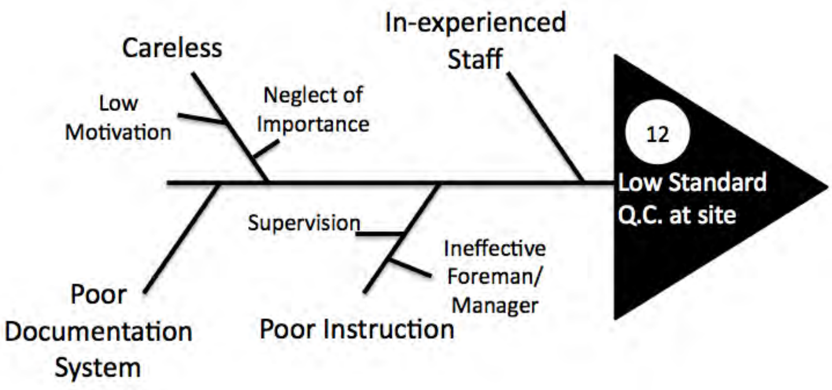


Figure 4-26. Fish bone analysis of critical risk number 12.

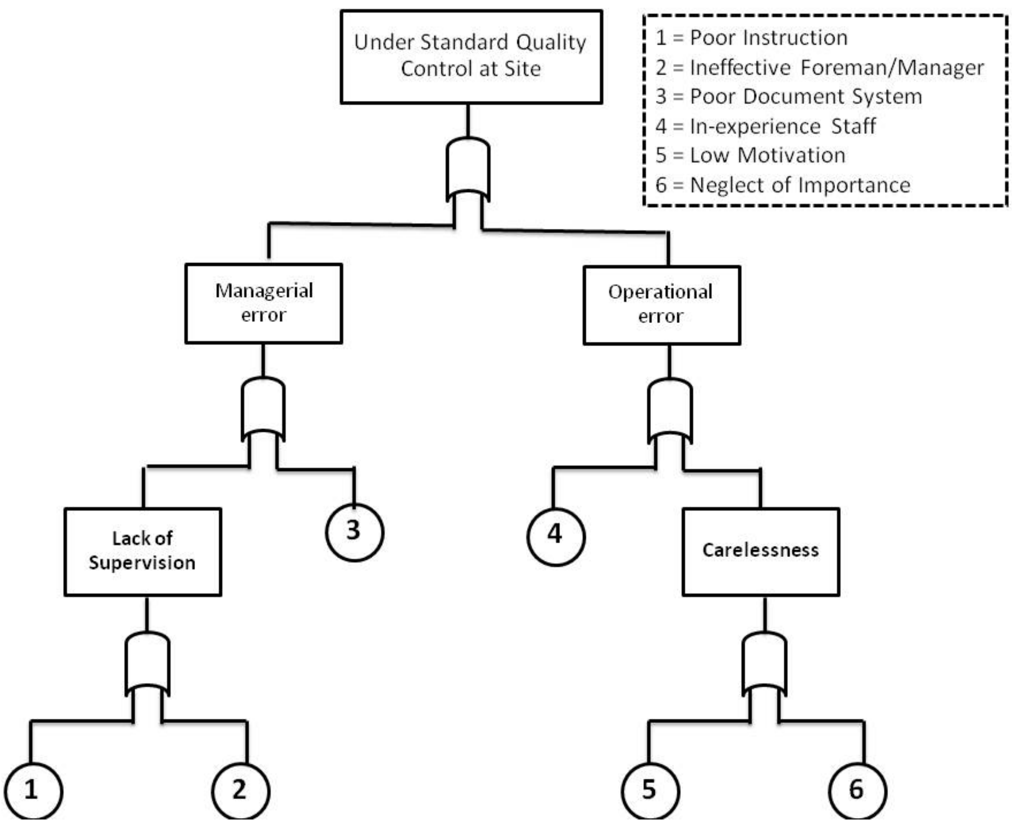


Figure 4-27. Fault tree analysis of critical risk number 12.

In this critical risk number 12 (figure 4-26 and 4-27), the main root cause is from the carelessness of the staff and the poor documentation system to control it. It is a result from the lack of care from the managers as well.

Risk number 13: Careless working culture

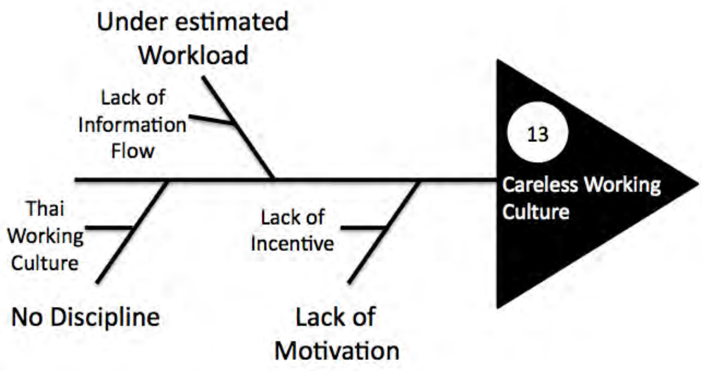


Figure 4-28. Fish bone analysis of critical risk number 13.

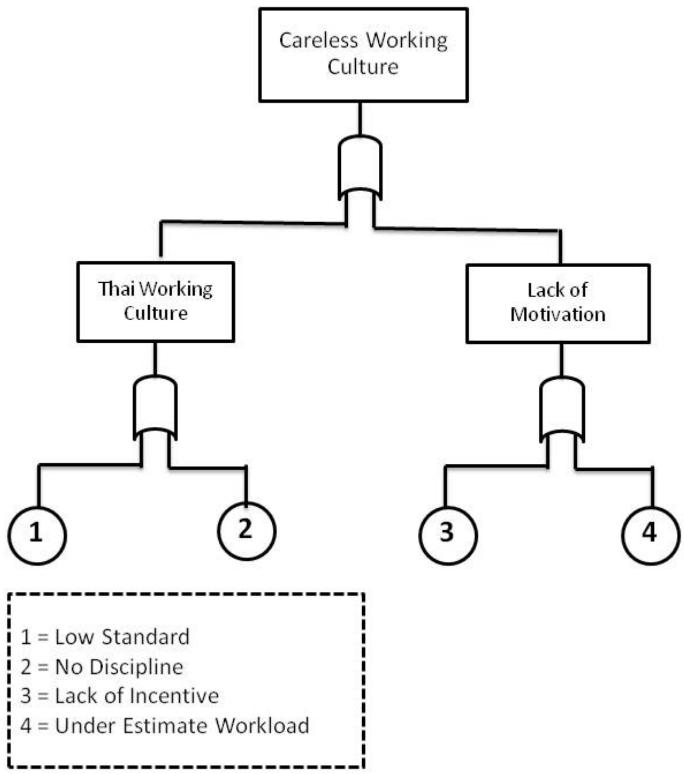


Figure 4-29. Fault tree analysis of critical risk number 13.

The careless working culture of Thai workers, as the member discussed about the root cause comes from (figure 4-28 and 4-29) the lack of incentive and motivation of staff. This is because they value extrinsic values from work, which mostly does not match their living costs. When the salary does not match the cost of living, it will create an effect of low motivation.

Risk number 14: Low efficiency in Manager Team

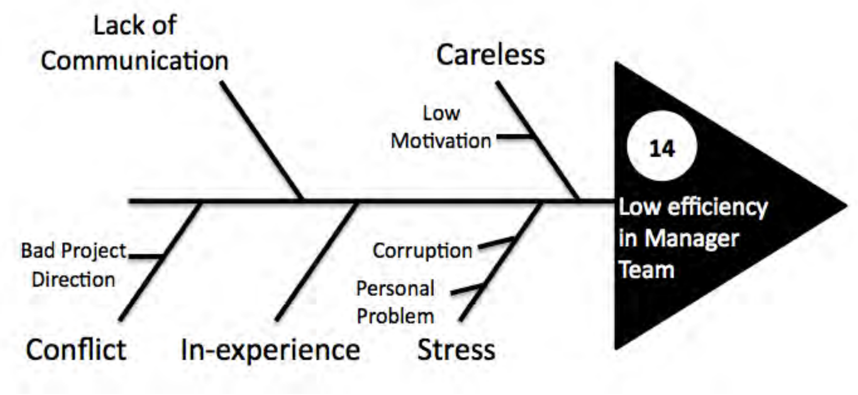


Figure 4-30. Fish bone analysis of critical risk number 14.

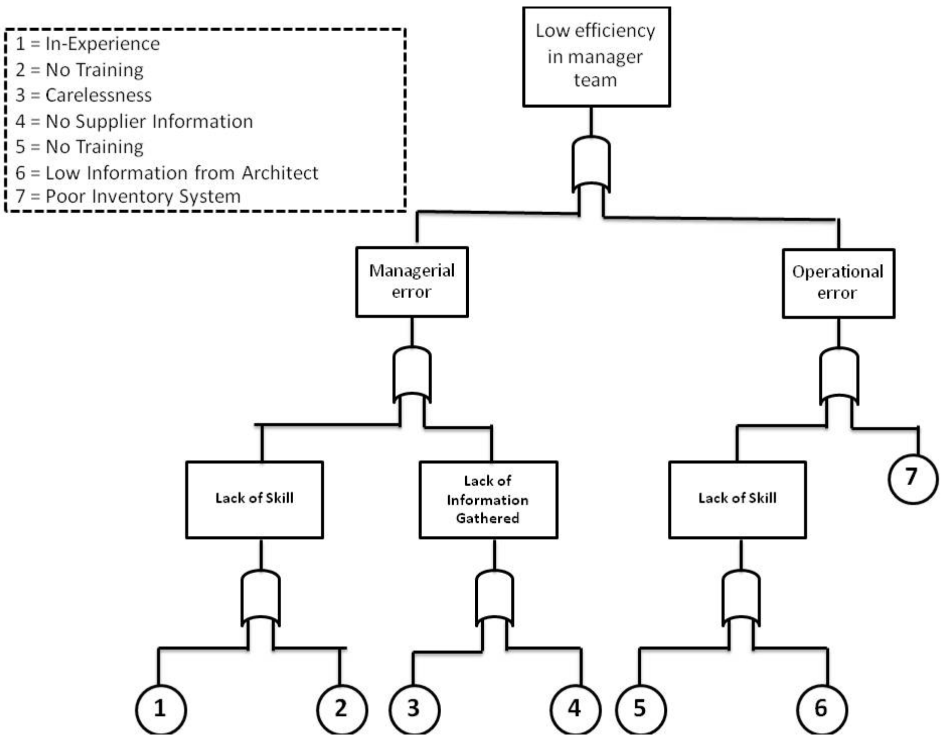


Figure 4-31. Fault tree analysis of critical risk number 14.

This critical risk is one of the risks that took some time to analyze because the managers are all in the risk management team members. The main root cause of this risk can be summarized (figure 4-30 and 4-31) to "lack of communication" because the manager team are experienced and devoted to the project but without communication, they cannot coordinate together very well.

Risk number 15: Poor material resource plan

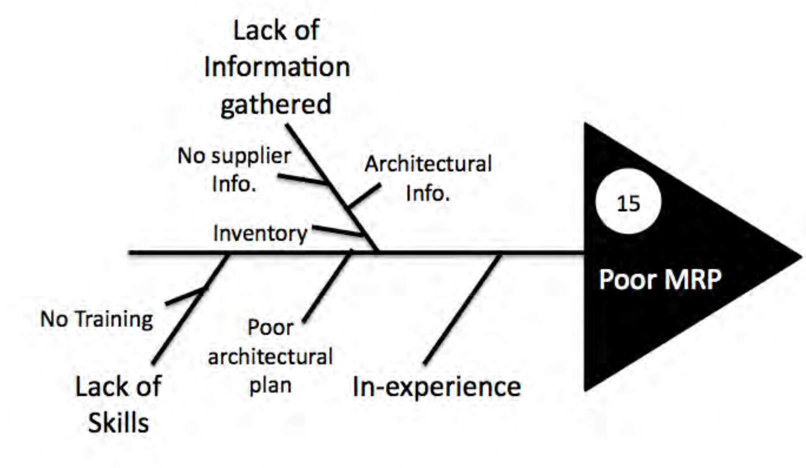


Figure 4-32. Fish bone analysis of critical risk number 15.

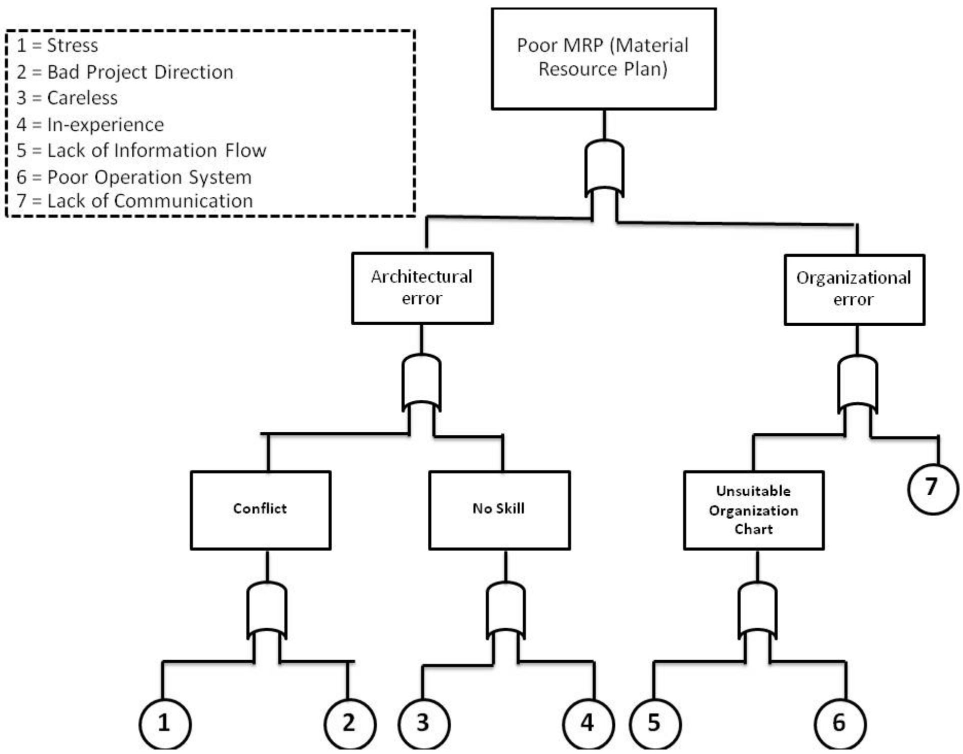


Figure 4-33. Fault tree analysis of critical risk number 15.

The material resource planning, as explained by the production manager, is depending on the information about the project. The information about the project can be gathered and given. Therefore, the risk (figure 4-32 and 4-33) lays in the error of information gathered or the error from communications of information given.

Risk number 16: Inaccurate in working details

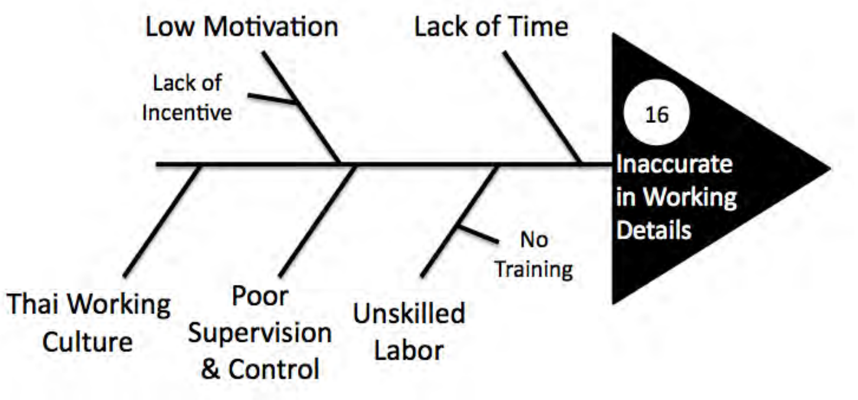


Figure 4-34. Fish bone analysis of critical risk number 16.

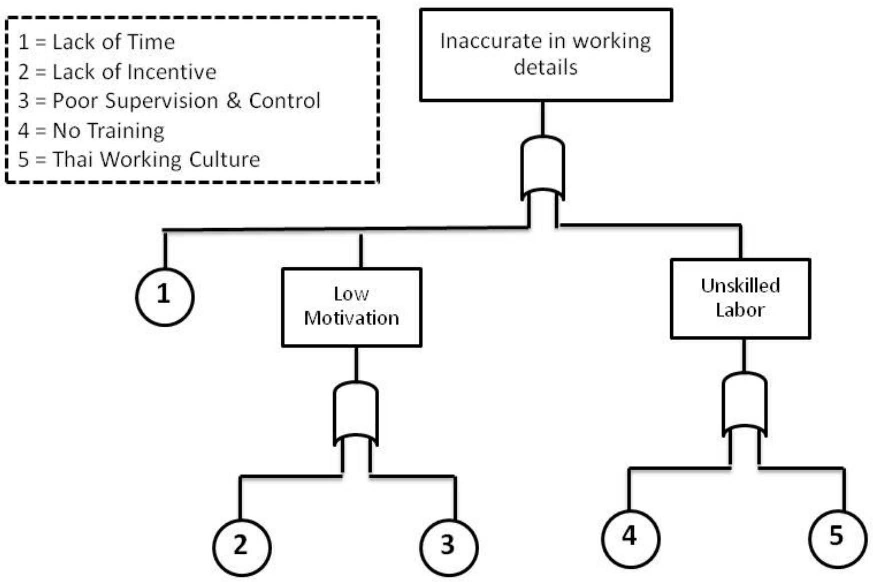


Figure 4-35. Fault tree analysis of critical risk number 16.

The critical risk number 16 (figure 4-34 and 4-35) is about the care and the devotion that the staff gives to their work. The team thinks that the main cause of this critical risk is from the lack of time and low motivation from the staff. Accurate in working details must be coming from an intrinsic value to the work.

Risk number 17: Poor information gathering from site and production factory to create master schedule of production and construction synchronization

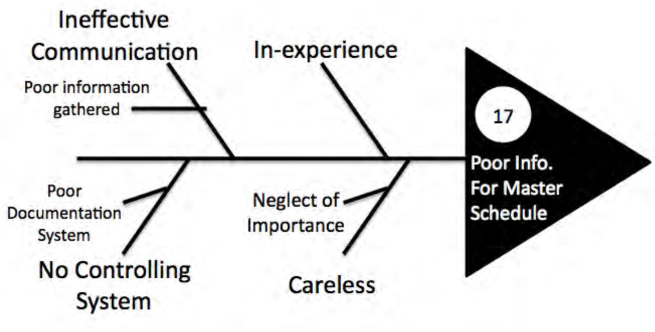


Figure 4-36. Fish bone analysis of critical risk number 17.

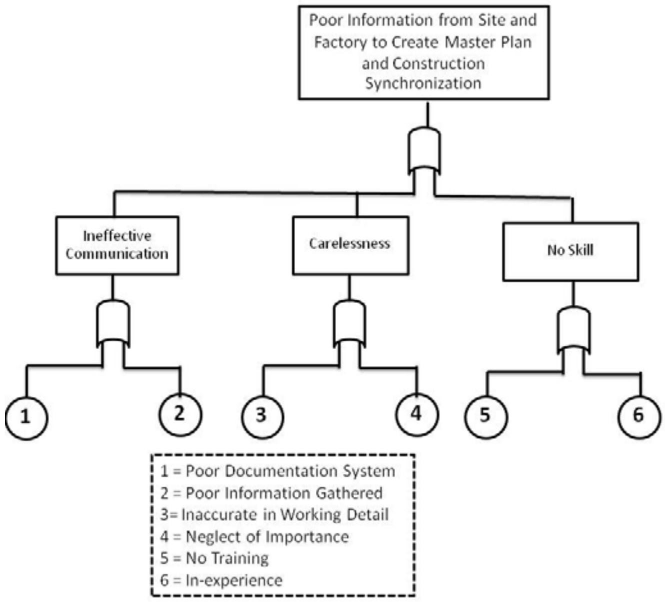


Figure 4-37. Fault tree analysis of critical risk number 17.

The final critical risk is analyzed (figure 4-36 and 4-37) by the risk management team and found out that the root cause for this risk is mainly "neglect of importance". This causes a chain of effect because when the staff ignores this process, there is no system designed to manage this process. The lacking in controlling system will result to lack of information gathered for the master schedule, therefore creating a poor master schedule plan.

When all of the root causes of the critical risks were determined, solving the problems to the root cause can prevent the critical risks. In some occasions, the root cause is something uncontrollable so the risks must be controlled by other methods.

After the critical risk prevention, the team will be asked to re-score the RPN again to assure the score of each risk reduces.

4.5.3 Preventive actions

All of the root causes for the critical risk is a key to solve them. In the fifth meeting, the risk management team is asked to discuss about the preventive actions. The preventive actions to manage the critical risk should reduce the RPN score of each of them. To reduce the score, at least one of the severity, occurrence or detection will have to change. The team came up with several methods to try and manage these risks. Each one of them will be explained which risks it solved and what is the benefit of doing it. After that, some of the preventive actions that could be implemented or carried out will be done. However, some of them might take more time or opportunity.

From all the 17 risks, the team has summarized them into its root cause and then prepares the preventive actions for them. There are all together 6 preventive methods to solve each risk. The risks are group together from their processes, root causes and their linkages, therefore the preventive method will be effective to many of them. The preventive methods are listed and explained as follow:

1. **Training to foreman**

To manage the risk from the cause related to skills, training the staff is a very good way of preventing the risk from happening. Prefabricated house construction requires a lot of special knowledge about material, woodworking, structural works and the concept of working method. Regular foremen do not usually possess these skills. The risk that concerns this preventive act is about the skills of the labor. However, all the team members concluded that no matter how they train the labor, there is no reliable way to keep them within the company and that the nature of Thai labor is they do not move too far away for other construction project. This is why the team will create a training course for the foreman. The foreman is perhaps one of the most important factors, which directly affects the labor and their working skills. A good foreman will be able to control and train their labors, in every aspects of the construction to finish the work with quality on time. The number of courses will depend on how complex the design and the house would be. For this project, one of the most important courses it needs is to train about the material Shera, because many of the workers do not have the skills.

Preventing critical risk number: 2 (Lack of skilled labors at site), 5 (Insufficient skilled labor at factory), 6 (Lack of supervision), 11 (Lack of efficiency in project monitoring and control), 13 (Careless working culture), 16 (Inaccurate in working details)

Benefits of preventive actions:

- Higher quality constructions from labor
- Faster construction time and faster repairing of defects
- More specialized foreman about prefabricated house constructions
- Improve labor working culture over time
- Smoother operations at construction site
- Better problem solving skills at construction site

Effecting SOD: Lower severity and occurrence

2. **Creating standard forms and documentations for various processes**

The main reason why Company ABC does not have a good information flow, poor monitoring and control of the project and understand quality control is because it is concluded that the document of the processes is not acceptable. Documentation system is the core to control a project. It gives evidence of work and how the work is done, and it also keeps standard quality of work. A process without documentation will not be kept statistically for improvement or investigation. Documentation is also a good way to be a standard guidance to all employees that the work they have to do will be according to these steps and following the information that needed to be filled. Documentation system such as training documentation, record of performance by staff or labor can enormously increase how a project manager controls and monitor the project. The documentations required for the projects are available in Appendix as an example of how the document should be and what is the containing information.

The reason why this company does not have a good documentation system is because their original business is not construction. They are manufacturers of machineries for iron and wood, however they did not take the time to set up a documentation system because the neglect of its importance. The past projects were also handled poorly and the result was a major delay.

Preventing critical risks number: 1 (Under standard quality control (Q.C.) at factory), 9 (Poor documentation), 10 (Low efficiency in information Flow and coordination), 11 (Lack of efficiency in project monitoring and control) and 12 (Under standard quality control at site)

Benefits of preventive actions:

- Better information flow between departments
- Increase coordination tendency between staff
- Increase structural approach to working culture and thinking method
- Better standard setting from managerial level to lower staff
- Improve project monitoring and control ability in quality and performance
- Availability of statistical record for improvement and evidential control
- Clear responsibilities to certain work and processes

Effecting SOD: Lower <u>occurrence</u> and <u>detection</u>

3. **Increase frequency of meetings with proper documentation**

The management of the project will depend on the coordination and efficiency of the manager team. For an effective project, the managers and involving staff will have to meet for discussions and coordination of the project. In the present time, the staff will usually meet up for a meeting once every two weeks. However in the prefabricated house construction, two weeks is the end of a phase for a house. The frequency of the meeting cannot be the same as a conventional construction. Therefore this preventive action is to increase the frequency of the meetings to be once a week so the staff can work more effectively with faster follow ups and updating of status from each department. The problems between the two-week meetings no longer have to wait until the next meeting or solved by each department without coordination first. However, the meeting will have to be recorded formally about all its content unlike the meetings the company conducted in the past several times. Formality and structural approach to the meeting (using meeting forms given in Appendix) will increase the efficiency of the total project.

Preventing critical risks number: 3 (Unclear roles and responsibilities), 6 (Lack of supervision), 10 (Low efficiency in information Flow and coordination), 11 (Lack of efficiency in project monitoring and control) and 14 (Low efficiency in Manager team)

Benefits of preventive actions:

- Establish a clear role and responsibilities for each task and processes
- Advising and discussion issues about problems from every staff in the meeting
- More frequent update of information about each processes and coordinate staff
- Increase motivation from communications
- Increase efficiency through information flow, motivation and communication
- Set project vision from upper management downstream to lower management and staff
- Increase problem solving skills
- Increase decision making skills for all staff due to increasing of information flow

Effecting SOD: Lower severity, occurrence and detection.

4. **Increase in incentive and welfare to foreman and staff**

This preventive method will be trying to solve the risk concerning the control and monitor of the project and labor. After considering several suggestions, the team decided that the best way to influence the labors is through the foremen. Effective foremen will make an effective labor team. Usually the skills of the labor will be in the basic level and they are usually careless. This means the people with direct control to them are the foremen. The job of a foreman is to coordinate the working schedule with junior supervisor and control and monitor the labor with guidance in skills, working culture and problem solving skills. This is why the risk team decided that if the foremen were more effective the labor team in both construction site and factory would increase their efficiency. The risk team will solve the problem with increasing the incentive to the foreman (workers at site) and staff (for workers at factory).

The method of giving incentive is to increase the bonus money based on the performance related with time of the project. If the project finishes earlier than planned in the schedule, then the foremen will get bonus money in the amount of 2% of the total profit of the company. However, if the project does not finishes early then they will be paid regularly in monthly basis.

Preventing critical risks number: 2 (Lack of skilled labors at site), 5 (Insufficient skilled labors at factory), 6 (Lack of supervision), 10 (Low efficiency in information Flow and coordination), 11 (Lack of efficiency in project monitoring and control), 13 (Careless working culture), 16 (Inaccurate in working details)

Benefits of preventive actions:

- Increase motivation to the foremen
- Project advances faster through incentive of time and bonus money
- Increase supervision to the workers due to tighter performance control
- Increase information flow and coordination because the workers are eager to finish the project and less carelessness
- Tighter monitoring and control of the project because workers are eager to do things right the first time and no repairing or wasting time
- The foremen pay more attention to the labor resulting more skill labors

Effecting SOD: Lower severity, occurrence and detection

5. **Hire consulting architect team and construction consult**

This preventive act is recommended to gain more control and increase the skills in construction of the company. To hire an outside consultation in either architecture or construction consult will increase the performance to the company. Since this project is still one of the first projects to the Company ABC, therefore it is suitable to hire experts and consults to control and help the team to operate and not to finish the project with delays and penalties like the project in PP Island (Previous project).

The responsibilities of the consult can be controlling or assisting the architect, which is apparently one of the critical risk positions. The team member agreed that in hiring consult to control the project, the architectural work such as information survey or design details will be improving and can solve the these risks. By hiring consults, the manager teams will also have to work more efficient because everyone will have an effect of being watched and monitored. This will improve the culture of working of the company. After a while, when the company have their cultures and working methods within them and their skills are improve up to the point of independent operations, then the consults are no longer needed.

Preventing critical risks number: 1 (Under standard quality control (Q.C.) at factory), 4 (Lack of information gathered by architect on the total project direction), 6 (Lack of supervision), 7 (Inaccurate shop drawing produced and gathered), 8 (Unclear architectural design for material breakdown), 11 (Lack of efficiency in project monitoring and control), 12 (Under standard quality control at site), 14 (Low efficiency in Manager team), 15 (Poor material resource plan) and 17 (Poor information gathering from site and production factory to create master schedule of production and construction synchronization)

Benefits of preventive actions:

- Improve total process involving architecture and less architectural errors
- Improve planning process due to expertise consults bring in
- Increase project monitoring and control due to consultations and advice from experts
- Accurate information gathering of the total project due to assistant from consultation

Effecting SOD: Lower Severity and occurrence

6. **Re-structuring organization chart to project base**

The basis of operations of a company lies on the organization chart settings. The organization chart is like the formation of a company, where every position and style is already pre-set. There are many kinds of organization chart and each of them is suitable for various types of organization. The problem that the team member recognize is that Company ABC were manufacturing company and in the present time they are focusing on the construction of prefabrication houses. This is a problem that can cause many risks in the organization. A company that did not design their organization chart for a specific job will not achieve the efficiency that it should have.

The organization of this company in the present time is a functional based organization type. This means that all the organization department are clearly separated and the work will flow from department to department, which works very well with a manufacturing company where each of the department will concentrate on their own responsibilities. However in a project, every department will have to work together and coordinating to achieve the project goal. This is why a functional type organization chart will not be effective to the company. So, the team decided to set plans to restructure the organization chart of the company to fit the project management type (or at least partly to gain better control and efficiency) without disrupting the manufacturing part of the company.

Preventing critical risks number: 3 (Unclear roles and responsibilities), 5 (Insufficient skilled labors at factory), 10 (Low efficiency in information Flow and coordination), 11 (Lack of efficiency in project monitoring and control) and 14 (Low efficiency in Manager team)

Benefits of preventive actions:

- Smoother project management and operations
- Clear roles and responsibilities
- Faster problem solving
- Increase motivation within the group and team supporting culture
- Project manager gains better control and is involved in every process
- Increase efficiency in upper management because of more efficient information flow

Effecting SOD: Lower occurrence and detection

Table 4-20. Summary of Preventive actions and its solving critical risks.

Critical Risk number	Preventive Action						Total
	1	2	3	4	5	6	
1		√			√		2
2	√			√			2
3			√			√	2
4					√		1
5	√			√			2
6	√		√	√	√	√	5
7					√		1
8					√		1
9		√					1
10		√	√	√		√	4
11	√	√	√	√	√	√	6
12		√			√		2
13	√			√			2
14			√		√	√	3
15					√		1
16	√			√			2
17					√		1
Total	6	5	5	7	10	5	38

According to table 4-20, the summary of the preventive actions and the critical risks solved will show the crossing between the two factors. This table shows the summary of the risks solved in each preventive action to see which act solves the most risks. In addition, this table also shows the total risks solved in each preventive act. The maximum number of risk solved in one single act is preventive action number 5 (hiring consultant). The only risk that is being solved in every single preventive act is the risk number 11 (lack of project monitoring and control). This means that all the preventive actions have a good influence in that specific risk.

4.5.4 Rescoring critical risks

In the meeting 5 and 6, the risk management team will have to rescore critical risk after they have been discussed and managed through preventive actions. The rescoring of the critical risk should reveal the difference that the preventive actions and how effective they are. The larger the range of difference between the RPN score means the more effective the preventive actions are. According to the table 4-20 and the information given in each preventive action, the risk team can use this information to reconfigure the score of the RPN. In the 6th meeting, the score of the new RPN is collected and is summarized to the following:

Table 4-21. Rescoring of critical risks and its RPN.

Risk NO.	**Failure Mode (Risk)**	**Estimated Severity (S)**	**Estimated frequency of Occurrence (O)**	**Estimated Detection (D)**	**RPN**
1	Under standard quality control (Q.C.) at factory	7	4	2	56
2	Lack of skilled labors (carpenter, foundation work labor, structuring work labor, fine architecture work labor)	3	5	5	75
3	Unclear roles and responsibilities	5	5	2	50
4	Lack of information gathered by architect on the total project direction	2	2	8	32
5	Insufficient skilled labors (carpenters, painters and general wood working skills)	4	4	5	80
6	Lack of supervision	2	2	4	16

7	Inaccurate shop drawing produced and gathered	4	3	8	96
8	Unclear architectural design for material breakdown	3	4	8	96
9	Poor documentation	7	2	2	28
10	Low efficiency in information Flow and coordination	3	3	2	18
11	Lack of efficiency in project monitoring and control	3	3	2	18
12	Under standard quality control	6	3	2	36
13	Careless working culture	4	4	5	80
14	Low efficiency in Manager team	3	4	7	84
15	Poor material resource plan	4	3	9	108
16	Inaccurate in working details	3	3	5	45

17	Poor information gathering from site and production factory to create master schedule of production and construction synchronization	4	2	6	48

In the table 4-21, the critical risks were rescored and the new RPN were calculated. The result shows that most of the risk management team feels that the critical risks have been managed and should reduce. The evidence is shown in the drastically decreasing RPN. All of the RPN in the critical risk of 1-17 have reduced to below 100. This means all the risks are no longer critical if all the preventive actions were implemented. After all the new RPN is calculated, comparing the old and the new RPN into percentage will show the decreasing percentage between them.

Table 4-22. Percentage comparison of old and new RPN.

Risk NO.	Failure Mode (Risk)	New RPN	Old RPN	Corrective Percentage (%)
1	Under standard quality control (Q.C.) at factory	56	504	88.9
2	Lack of skilled labors (carpenter, foundation work labor, structuring work labor, fine architecture work labor)	75	480	84.4
3	Unclear roles and responsibilities	50	448	88.8
4	Lack of information gathered by architect on the total project direction	32	448	92.9
5	Insufficient skilled labors (carpenters, painters and general wood working skills)	80	448	82.1
6	Lack of supervision	16	448	96.4
7	Inaccurate shop drawing produced and gathered	96	432	77.8
8	Unclear architectural design for material breakdown	96	392	75.5
9	Poor documentation	28	392	92.9
10	Low efficiency in information Flow and coordination	18	384	95.3

11	Lack of efficiency in project monitoring and control	18	384	95.3
12	Under standard quality control	36	378	90.5
13	Careless working culture	80	343	76.7
14	Low efficiency in Manager team	84	336	75.0
15	Poor material resource plan	108	315	65.7
16	Inaccurate in working details	45	288	84.4
17	Poor information gathering from site and production factory to create master schedule of production and construction synchronization	48	126	61.9

According to table 4-22, the old and the new RPN are used to calculate the comparing percentage. To compare the percentage, the following formula will have to be used.

Comparing percentage (%): $\frac{(RPN_{old} - RPN_{new})}{RPN_{old}} \times 100$

The comparing percentage shows the difference between the new and the old RPN or in other words, how it is improved. From the percentages showing in table 4-22, it can be concluded that the risk management team believe that the preventive actions will be effective and will be improving and solving the critical risks to gain a better organization.

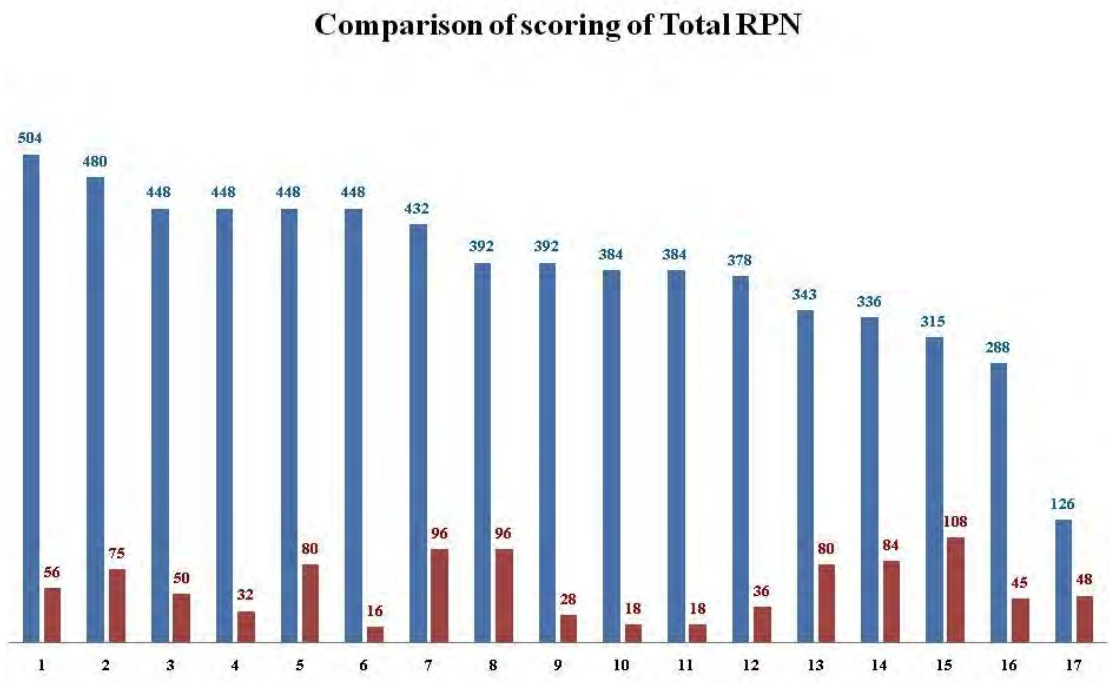
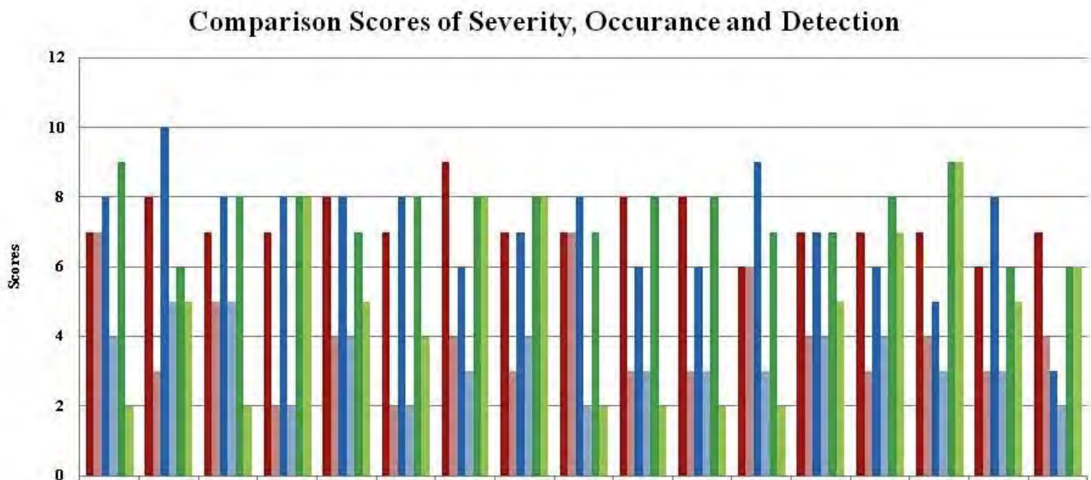


Figure 4-38. Comparison of scoring between old and new RPN.

The comparison of the two sets of RPN (old and new RPN score) can be clearly expressed in the figure 4-38. It can be seen that the new score is significantly lower than the old scoring, which means the preventive actions should be effective. To further analyze the old and the new scoring, the SOD of each scoring will be compared (figure 4-39). The figure can show the comparing details of each scoring showing which factor changed.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
S Old	7	8	7	7	8	7	9	7	7	8	8	6	7	7	7	6	7
S New	7	3	5	2	4	2	4	3	7	3	3	6	4	3	4	3	4
O Old	8	10	8	8	8	8	6	7	8	6	6	9	7	6	5	8	3
O New	4	5	5	2	4	2	3	4	2	3	3	3	4	4	3	3	2
D Old	9	6	8	8	7	8	8	8	7	8	8	7	7	8	9	6	6
D New	2	5	2	8	5	4	8	8	2	2	2	2	5	7	9	5	6

Figure 4-39. Comparison of SOD of old and new scoring.

After the rescoring of the critical risk, the preventive actions that are planned out for them will have to be implemented. The implementation of some of the preventive actions is shown in the next section.

4.5.5 Implementation

The implementation of the preventive plans is carried out in phase 3 (October 2009). In the meeting 6, all the implementation plans have been discussed and summarized that there were only some plans that could be implemented due to inappropriate timing and other factors within the company. So to summarize, the following critical risk prevention methods were carried out to implementation:

- **Preventive action number 1**: Training foreman (partial training)
- **Preventive action number 2**: Creating standard forms and documents (partial system implementation)
- **Preventive action number 3**: Increase frequency of meetings (beginning of third phase)

- **Preventive action number 4**: Increase incentive and welfare to foreman and staff (person in charge with all operations and in contact with labors)
- **Preventive action number 5**: Hire construction consultant (partially effective due to timing)

The preventive action number 6 will not be implemented yet because all of the risk management team discussed about it and conclude that it will take a long time to change the organization chart. The change will have to be implemented after the project is completed. Therefore, the implementation of the changing in organization chart will not be implemented. However, the new organization chart of the project-oriented style of organizational structure is shown in Appendix.

Preventive action number 1: Training foreman

The risk management team decided to train the foremen (figure 4-40) to gain better control. The subject that the foremen should be train is the handling with Shera wood and training in the structural construction of the houses. The team feels that these subjects are still the weakness of the labor. Therefore, in the third phase Sunday mornings, the foremen attended training courses, trained by the consults and architects that the company hired.

Figure 4-40. Training course of staff and foremen.

Preventive action number 2: Creating standard forms and documents

Company ABC is a Thai company. It is run by the owner himself, and has grown from a small business therefore; the documentation system is not very tight. The documentation systems were used in phase 3 are quality control documents, training documents and meeting form (shown in Appendix). There are some other documents and systems that needed to be implemented, however most of the documents cannot be created without discussing with the architect first, and the system will need planning and testing as well, however the team has set the objective of creating a documentation system after the project is completed.

Preventive action number 3: Increase frequency of meetings

The frequency of the meeting in this company is usually 2 weeks or twice a month, but with such fast construction project, where many factors are changing and a lot of problems are at hand, the team in phase 3 met for a meeting once a week at minimum (figure 4-41). The policy of the company should be that all members that matter to the project such as all managers, project site managers and staff will have to attend the meeting without a reasonable excuse. The meetings will have to be strictly documented and signed at the end to follow up.

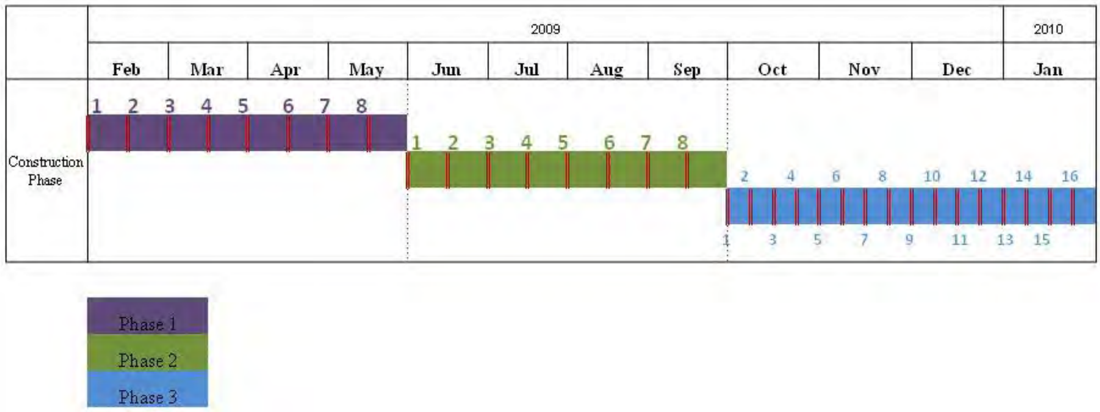


Figure 4-41. Increasing frequency of meetings in phase 3.

In figure 4-24, the actual meeting schedule is presented. There are in total of 16 meetings in phase 3, which is more than phase 1 and phase 2. However, there are absent of staff in some meetings, so some meetings are canceled. There are 3 meetings, which were canceled, which are meeting number 5, 12 and 15.

Preventive action number 4: Increase incentive and welfare to foreman and staff

After the discussions about increasing the incentive to the foremen and staffs, the risk management team decides that they will give 2% of the profit to the staffs and foremen to share between them if they finish the project before the time. Although there are many factors influencing the early finishing of the project but these people will have the most influence to the labor, which is the heart to the construction.

Preventive action number 5: Hire construction consultant

Hiring the construction consultant has helped a lot in phase 3 by guiding and teaching many useful working cultures to the staff. The consultant is a lot of experience in working with many types of construction and has helped with changing the way of thinking for the manager team to gain more efficiency as well. However, according to the consult, 4 months is not enough to improve significantly and the process of improvement in the architectural and construction area will need more time. (Consultant contract is attached in Appendix)

Future preventive action 6: Re-structuring of organization chart

The re-structuring of the organization chart could not be implemented in the present time due to lack of time and in need of serious management of change but the new organization chart (figure 4-42) is presented as follow:

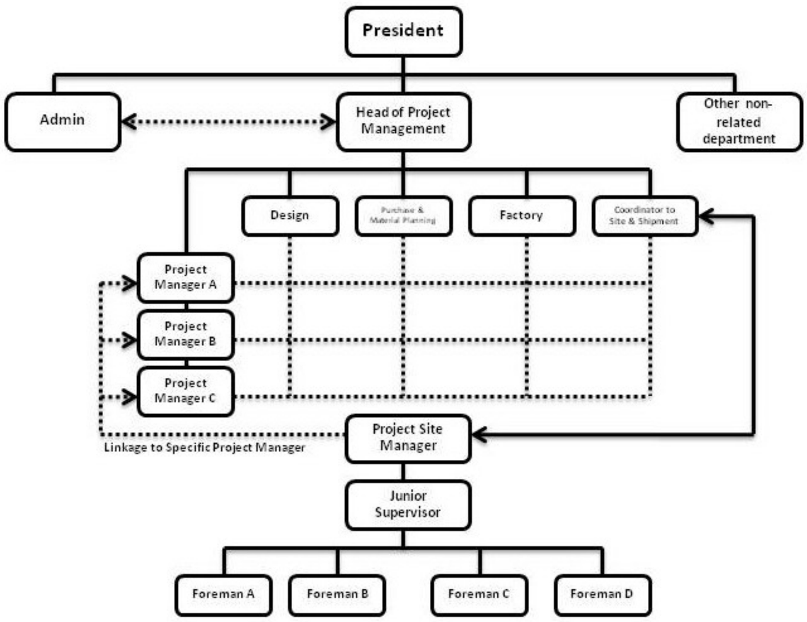


Figure 4-42. New re-structured organization chart.

Improvement from implementations

The improvement from the implementation is difficult measure because the lack of documentation of the company. However, the best way to measure improvements in a construction project is the time. Measuring the time of completion is the best way to see whether the construction team has improved. To measure the time of the construction, the best measurement is the payment. Payment in the construction is separated into percentages and pays by the lot according to the ration and percentages such as 10% completed or foundation stage of phase 1 completed etc. This is how the improvement of the construction can be measured.

This project agreement of the contractor and the customer is set that each completion of each finish stages, the customer will pay only when they are satisfied with the product given and they will pay in percentage according to this information:

- Phase 1 completion payment = 30%
    - Foundation complete = 10%
    - Structure complete = 10%
    - Finishing product complete = 10%
- Phase 2 completion payment = 30%
    - Foundation complete = 10%
    - Structure complete = 10%
    - Finishing product complete = 10%
- Phase 3 completion payment = 40%
    - Foundation complete = 10%
    - Structure complete = 10%
    - Finishing product complete = 20%

At the end of each stage in a phase in the construction, the customer will transfer the payment to the Company ABC. This concept can be summarized in to the following figure 4-23:

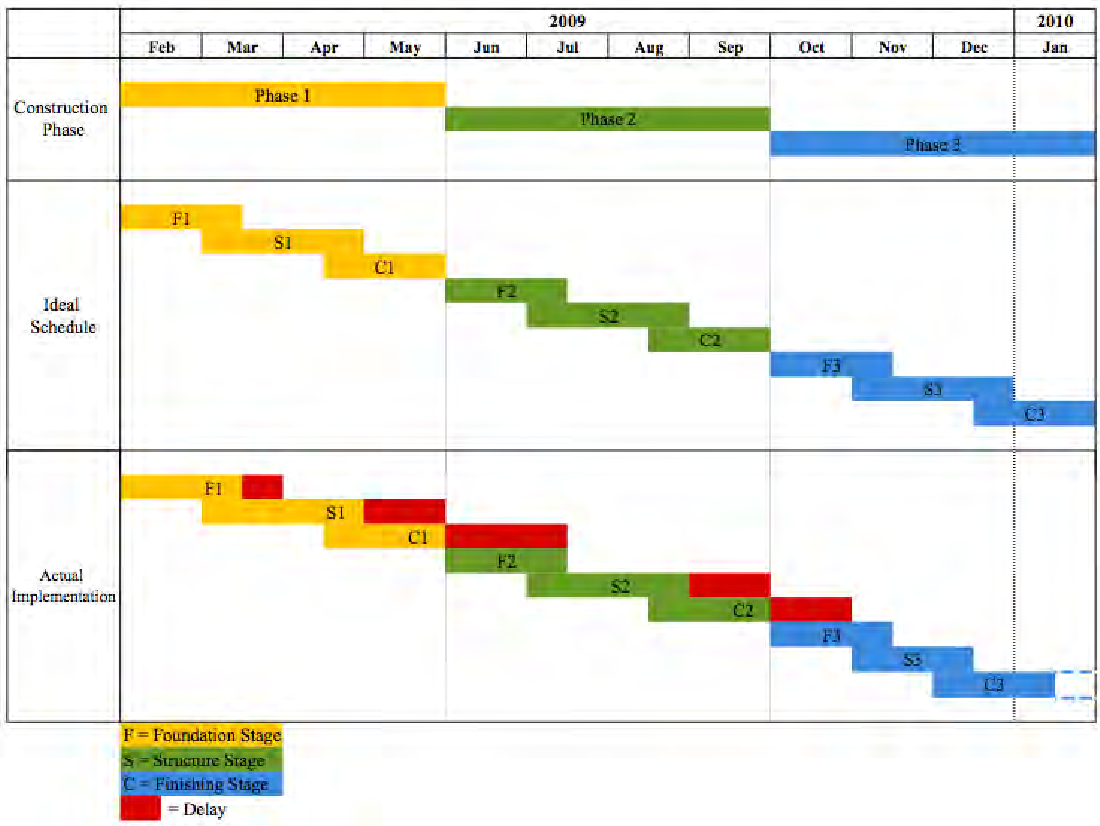


Figure 4-43. Detailed implementation schedule

The implementation schedule (figure 4-43) shows the schedule that the project was implemented. It is separated into 3 parts, which are construction phase, ideal schedule and actual implementation. The construction phase is the rough timing of the phasing of the project. The ideal schedule is what the processes within the construction should be, and the actual implementation is the schedule that actually happened.

The actual implementation schedule shows that the project was running with delays in the first two phases. The first phase is delayed by 6 weeks, which started from the foundation stage. Then the delay backlogged in the structural stage because of the following consequences from the first stage. Then the completion stage (finishing stage) has a delay of 6 weeks in total. However, with the rotation system of labor, the labor started the foundation construction at the second phase already. So the delay in the first phase did not cause problems in the second phase. In the second phase, the same effect happened to it but with some improvement because the labor was more skilled and is more used to the work. The total delay in the second phase is in total of 4 months. This is when the risk management team meeting ended and starting implementation. In the third phase, the implementation of preventive actions started. As shown in the figure 4-20, the structural phase in the third phase is 2 weeks ahead of schedule. This has caused the finish stage to finish early as well. This means that the project in phase 3 took only three and a half months to finish. This shows that the implementation of the preventive actions does have effect to the project result.

The risk management team observed the improvement in time factor of what could influence it and concluded the following:

- The labor force gained more experienced and finish the daily work faster than usual
- The foremen are much more effective through the incentive increasing method
- The construction consult solved a lot of problems for the labors that increases the speed of the construction such as roofing techniques and structural techniques
- The documentation of quality control was effective enough to see some rejects of defects and repairing of parts
- According to the risk team, the information flow and coordination is much better after increasing the meetings, because every problem was taken care of and there are lesser importation left out when using standard form for meetings.

After the implementation was implemented and the results are that there were improvements by 2 weeks until the handing over day. This is considering a success for the company because based on past performance in this project and the last projects; the company did not have to pay the penalties. However, there were some defects such as defecting in roofing causing water to leak, faulty structural causing wrong house angle or some material such as assembly parts that were sent from the factory did not fit or was in a wrong specifications e.g. stairs sent was in the wrong side. However, it is still considered a success and the risk management granted more understanding to the construction project of the prefabrication houses.

4.6 Conclusion

In this chapter, there were many analysis and results shown. The chapter started risk identification of the prefabricated house construction project. From the results, there were 83 risks identified spread out to 7 processes of FMEA. The risk management team using the FMEA criteria scored these risks. The criteria are separated into 3 parts, which are severity, occurrence and detection. The RPN can be calculated based on this information. There were some risks standing out, which using Pareto analysis can separate them out. At the end, there are only 17 critical risks left. These risk needed to be solved so after analyzing them. The risk management team came up with preventive actions to solve them. There were all together 6 preventive actions. These preventive actions were planned to solve each risks and they were implemented. To measure the implementation, the payment of the customer will be used. It is found out that the third phase is faster by 2 week, which is considered an improvement to the company.

To summarize the total risk management program of the construction, this information will again be summarized in the next chapter. This is the end of the analysis part. The results of all analysis were shown in this chapter. The next chapter will be about concluding all the information and recommendation of improvement and further studies.

CHAPTER V

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The risk management of prefabricated Thai classical house construction is a field combining many area of expertise together. To understand the risk management of the project, the character of prefabricated Thai classical house will first need to be explained. The nature of prefabricated house construction is unlike a conventional construction method. The prefabricated house construction is separated into 2 parts, which are production part and construction part, where as conventional construction does not consist of the production part. The prefabricated house construction will be consisting of assembly parts to be assembled at site, which are prefabricated at the factory located elsewhere. The prefabrication of assembly parts is manufactured in mass to gain speed in both at factory and at site and when all the parts are completed, the parts can be sent to the site. At the site, all the parts can be assembly in a much faster way than the conventional construction method. With the technique of pre-building the parts and fast assembly at construction site, the prefabricated house construction is much faster than other types of construction. In addition, it also has a wide range of availability of designs and high durability. Prefabricated house construction is considered to be the future of housing project, which can be improved up to the point of lean project management.

The prefabricated house construction method is a very useful method, however with such a continuous flow of material and information in the operations stage, there will be a lot of risks. The main advantage of the prefabricated house construction is speed but in this case, speed is also a main disadvantage because speed in operations results to errors and risks to fail certain tasks. With a small time frame, one delay delivery from the supplier can delay the production unit, which will delay the construction operations and can affect the completion date of the product. This is why risk management is suggested to prefabricated house construction. Without risk management, the chance of improvement will be much lower.

In the beginning, all the tools and techniques were researched and the details of risk management were studied and presented. These tools and techniques are very helpful during the discussions about the risk. Many useful tools that were used in the discussion in risk identification are scenario building, use of flow chart, use of organization chart or checklist. The tool that is being used for risk assessment is the tool FMEA, which is a type of qualitative risk management. The type of FMEA used will be process FMEA, which means that the process of the construction will have to be separated out to be analyzed process by process. By doing this, the analysis of the risk will be deepened and the cause and effect of them will be more accurate. The system of using FMEA will require a score-rating table, which will be used differently each project.

The FMEA analysis is the analyzing of the failure mode that could happen in each process. Using the experience, judgment and estimation of the risk management team, the FMEA analysis can be completed. To analyze the risks, risk criteria for each variables of FMEA will be needed. The Risk Priority Number (RPN) consists of 3 variables, which are Severity (S), Occurrence (O) and Detection (D) rating from 1-10. These 3 factors multiplying together will create a RPN score. This score can be used to analyze the sensitivity of the risks and respond to them with suitable actions.

After the study of the tools and techniques concerning risk management, all the information concerning the project is given. This project is located in Phang-nga about 700 kilometers from Bangkok. The project will consist of 35 units of wooden classical Thai house, which will be operated as a resort. In the construction of the resort, Company ABC will be acting as a contractor building the houses, whereas the infrastructure of the project will be sub-contract to other company. The total labor at site is approximately 25-30 people, which they will rotate from stage to stage. The rotation labor system is when the labor is separated into groups and they will concentrate on the job given such as foundation group or structuring group. This system is usually used for mass construction of housing project, which it will increase the speed of the construction and reduce the risk as well. The factory for prefabrication of the parts is located in Bangkok, where all the designs and manufacturing tasks are done there. The Bangkok base will also be operating the administration of all process including scheduling, material checking and project management work. At the site, there will be a project site manager, junior supervisor and foremen standing by controlling and coordinating the construction site.

The process of building a prefabrication house can be separated into 3 parts, which are foundation stage, structural stage and finishing (architectural work) stage. The project will be separated into 3 phase where each phase is separated into 4 months adding up to 1 year. Each phase consist of 11-12 houses built within 4 months. Using the rotation system, the house building process should be faster and the labor will gain more expertise in their specific job. Same as the construction site, the production part is also separated into stages. The productions of the assembly parts will be separated in to inventory checking and preparing the raw material, Specification Measurement and Manufacturing and Finishing work and Quality Control before packing. After the assembly parts are packed and labeled, they can be loaded to the truck and sent off to the construction site to be used.

The risk management process will be done using risk management teams and meetings to discuss about the risks. The risk management team will consist of all the major stakeholders and the key operators within the project. The risk management process will be done in 4 steps, which are risk identification, risk assessment and allocation of risk sensitivity, risk response and preventive actions and finally re-assessment of risks. The risk management process consists of 6 meetings, which is summarized into the following (figure 5-1):

- **Meeting 1**
    - 1.1 Give all participants resources
    - 1.2 Individual risk generation
    - 1.3 Generate of FMEA ranking criteria’s
- **Meeting 2**
    - 2.1 Risk identification presentation
    - 2.2 Risk identified gathering
    - 2.3 Identified risk discussion & summary
- **Meeting 3**
    - 3.1 FMEA introduction
- **Meeting 4**
    - 4.1 FMEA score collection & discussion

- o 4.2 Calculation of RPN

- **Meeting 5**
  - o 5.1 Critical RPN risk evaluation
  - o 5.2 Critical risk introduction
  - o 5.3 Discuss risk response for each critical risk
  - o 5.4 Summary of critical risk prevention
  - o 5.5 New RPN scoring after risk prevention
- **Meeting 6**
  - o 6.1 Gathering of new RPN score
  - o 6.2 Discussion on implementation of preventive action

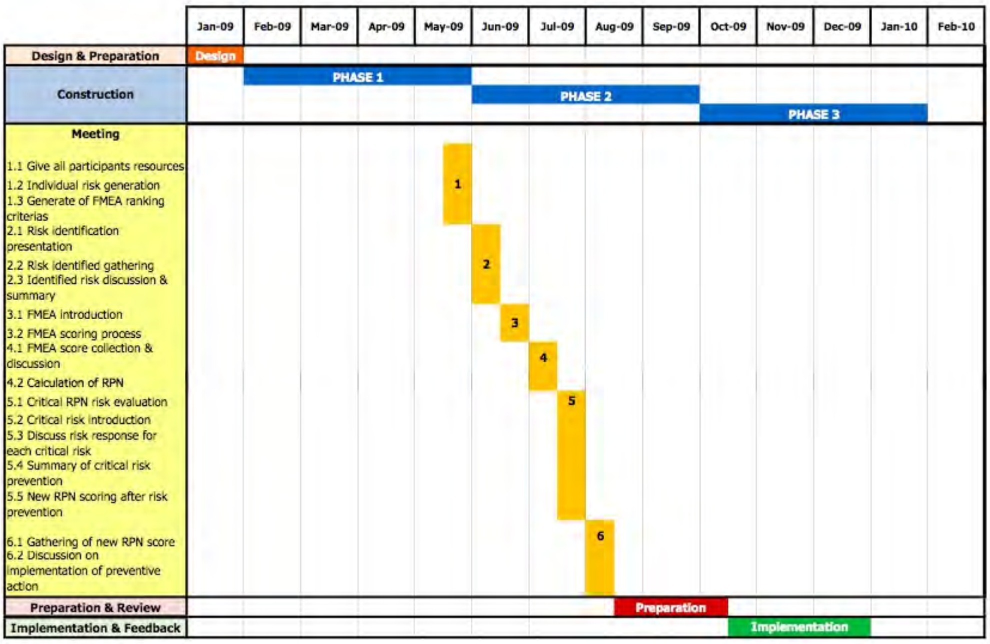


Figure 5-1. Schedule for risk management meetings and implementation.

These meetings were set for the risk management team, which consist of 8 people, which are owner, architect, project manager, engineer, production manager, project site manager, junior supervisor, two foremen and the author. These people were selected to be in the risk management team to analyze the risk. The people chosen will be responsible to some part of the project in every aspect to gain the best insight of the risks in each process.

The risk management objective is set in the beginning of the meeting. The risk management object is “To identify and solve the critical risk that could impact the project Time and Quality of the Product, therefore not experiencing the penalty of delay and suffer from defects responsibilities”. The objective is set so that the risk management team have a direction of discussion. Risk management was very new to the risk management team members; therefore these details will have to be set before implementing the risk management program.

The process of the construction is separated into 7 processes, which can be summarized as follow:

1. Define customer objectives and design drawing
2. Material Checking
3. Construction site preparation
4. Factory operations
5. Construction site operations
6. Finishing product
7. Overall process

The risk of each process can be determined by considering the risks and failure mode in manners of process by process. After discussion and analysis using some techniques and tools, the total number of risks has reached up to 83 risks in total. After the scoring of severity, occurrence and detection, the RPN can be calculated. The RPN (Risk priority number) is the main number to classify the risk in to critical risks. To allocate the risk according to the sensitivity, Pareto analysis is used. There are in total of 17 critical risks from the Pareto analysis. The critical risks means that the risk is dangerous to the project and could harm the project in time or quality. So all the 17 critical risks will need to be prevented.

To prevent all the 17 risks, the risk management team analyzed the cause of each of them first. Analyzing the cause will make the risk management team prevent these risks right to the cause of it. Fish bone analysis was used to analyze the cause of the critical risks. After the causes of each risk are analyzed, the risk management team discussed about the preventive actions and came up with 6 acts to prevent these critical risks. The risk management team has noticed that there are linkages between the critical risk and a cause and effect relationship that could connect them. Therefore, the preventive actions that were plan out to be implemented will cover more than one critical risk. The preventive actions can be summarized in to the following:

- **Preventive action number 1**: Training foreman on specific subjects
- **Preventive action number 2**: Creating standard forms and documents
- **Preventive action number 3**: Increase frequency of meetings
- **Preventive action number 4**: Increase incentive and welfare to foreman and staff that can influence the labors
- **Preventive action number 5**: Hire consultants
- **Preventive action number 6**: Re-structuring organization chart into a more project suitable organization

Each of the preventive actions will solve specific number of critical risks. The preventive actions that can prevent most of the risks are preventive action number 5: hiring construction consultant. All of the critical risk will be prevented with at least one preventive action. This way, all the critical risks should be prevented.

After the preventive action analysis, all of the critical risks will have to be rated again by the risk management to see the difference in result (figure 5-2) of the "before and after effect" of the preventive actions that influence the RPN of the risks. So in meeting 5 and 6, the critical risks were re-scored and re-calculated the RPN. Comparing the new and the old RPN, a drastic difference was achieved. The difference in the two scores is up to 70-90% difference. This means that the critical risks should all be prevented if all the preventive actions were implemented. However, not all the preventive actions could be implemented in the present time because some of them require some time. There are parts of the preventive actions that could be implemented and improve the total result of the project.

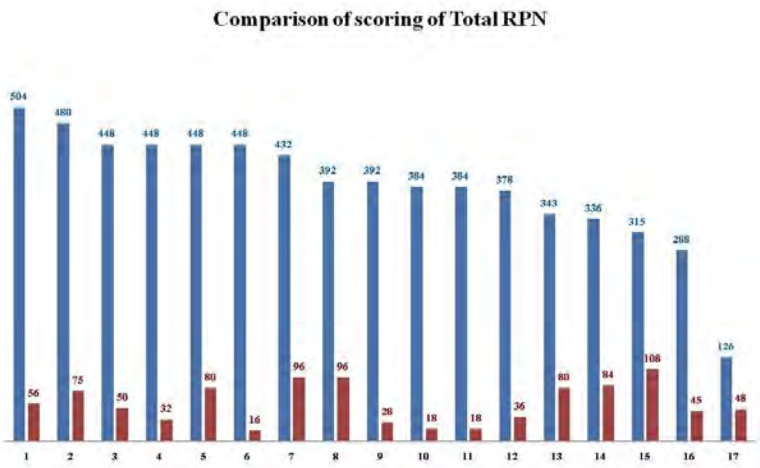


Figure 5-2. Comparison of scoring between old and new RPN.

The preventive action that could not be implemented in this project is the preventive action number 6. It is because changing the organizational structure requires a lot of time and involves a lot of management; therefore it cannot be implemented for now. However, other preventive actions were implemented. Some of them might not be able to operate fully because it requires time for system designs such as documentation system.

The summary of the project shows that the phase that the preventive actions were implemented did finish before the dead line. This means that the preventive actions did have an effect on the project.

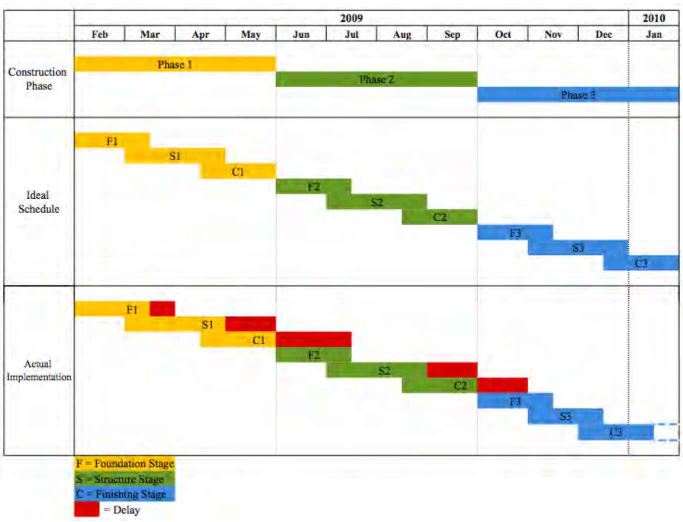


Figure 5-3. Summary of implementation schedule.

The implementation and operations of the project can be summarized in to figure 5-3. Comparing the ideal schedule to the actual implementation schedule, the red area indicates the delay. In the first phase, there were 6 weeks of delay from the ideal schedule. In the second phase, there were 4 weeks of delay but in the third phase, it ended 2 weeks faster than it should. Because the implementations of the preventive actions were carried out at third phase, there was an effect to the phase. The factors that could have change in the third phase were discussed and summarized into the follow:

- The labor force gained more experience and finish the daily work faster than usual
- The foremen are much more effective through the incentive increasing method
- The construction consult solved a lot of problems for the labors that increases the speed of the construction such as roofing techniques and structural techniques
- The documentation of quality control was effective enough to see some rejects of defects and repairing of parts, which means there are improvement in quality control department
- According to the risk management team, the information flow and coordination is much better after increasing the meetings, because every problem was taken care of and there are lesser problems left out when using standard form for meetings. All the important information were noted and follow up to solve each of them

According to the scope that is set for this research, the risk of the construction project will be assessed from 3 main scopes, which are:

- Production and prefabrication
- Logistics management and planning
- Construction site operations

To summarize the risk identification of the project, the risks can be separated into these scopes to clarify these identified risks better. The risks that were identified from the project were separated into process, which these process were broken down from the flow chart of the operations of the project presented in chapter 3. This means the risk that was identified will have to be put into its scope; however some of the risks might influence more than one scope because of the way that it was identified. The summary of the sorted risk is as follow:

- Production and prefabrication risks: 15 risks
- Logistics management and planning risks: 25 risks
- Construction site operation risks: 35 risks
- Other related risks: 25 risks

The total risks according to the scope separation is 110 risks however, as stated that there are many risks that fits more than one criterion due to the way it was identified. These 110 risks can be narrowed down to critical risks as follow:

Table 5-1. Summary of scope of critical risks.

No.	Critical Risks	Involving Operations		
		Production	Logistics and planning	Construction Site
1	Under standard quality control (Q.C.) at factory	√	-	√
2	Lack of skilled labors (carpenter, foundation work labor, structuring work labor, fine architecture work labor)	-	-	√
3	Unclear roles and responsibilities	√	√	√
4	Lack of information gathered by architect on the total project direction	√	√	√
5	Insufficient skilled labors (carpenters, painters and general wood working skills)	√	-	-
6	Lack of supervision	√	-	√
7	Inaccurate shop drawing produced and gathered	√	√	-
8	Unclear architectural design for material breakdown	√	√	-
9	Poor documentation	√	√	√

10	Low efficiency in information Flow and coordination	√	√	√
11	Lack of efficiency in project monitoring and control	√	√	√
12	Under standard quality control	√	-	-
13	Careless working culture	√	-	√
14	Low efficiency in Manager team	√	√	-
15	Poor material resource plan	√	√	-
16	Inaccurate in working details	-	-	√
17	Poor information gathering from site and production factory to create master schedule of production and construction synchronization	√	√	√

From the list of critical risks, table 5-1 shows how the critical risks are sorted into production, logistics and operations according to the scope. Using this table, it can also be further analyzed that the preventive actions that would solve these risks will affect which factor in the business.

From these analysis of risks into scopes, it can show that the risks in the production and prefabrication category is the minimum in quantity, however the critical risks scope analysis shows that the scope that is being influenced most by the critical risks is production and prefabrication. This means the production and prefabrication department contains the highest risks and has a high influential effect to the project.

To summarize the risk management effectiveness in this project, measurement method and criteria is to use the basic factors of the project management principle.

The basic of project management criteria consist of quality, cost and time. These three criteria is the factor in balancing act in every project. In this project, it is being executed in 3 phases. According to figure 5-1, the implementation period is in the third phase (Oct 09 – Jan 10). This means that in the point of view of the project manager, if there is a difference in management system such as risk preventive actions implemented, there must be a distinct deviation between the first two phases and the third phase. In this case, the prefabrication housing project also has another factor involve which is quantity because there are both production and construction part. To summarize these factors, table 5-2 will present the percentage effective of each preventive actions that generated a differences in the deviation from these criteria. The deviation of these 4 factors is the difference in quality, cost, time and quantity between the first two phases and the third phase where the implementations of preventive actions were implemented.

Quality: To measure quality, the number of times of rework is used. Before the implementation, the rework in both at the production unit and at the construction site is in average of 20 rework per week. After the implementation, with the increase in experience and preventive actions, the rework is reduced to approximately 5-7 rework per week. This means that the deviation in quality improvement is at approximately 15 rework per week improvement.

Cost: The deviated costs of before and after the implementation is approximately at 350,000 – 500,000 Baht. This cost is derived the 2 weeks before the project dead line, which is at the time the project finish. The reduced cost of the project is the result from finishing the project early. The main cost reduction comes from absence of salary of staff.

Time: As shown in the figure 5-3, the approximate time delay from finishing the first two phases is 4-6 weeks. In the third phase, with 2 weeks finishing before deadline, the total difference is 7 weeks improvement in time.

Quantity: The quantity of this project is the number of house and the number of assembly parts produced. From these two aspect, the risk management preventive actions does not have influence to both of the quantity of production and quantity of finish products in this project.

The influential scoring and the percentage influence of preventive actions can be summarized into table 5-2 and 5-3.

Table 5-2. Influential scoring of critical risks.

Critical risk No.	**Project Criteria**		
	Quality	**Cost**	**Time**
1	3	3	3
2	3	2	2
3	1	1	2
4	1	2	3
5	3	2	3
6	3	2	2
7	2	1	3
8	1	2	3
9	3	2	3
10	2	1	3
11	2	1	3
12	3	3	3
13	3	3	2
14	1	3	3
15	1	1	3
16	3	1	1
17	1	1	2

The table 5-2 is the scoring of the influential effect of the critical risks to the 3 criteria (quality cost and time). The risks are listed and scored using numbering system. Number 1, 2 and 3 are scores representing low, medium and high influential effect respectively. Using this information, the percent influential effect of the 3 criteria can be calculated into percentages. The percentages can show how each preventive action has influenced the deviation of the 3 criteria in this project (table 5-3).

Table 5-3. Percentage influential effect of preventive actions and 3 criteria.

Preventive action No.	Quality (%)	Cost (%)	Time (%)
Preventive action 1	**20.0**	**16.3**	**13.3**
Preventive action 2	**15.2**	**14.7**	**15.3**
Preventive action 3	**10.6**	**11.5**	**13.3**
Preventive action 4	**22.3**	**18.0**	**16.3**
Preventive action 5	**21.2**	**24.5**	**28.6**
Preventive action 6	**10.6**	**14.7**	**13.3**

According to table 5-3, each preventive action has contributed in the improvement in the third phase; some has higher effects than others. Preventive action number 5 has the highest influential effect percentage to all three criteria. For more accurate calculation, each percentage can be calculated with the approximate improvement value shown previously to see the exact improvement in quality, costs and time.

The summary of the risk management program that was applied to the prefabricated Thai classical house construction shows that there are still a lot of risks that the Company ABC could not cover. With the lack of experience and lack of system, the Company is still unfit for a larger project. However, there are implementations of changes in the organization to prevent the risks such as changing the organization chart. It is believed in the risk management team that if all the preventive actions were put to use combining with the experiences that the staff have learnt, the next project will be a lot smoother. It is learnt that the key to the prefabricated house construction is communication, information flow and the monitoring and control of the project because in its nature, it is a fast constructing style of construction method therefore all of the details and decisions will need to be coordinated first. It is also known that the problems at the factory operations will cause more damage to the project than the construction process. The factory operation is like a core distributor of assembly parts to the construction site, therefore all the preparation and planning will have to be managed there. If the supplying of the materials and resources are not well planned, then the construction process will not be smooth and there will be more problem solving at the construction site.

5.2 Recommendations

Recommendations to the risk management are ways to improve it in the future with time. With the given time, the risk management of a construction project could not be 100% completed because there was a lot more study deep into the factors that were influencing them. These are some of the factors that should be improved over time to gain more effective risk management.

1. Training and understanding of risk management

Risk management is still a very new subject to the company, and it can easily be misunderstood. Especially for the Thai staff, which are not familiar to it at all. Many of the staff have questioned the method or some against it because the reason of time wasting. There are still misunderstanding that the risk management process can help the Company ABC improve their performance and control their business into another level. Therefore, there should be trainings and explanations about risk management and how important it should be to the staff.

2. Continuous improvement use of FMEA

The FMEA used in these risk meeting is the first FMEA ever used in the history of the company, which there were confusion and misunderstandings. The FMEA tables and criteria will need to improve over time to be more accurate and gain more insight to the project. The criteria of the FMEA will need to be updated to fit the projects at hand and the past risks will need to be reviewed to gain better understanding of the projects in the future.

3. Team member

The team members will have to be updated to fit the projects in the future. The team members in this case were selected to fit this project, however this set of members cannot be running the risk management program in the future of the external factors have changed. Therefore, the team members will have to be selected according to the suitability of each project.

4. Set higher vision of the company

In order to improve, the company will have to set their visions of the company to a higher point. Risk management is not only about how the risk is managed but it is about improvement and creating systems to prevent it. If the visions of the managers are not set to a high point, then the risks identification and risk response might not be the best for the company. The company will need to aim higher in improvement and believe in their core competency.

5. Increase the use of tools and techniques

In each process of risk management, there are tools and techniques used to gain faster and better results. In the future, these tools and techniques will have to improve. With better tools and techniques, the risk management process will get more accurate and more effective.

5.3 Further studies

The further studies of this thesis can be separated out into many branches depending on the area of interests. Because construction is such as wide topic, there are many concerning points that could be further developed. These are some of the concerning points for further studies:

1. Preventive action implementation methods

The method of implementation is very crucial to the result of the preventive action. To study the implementing methods or approaches for the preventive actions can benefit the company.

2. Improvement of prefabricated house construction operation system

The prefabricated house construction is a type of construction that is designed for speed. To study the factors for increasing the speed of construction project will be very useful. The prefabricated house construction can be improved up to lean manufacturing.

3. Implementation Method

The method of implementation of the preventive actions will need to be studied because the method of implementation can influence a lot of the results whether the preventive actions are effective or not.

4. Management of change

The implementation of preventive actions will change the working culture of the company; therefore a lot of problems will arise. Management of change is the best way to handle these problems.

REFERENCES

Ahadzie, D.K., Proverbs, D.G. and Olomolaiye P.O. Critical success criteria for mass house building projects in developing countries. International Journal of Project Management 26 (2008): 675-687.

Akintoye, A., Beck, M. and Hardcastle, C. Public-Private Partnerships – Managing Risks and Opportunities. Oxford UK: Blackwell Publishing, 2003.

Akintoye, A. and Macleod M. Risk Analysis and Management in Construction. International Journal of Project Management 15 (1997).

British Standard Institute. British Standard BS 6076: Guide to Project management. [Online]. 2000. Available from : http://www.bsigroup.com/ [2009, October, 10]

Carr, V. and Tah, J.H.M. A Fuzzy approach to construction project risk assessment and analysis: construction project risk management system. Advanced in Engineering Software 32 (2001): 847-857.

Chapman, R.J. The controlling influences on effective risk identification and assessment for construction design management. International Journal of Project Management 19 (2001): 147-160

Charnwasununth, P. A Case Study of a Framework for Scheduling Prefabricated Housing Construction. Master's Thesis, Department of Civil Engineering Faculty of Engineering Chulalongkorn University, 2006.

CIOB. Code of Practice for Project management for Construction and Development. Third Edition. Oxford: Blackwell Publishing, 2002.

El-Sayegh, S. Risk Assessment and Allocation in the UAE construction industry. International Journal of Project Management 26 (2008): 431-438.

Fearon, H., Ruch, W. and Weiters, D. Fundamentals of Production/Operations Management. Fourth Edition, USA, West Publishing Company, 1989.

Fewings, P. Construction Project Management: An Integrated Approach. London and New York, Taylor & Francis, 2005.

Ford Design Institute. Failure Mode and Effect Analysis: FMEA Handbook with Robustness Linkages. Dearborn, MI, 2004

Google. Google Maps. [Online]. 2000. Available from :http://maps.google.co.th/maps?hl=en&tab=wl [2009, October, 02]

Johnson, K.G. and Khan, M.K. A Study into the use of the Process Failure Mode and Effect Analysis (PFMEA) in the Automotive Industry in the UK. Journal of Material Processing Technology 139 (2003): 348-356.

Koller, G. Risk Assessment and Decision Making in Business and Industry: A Practice Guide. USA, Taylor & Francis Group, 2005.

Lam, K.C., Wang, D., Lee, P.T.K. and Tsang, Y.T. Modelling risk allocation decision in construction contracts. International Journal of Project Management 25 (2007): 485-493.

Leopoulos, V. N., Kirtytoloulos K. A. and Malandrakis, C. Risk Management for SMEs: Tools to use and how. Journal of Production, Planning & Control 17 (2006): 322-332.

Liang, R., Craig, A. and Edge, H. M. Prefabricated Housing: An Assessment of Cost, Value and Quality. Journal of Design (2001).

Loosemore, M., Raftery, J., Reilly, C. and Higgon D. Risk Management In Projects, Second Edition, London and New York, Tylor & Francis Group, 2006.

Mills, A. A systematic approach to risk management for construction. Journal of Architecture, building and planning 19 (2001): 245-252.

Mulholland, B. and Christian, J. Risk Assessment in Construction Schedule. Journal of Construction Engineering and Management 125 (1999)

Naaranoja, M., Haapalainen, P. and Lonka, H. Strategic Management tools in Projects case construction project. International Journal of Project Management 25 (2007): 659-665.

Osborn, A. Applied Imagination, New York, Scribner's (1953).

Pipattanapiwong, J. Development of Multi-party Risk and Uncertainty Management Process for an Infrastructure Project. Doctorate's Thesis, Kochi University of Technology, Kochi, Japan, 2004.

Raz, T. and Michael, E. Use and Benefits of tools for project Risk Management. International Journal of Project Management 19 (2001): 9-17.

Richard, R. Some Strengths and Weakness of AS/NZS 4360 (The Risk Management Standard). Australia, Due Diligence Engineers, 2009.

Rowe, W. An Anatomy of Risk. New York, John Wiley & Sons, 1977.

Scholtes, P. R., Joiner, B.L. and Streibel, B.J. The Team Handbook. Third Edition, Madison, Joiner Associates, 1988.

Stewart, R. W. and Fortune, J. Applications of systems Thinking to the Identification, Avoidance and Prevention of Risk. International Journal of Project Management 13 (1995): 279-286.

Teoh, P.C. and Case, K. Failure Modes and Effects analysis through knowledge modeling. Journal of Material Processing Technology 153/154 (2004): 253-260.

Truong, L. V., Kim, S., Van Tuan, N. and Ogunlana, S. Qualtifying schedule Risk in construction projects using Bayesian belief networks. International Journal of Project Management 27 (2009): 39-50.

Van Leeuwen, J.F., Nauta, M.J., De Kaste, D., Odekerken-Rombouts, Y.M.C.F., Oldenhof, M.T., Vredenbregt, M.J. and Barends, D.M. Risk Analysis by FMEA as an Element of Analytical Validation. Journal of Pharmaceutical and Biomedical Analysis 50 (2009): 1085–1087.

Warwick WMG Course. Project Planning Management and Control: Managing Construction Projects. RCMSE, 2008. (Unpublished manuscript)

Warwick WMG Course. Competitive Design Management. RCMSE, 2008. (Unpublished manuscript)

Watts, D. J., Kyis, B. and Willey K. Identifying key factors in the evaluation of tenders for projects and services. International Journal of Project Management 27 (2009): 250-260.

Wyk, R., Bowen, P. and Akintoye, A. Project risk management practice: The case of a South African utility company. International Journal of Project Management 26 (2008): 149-163.

APPENDIX

FMEA of Critical Risks (1)

Risk NO.	Risk in process	Failure Mode (Risk)	Possible Effect	Possible Cause	Old Scoring				Corrective Actions	New Scoring				Corrective %
					S	O	D	RPN		S	O	D	RPN	
1	4.10	Under standard quality control (Q.C.) at factory	Highly defect products delivered to construction site, conflict with customers, Delay caused by training.	Low motivation, ineffective documentation, in-experience quality control team, poor quality standard judgement.	7	8	9	504	Creating standard form & documents; Hire architect team and construction consults.	7	4	2	56	88.9
2	5.9	Lack of skilled labors (carpenter, foundation work labor, structuring work labor, fine architecture work albor)	Construction delay, increasing of defect, low quality, increase of workload in quality control department, stress to foreman.	Unavailable skill labor in local area, insufficient training.	8	10	6	480	Training foreman; Increase incentive & welfare to foreman and staff consulting	3	5	5	75	84.4
3	7.1	Unclear roles and responsibilities	Project delay, confusion in responsibilities, confusion in internal staff position ranking, internal conflict, same jobs done multiple times	Carelessness, unclear contract agreement, internal conflict, ineffective communication	7	8	8	448	Increasing frequency of meetings; Re-structuring organization chart	5	5	2	50	88.8
4	1.2	Lack of information gathered by architect on the total project direction	Poor design function, unsuitable deisng, delay in designing process, error in foundation process, effect total project outcome.	Lack of time (faulty assumptions), low motivation, carelessness, architect in-experienced.	7	8	8	448	Hire architect team and construction consults	2	2	8	32	92.9
5	4.6	Insufficient skilled labors (carpentors, painters and general wood working skills)	High defect rate, misuse of tools, low quality products, production delay, internal conflict, delay caused by training.	Lack of training, unavailable skilled labor at factory area, low motivation.	8	8	7	448	Training foreman; Increase incentive & welfare to foreman and staff consulting	4	4	5	80	82.1

FMEA of Critical Risks (2)

6	7.7	Lack of supervision	Project delay from confusion and lack of leadership from upper and middle management, high defect rate, low motivation, lack of monitoring and control,	Carelessness, lack of leadership, lack of understanding in process, lack of communication, over-work of foreman, in-experience in process, low motivation, over-complicated process, unskilled foreman and managers.	7	8	8	448	Training foreman; Increase frequency of meetings; Increase incentive & welfare to foreman and staff consulting; Hire architect team and construction consults, Re-structuring organization chart	2	2	4	16	96.4
7	1.9	Inaccurate shop drawing produced and gathered	Difficulties in construction, difficulties in production, project delay, a lot of construction correction and problem with process	Poor database system from past project, insufficient skill , lack of information, carelessness, in-experience	9	6	8	432	Hire architect team and construction consults	4	3	8	96	77.8
8	2.1	Unclear architectural design for material breakdown	Unable to breakdown Bill of Quantity, poor production schedule and planning, project delay, House assembly problem at site, problem with purchasing materials	Carelessness from architect, over-complex details in house required from customer, in-experience architect.	7	7	8	392	Hire architect team and construction consults	3	4	8	96	75.5
9	7.2	Poor documentation	Confusion in any process, conflicts in any process, project delay.	Carelessness, ineffective documentation system, insufficient documentation organizing skills, Neglect importance of good documentation system.	7	8	7	392	Creating standard form & documents	7	2	2	28	92.9
10	7.3	Low efficiency in information Flow and coordination	Confusion in any process, conflicts in any process, project delay,	Unclear organization position and ranking, in-experience, carelessness, ineffective information flow system, misuse of technology, non-information sharing cultures, corruption.	8	6	8	384	Creating standard form & documents; Increase frequency of meetings; Increase incentive & welfare to foreman and staff consulting; Re-structuring organization chart	3	3	2	18	95.3

FMEA of Critical Risks (3)

11	7.9	Lack of efficiency in project monitoring and control	Project delay, high defect rate, confusion in any progress, conflict in any progress, low efficiency in total project, low problem solving ability, low detection of problems.	Carelessness, ineffective communication, in-experience, misuse of technology, neglect of importance.	8	6	8	384	Training foreman; Creating standard form & documents; Increase frequency of meetings; Increase incentive & welfare to foreman and staff consulting; Hire architect team and construction consults; Re-structuring organization chart	3	3	2	18	95.3
12	5.30	Under standard quality control	Low product quality, customer's disappointment, delay caused from training and rework.	Unclear standard setting, lack of training, carelessness, ineffective documentation, unskilled staff, lack of monitoring and control.	6	9	7	378	Creating standard form & documents; Hire architect team and construction consults	6	3	2	36	90.5
13	7.6	Careless working culture	Defects in every process, difficult to monitor and control, project delay from various factor, customer dissatisfaction.	Lack of motivation ,Thai working culture, under estimating workload, no disciplin.	7	7	7	343	Training foreman; Increase incentive & welfare to foreman and staff consulting	4	4	5	80	76.7
14	7.5	Low efficiency in Manager team	Confusion in any process, conflicts in any process, project delay, delay in decision making, ineffective problem solving, project termination.	Stress, corruption, carelessness, low motivation, in-experience, internal conflicts, lost of project direction, ineffective communication, external personal problem.	7	6	8	336	Increase frequency of meetings; Hire architect team and construction consults; Re-structuring organization chart	3	4	7	84	75.0
15	2.6	Poor material resource plan	Production and construction process delay causing project delay, difficulties and confusion in work, unproductive labor use at site and at factory.	In-experience in planning process, carelessness, lack of material information, lack of contact to supplier, inaccurate inventory information, ineffective communication with supplier .	7	5	9	315	Hire architect team and construction consults	4	3	9	108	65.7

FMEA of Critical Risks (4)

16	5.17	Inaccurate in working details	High workload of quality control, defects, delay caused from rework, penalty.	Unskilled labors, ineffective documentation, ineffective communication, insufficient leadership, carelessness, low monitoring and control of quality.	6	8	6	288	Training foreman; Increase incentive & welfare to foreman and staff consulting	3	3	5	45	84.4
17	2.9	Poor information gathering from site and production factory to create master schedule of production and construction synchronization	Project delay in construction and production process, conflicts from misunderstandings, stress from delayness and confusion, lower motivation, disrupt the work flow in both site and factory, cause for re-organizing total project management issue, cause a lot of problems in both daily basis and long-term.	Carelessness, no system of information gathering, in-experience survey team, lack of information flow, ineffective communication.	7	3	6	126	Hire architect team and construction consults	4	2	6	48	61.9

FMEA Criteria of FORD DESIGN INSTITUTE

SEVERITY

Effect	Criteria: Severity of Effect This ranking results when a potential Failure Mode results in a final customer and/or a manufacturing/assembly plant defect. The final customer should always be considered first. If both occur, use the higher of the two severities.		Ranking
	(Customer effect)	(Manufacturing/ Assembly Effect)	
Hazardous without warning	Very high Severity ranking when a potential Failure Mode affects safe vehicle operation and/or involves noncompliance with government regulation without warning.	Or may endanger operator (machine or assembly) without warning.	10
Hazardous with warning	Very high Severity ranking when a potential Failure Mode affects safe vehicle operation and/or involves noncompliance with government regulation with warning.	Or may endanger operator (machine or assembly) with warning.	9
Very High	Vehicle/item inoperable (loss of primary function).	Or 100% of product may have to be scrapped, or vehicle/item repaired in repair department with a repair time greater than one hour.	8
High	Vehicle/Item operable but at a reduced level of performance. Customer very dissatisfied.	Or product may have to be sorted and a portion (less than 100%) scrapped, or vehicle/item repaired in repair department with a repair time between half an hour and an hour.	7
Moderate	Vehicle/Item operable but Comfort/Convenience item(s) inoperable. Customer dissatisfied.	Or a portion (less than 100%) of the product may have to be scrapped with no sorting, or vehicle/item repaired in repair department with a repair time less than half an hour.	6
Low	Vehicle/Item operable but Comfort/Convenience item(s) operable at a reduced level of performance. Customer somewhat dissatisfied.	Or 100% of product may have to be reworked, or vehicle/item repaired off-line but does not go to repair department.	5
Very Low	Fit and finish/Squeak and rattle item does not conform. Defect noticed by most customers (greater than 75%).	Or the product may have to be sorted, with no scrap, and a portion (less than 100%) reworked.	4
Minor	Fit and finish/Squeak and rattle item does not conform. Defect noticed by 50 percent of customers.	Or a portion (less than 100%) of the product may have to be reworked, with no scrap, on-line but out-of-station.	3
Very Minor	Fit and finish/Squeak and rattle item does not conform. Defect noticed by discriminating customers (less than 25 percent).	Or a portion (less than 100%) of the product may have to be reworked, with no scrap, on-line but in-station.	2
None	No discernible effect.	Or slight inconvenience to operation or operator, or no effect.	1

OCCURRENCE

Probability of Failure	***Likely Failure Rates***	***Ranking***
Very High: Persistent failures	*≥100 per thousand pieces*	*10*
	50 per thousand pieces	*9*
High: Frequent failures	*20 per thousand pieces*	*8*
	10 per thousand pieces	*7*
Moderate: Occasional failures	*5 per thousand pieces*	*6*
	2 per thousand pieces	*5*
	1 per thousand pieces	*4*
Low: Relatively few failures	*0.5 per thousand pieces*	*3*
	0.1 per thousand pieces	*2*
Remote: Failure is unlikely	*≤0.01 per thousand pieces*	*1*

DETECTION

Detection	Criteria	A	B	C	Suggested Range of Detection Methods	Ranking
Almost Impossible	Absolute certainty of non-Detection.				Cannot detect or is not checked.	10
Very Remote	Controls will probably not detect.				Control is achieved with indirect or random checks only.	9
Remote	Controls have poor chance of Detection.				Control is achieved with visual inspection only.	8
Very Low	Controls have poor chance of Detection.				Control is achieved with double visual inspection only.	7
Low	Controls may detect.				Control is achieved with charting methods, such as SPC {Statistical Process Control}.	6
Moderate	Controls may detect.				Control is based on variable gaging after parts have left the station, OR Go/No Go gaging performed on 100% of the parts after parts have left the station.	5
Moderately High	Controls have a good chance to detect.				Error Detection in subsequent operations, OR gaging performed on setup and first-piece check (for set-up Causes only).	4
High	Controls have a good chance to detect.				Error Detection in-station, OR error Detection in subsequent operations by multiple layers of acceptance: supply, select, install, verify. Cannot accept discrepant part.	3
Very High	Controls almost certain to detect.				Error Detection in-station (automatic gaging with automatic stop feature). Cannot pass discrepant part.	2
Very High	Controls certain to detect.				Discrepant parts cannot be made because item has been error proofed by process/product design.	1

Inspection Types:
A Error Proofed
B. Gaging
C. Manual Inspection

A Checklist for common risks and opportunities in construction projects

Technology

- Availability of materials/technologies/equipment.
- Experience of working with materials/technologies/equipment.
- Lead times for orders of materials/technologies/equipment.
- Stability of design, design changes etc.
- Availability of key components and spares.
- Equipment reliability/safety/productivity.
- Innovation – need for further development.
- Maintenance and spare parts costs.
- Reliability, maintainability, availability, support availability
- Specification completeness and accuracy.
- Clarity of technical performance, standards or regulations.
- Technological change, updates, obsolescence.
- Materials quality/safety.
- Workmanship.
- Productivity of equipment.
- Availability of critical plant/equipment/spare parts, fuel, skills for operating etc.
- Sampling/testing.
- Ground conditions (mining activities, rock, services, antiquities, contamination etc.).
- Suitability, availability and supply of materials.
- Transport (difficulties, availability, suitability, police and liaison requirements, usage constraints, site access, noise, pollution, weather impact etc.)
- Control over design process (opportunities for influence over design decisions, designers' understanding of issues, communication with designers etc).
- Availability of design information/design changes.
- Quality of design (buildability, omissions, incompatibility between different designs, details, components, sub-standard performance when built, difficult to build etc).
- Innovation in design (level of standardization, newness of technology/details/materials etc).
- New technology (unfamiliarity, application, feasibility, specialist controls/monitoring needed).
- Software (theft, misuse, abuse, database size and complexity, development required, training required etc).
- Security.
- Product contamination.
- Product safety, safety guidelines, hazardous materials etc.

- Overseas voltage compatibility.

Human

- Effectiveness of communications (language difficulties, use of translators, accuracy of translators etc.)
- Working and living conditions for staff.
- Crimes against people, property, vandalism, bribery, espionage, terrorism and extortion.
- Security and safety of staff, personnel and public.
- Industrial relations.
- Labour sickness/absenteeism.
- Quality, capability, reliability, productivity and availability of labour (operatives (sub-contractors) and managers).
- Attitudes of staff towards quality, costs, environment, safety, trust, opportunities etc.
- Staff reliability, skills, capability etc.
- Culture (compatibility, different ways of working, different standards, different priorities, cultural assimilation etc.).
- Personality conflicts.
- Skills and staffing issues (Adequate prior experience, availability and mix of skills staff, learning curve effects, loss of critical skills/staff, staff turnover, recruitment, induction, training needs/timeframe/effectiveness, willingness of key staff to relocate etc.).
- Intimidation/racism/discrimination.
- Malicious damage/sabotage to property/vandalism.
- Theft.
- Bribery.
- Corruption.
- Malicious attacks upon individuals/personal conflicts.
- Sabotage.
- Mistakes/errors/incompetence.
- Stupidity.
- Inefficiency.
- Personality conflicts.
- Negligence.
- Differing professional/personal values and beliefs.
- Different ways/methods of working.
- Interference between trades.
- Communication effectiveness.
- Misunderstandings/misinterpretation.
- Cultural differences (language, traditions, food, beliefs, religious etc).

- Indecisiveness.
- Unreasonableness.

Environmental

- Force Majeure (acts of god) – heat-wave, rain, wind, heat, cold, humidity, fire, tidal wave, volcanic, earth quake, flood, storms/cyclones, landslide, lightening strike etc.
- Pest/vermin infestation.
- Industrial/environmental disaster.
- Pestilence.
- Disease and health risks.
- Pollution.
- Ecological damage.
- Endangered species.
- Contamination of land, water and air.
- Conservation.
- Hazardous chemical or gas release.
- Hazardous sites and materials.
- Legislative and regulatory constraints.
- Noise.
- Waste, recycling etc.

Commercial and legal relationships

- Overseas (compatible or familiar legal system, corruption).
- Finance.
- Conditions of contract (clarity, complexity, fairness, variations to standards).
- Conditions of acceptance.
- Purchase agreements.
- Contractual requirements (joint venture partners, local labour etc).
- Disputes/claims.
- Breaches of contract (liquidated damages etc).
- Completion dates.
- Potential professional liability.
- Fraud/corruption.
- Enforceability of contracts with governments.
- Delay in possession of site – access problems.
- Determination.
- Contract revisions/changes.
- Supply (shipping/delivery – materials, plant and labour).
- Delay in resolving disputes.
- Costs of obaaining decisions.

- Delays in enforcing decisions.
- Joint venture partner (potential for litigation, complexity of contracts and documentation, level of control and responsibility, complexity of organizational structure etc.).
- Overseas contracts – approval processes, level of prescription, local conditions, local biases, corruption, corporate and licensing arrangements/regulations etc.

Management activities/controls/systems

- Documentation quality (errors/omissions in bill of quantities, inadequate information, conflicting information on designs, poor specification, unbuildable designs, inaccurate estimates etc).
- Information to make decisions (poor databases, out-of-date information, late information, inaccurate information, ambiguous information, unusable information, difficult to understand information etc).
- Quality of planning – realistic programmes etc.
- Coordination between different sub-contractors.
- Motivation.
- Communication.
- Decision-making.
- Leadership.
- Crisis preparedness – emergency plans.
- Level of planning (fast-tracking/design completion).
- Monitoring/control systems (quality, costs, time).

Economic/financial

- Availability of funds/funding sources.
- Joint venture partners (requirements for skills/equity).
- Complexity of funding arrangements (equity funding and ownership).
- Financing costs/terms/conditions – interest rates, investment conditions etc.
- Availability of extra funds if needed.
- Agents fees.
- Price fluctuations/inflation.
- Market factors/revenue fluctuations.
- Market competition.
- Demand change.
- Demographic changes.
- Exchange rate fluctuations.
- Currency value changes.
- Funding/payment problems/constraints.
- Cash flow problems (us, sub-contractors, suppliers, client).
- Bankruptcy/insolvency (Ditto).

- Payment problems/delays/valuation.
- Pay demands/constraints.
- Local and national taxes (payment, avoidance, enforcement).
- Cash management/foreign exchange management.
- Working capital requirements.
- Market factors influencing cost of working capital and prices of goods and services offered and bought (e.g. energy, materials, maintenance).

Business partners (principals, partners, contractors, sub-contractors and suppliers)

- Communication (proximity, remoteness, infrastructure, systems)
- Liquidity, solvency, business failure, stability, change of ownership, vulnerability.
- Ability and willingness to pay, payment philosophy etc.
- Credit rating.
- Client/user/operator – clarity and compatibility of expectations/perceptions/requirements.
- Ability to meet contract commitments.
- Attitude to changes in scope, specifications, costs, time etc.
- Attitude to litigation.
- Availability of information about business.
- Attitudes towards environment, safety, quality, time cost etc.
- Ability to take delivery of product, transition arrangements etc.
- Principal interaction.
- Representatives – personalities, number, experience etc.
- Trust.
- Past relationships.
- Future business relationship.
- Technical knowledge, skills and experience to deal with specified technologies.
- Availability.
- Compatibility (business culture, systems, geographic, personalities, assimilation requirements etc.).
- Speed of response, bureaucracy, decision-making, communications with etc.
- Organizational structure (general and for contract)
- Ability to deliver on time and within budget.
- Lead times for orders.
- Accreditation for safety, quality etc.
- Alternative suppliers/sub-contractors etc in case of insolvency, failure to deliver etc.
- Commercial terms.
- Contract team, management, control and supervision.

- Costs of goods and services, costs of extras, costs of delays (consequences if things go wrong) etc.
- Warranty on goods and services.
- Quality of goods and services.
- Reliability of goods and services.
- Failure in supplier/sub-contractor supply chain.
- Quality of supplier/sub-contractor supply chain.
- Flow-on conditions, criticality of service, dependence upon.
- New or existing contract/supplier etc.
- Joint venture partner (financial stability, compatibility, technical resources, skills, knowledge, expertise, commitment, familiarity).
- Overseas (quality of business agents).

Political

- Customs/export/import restrictions (embargos etc).
- Overseas (political/social stability, cultural and religious factors, relationship with host government, international relations, support from embassy/trade commission, prejudice against foreign companies/employees, lobbying etc.)
- Requirements for permits etc.
- Ability to repatriate profits.
- Availability of foreign exchange.
- Changes in government.
- Changes in government policy.
- Changes to taxation/royalty regimes.
- New legislation (taxes, labor, safety, waste, environmental etc.).
- Expropriation.
- Government constraints on operations.
- Government endorsement/intervention.
- Native title, native owners issues.
- Import/export restrictions.
- Withdrawal of approvals and licenses.
- Enforcement bodies (inspections relating to legislation).
- Local government/services (liaison, planning, approvals, inspections etc).
- Civil commotion, wars.
- Public relations/perceptions.
- Pressure groups/canvassing/consultation/protests/support (environmental, disabled etc).
- Public reaction/complaints/perceptions/misperceptions/protests (relating to dust, noise, lighting, security, inconvenience etc).
- Probity.

Filtered checklist for Prefabricated House Construction in Thailand of common risks and opportunities in construction projects

Technology

- Availability of equipment.
- Experience of working with materials/technologies/equipment.
- Lead times for orders of materials/technologies/equipment.
- Stability of design, design changes etc.
- Maintenance and spare parts costs
- Specification completeness and accuracy.
- Clarity of technical performance, standards or regulations.
- Availability of critical plant/equipment/spare parts, fuel, skills for operating etc.
- Ground conditions (mining activities, rock, services, antiquities, contamination etc.).
- Transport (difficulties, availability, suitability, police and liaison requirements, usage constraints, site access, noise, pollution, weather impact etc.)
- Control over design process - (opportunities for influence over design decisions, designers' understanding of issues, communication with designers etc).
- Availability of design information/design changes. – Design change from customer, limited number of design.
- New technology (unfamiliarity, application, feasibility, specialist controls/monitoring needed).
- Software (theft, misuse, abuse, database size and complexity, development required, training required etc).
- Security.
- Product safety, safety guidelines, hazardous materials etc.

Human

- Crimes against people, property, vandalism, bribery, espionage, terrorism and extortion.
- Security and safety of staff, personnel and public.
- Labor sickness/absenteeism.
- Quality, capability, reliability, productivity and availability of labor and staff (operatives (sub-contractors) and managers).
- Attitudes of staff towards quality, costs, environment, safety, trust, opportunities etc.
- Culture (compatibility, different ways of working, different standards, different priorities, cultural assimilation etc.).

- Skills and staffing issues (Adequate prior experience, availability and mix of skills staff, learning curve effects, loss of critical skills/staff, staff turnover, recruitment, induction, training needs/timeframe/effectiveness, willingness of key staff to relocate etc.).
- Mistakes/errors/incompetence.
- Stupidity.
- Inefficiency.
- Personality conflicts.
- Negligence.
- Different ways/methods of working.
- Communication effectiveness.
- Indecisiveness.

Environmental

- Force Majeure (acts of god) – heat-wave, rain, wind, heat, cold, humidity, fire, tidal wave, volcanic, earth quake, flood, storms/cyclones, landslide, lightening strike etc
- Pest/vermin infestation.
- Waste, recycling etc.

Commercial and legal relationships

- Conditions of contract (clarity, complexity, fairness, variations to standards).
- Conditions of acceptance.
- Purchase agreements.
- Contractual requirements (joint venture partners, local labor etc).
- Completion dates.
- Contract revisions/changes.
- Supply (shipping/delivery – materials, plant and labor).
- Joint venture partner (potential for litigation, complexity of contracts and documentation, level of control and responsibility, complexity of organizational structure etc.).

Management activities/controls/systems

- Documentation quality (errors/omissions in bill of quantities, inadequate information, conflicting information on designs, poor specification, unbuildable designs, inaccurate estimates etc).
- Information to make decisions (poor databases, out-of-date information, late information, inaccurate information, ambiguous information, unusable information, difficult to understand information etc).
- Quality of planning – realistic programmes etc. – not good
- Coordination between different sub-contractors.
- Motivation.
- Communication.

- Decision-making.
- Leadership.
- Crisis preparedness – emergency plans.
- Level of planning (fast-tracking/design completion).
- Monitoring/control systems (quality, costs, time).

Business partners (principals, partners, contractors, sub-contractors and suppliers)

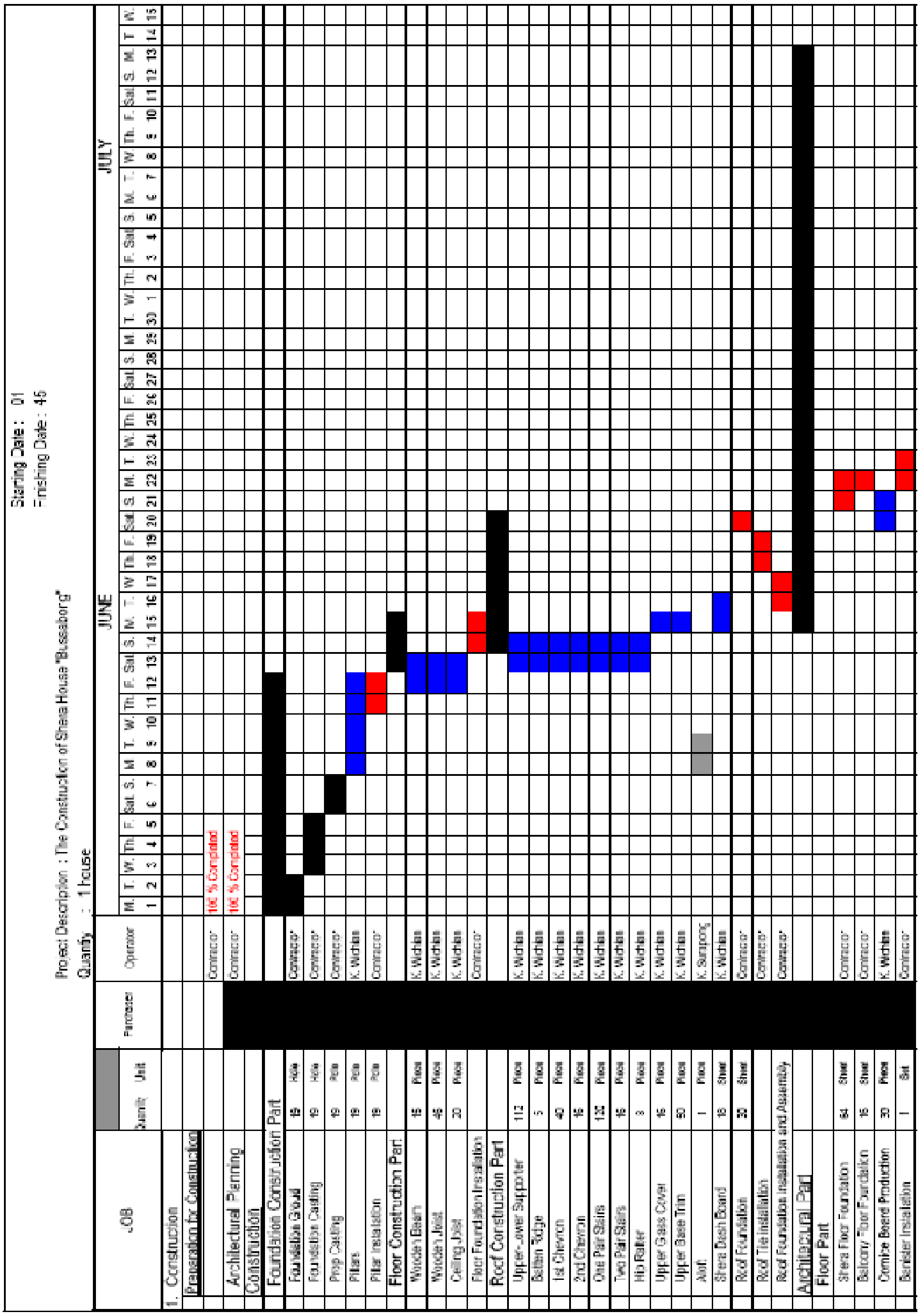
- Communication (proximity, remoteness, infrastructure, systems)
- Ability and willingness to pay, payment philosophy etc.
- Client/user/operator – clarity and compatibility of expectations/perceptions/requirements.
- Ability to meet contract commitments.
- Attitude to changes in scope, specifications, costs, time etc.
- Attitudes towards environment, safety, quality, time cost etc.
- Ability to take delivery of product, transition arrangements etc.
- Technical knowledge, skills and experience to deal with specified technologies.
- Compatibility (business culture, systems, geographic, personalities, assimilation requirements etc.).
- Speed of response, bureaucracy, decision-making, communications with etc.
- Organizational structure (general and for contract)
- Ability to deliver on time and within budget.
- Lead times for orders.
- Costs of goods and services, costs of extras, costs of delays (consequences if things go wrong) etc.
- Warranty on goods and services.
- Quality of goods and services.
- Failure in supplier/sub-contractor supply chain.
- Quality of supplier/sub-contractor supply chain.

Prefabrication

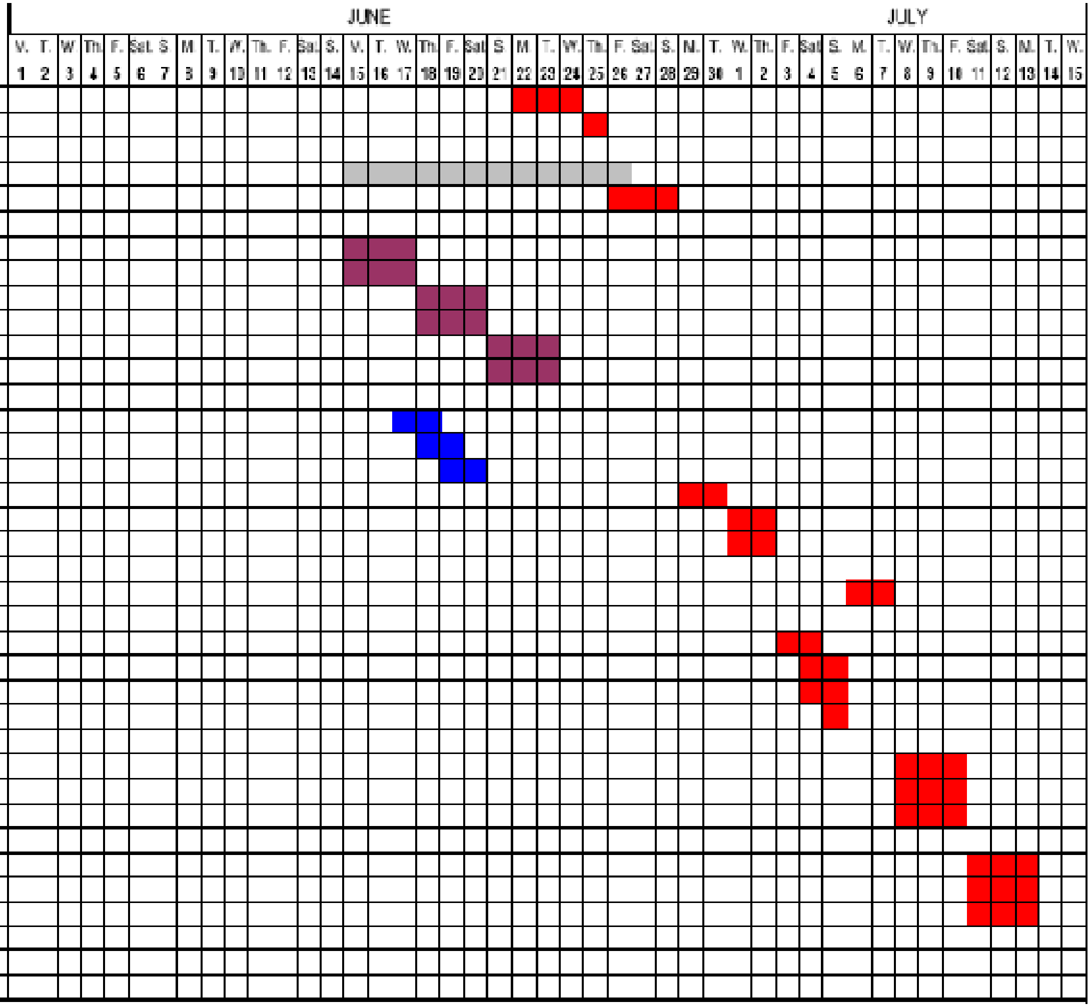
- Under standard quality control (Q.C.)
- Lack of skilled labors (carpenter, foundation work labor, structuring work labor, fine architecture work, labor, carpenters, painters and general wood working skills)
- Unclear roles and responsibilities
- Lack of information gathered by architect on the total project direction
- Lack of supervision
- Unclear architectural design for material breakdown
- Poor documentation (Standard forms, architect plans, shop drawings)

- Low efficiency in information Flow and coordination, project monitoring and control
- Careless working culture
- Low efficiency in Manager team
- Poor material resource plan
- Poor information gathering from site and production factory to create master schedule of production and construction synchronization

Schedule of Single House Construction

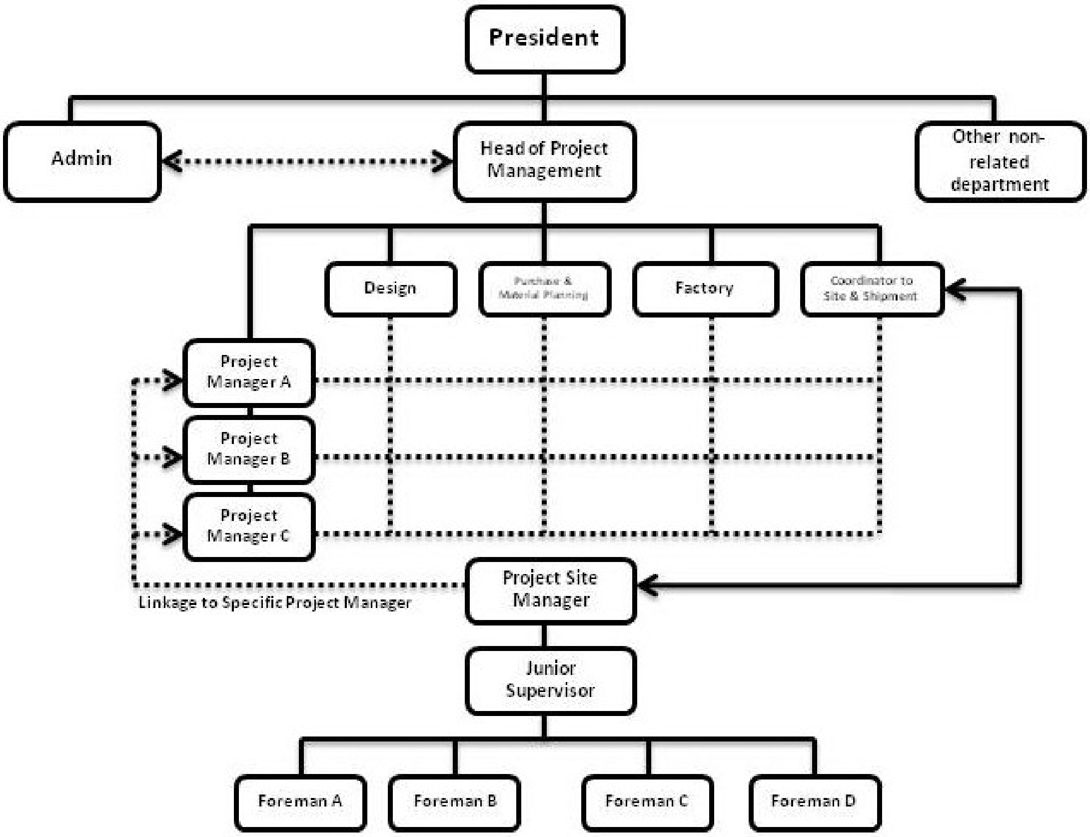


JOB	Quantity	Unit	Purchaser	Operator
Stairs Installation	-	Set	[redacted]	Contractor
Restroom Tile Flooring	5	Sq. Metre		Contractor
Wall Part				
Shera Wall Production	15	Sheet		K. Wichian
Shera Wall Installation	15	Sheet		Contractor
Door - Window Part				
Door Frame Production	3	Set		K. Koon
Window Frame Production	8	Set		K. Koon
Door Production	2	Set		K. Koon
Window Production	8	Set		K. Koon
Upper-Lower Aqueduct	20	Piece		K. Wichian
Handle & Lock	10	Set		K. Koon
Attic Ceiling Part				
Decorate Fabric Production	100	Sq. Metre		K. Wichian
Attic Ceiling Cover Base Tri	60	Sheet		K. Wichian
Decorate Base Trim Productio	200	Metre		K. Wichian
Interior Attic Ceiling Installatio	-	House		Contractor
Exterior Attic Ceiling Installati	-	House		Contractor
Attic Ceiling Eaves Installatio	-	House		Contractor
Sanitary Part				
Sanitary ware installation	-	House		Contractor
Painting Part				
Attic Ceiling Painting	-	House		Contractor
Interior Painting	-	House		Contractor
Exterior Painting	-	House		Contractor
Door-Window Painting	-	House		Contractor
Electrical Installation Part				
Electrical Wire Channel Instal	-	House		Contractor
Inner-Outer Electrical Wire In	-	House		Contractor
Spotlight-Plug Installation	-	House		Contractor
Sanitary System Part				
Clean Water Piping	-	House		Contractor
Copper Piping	-	House		Contractor
Waste Water Piping	-	House		Contractor



Standard Forms

New Organization Chart



Contract Agreement of Consultant Service

Contract number: [redacted]

AGREEMENT INFORMATION

This contract is made in duplicate on the: ....20 October 2009.......................

At: ....[redacted] Project...

District: .....[redacted]........... Province: ....Phang-nga........................

By and Between

Between: ....[redacted] Company limited and Consultant................................

By: ....Mr. [redacted] (President of [redacted] Company limited)............................

Which in this contract, will be called as “**The Client**”

And: ....Mr. [redacted]......(Consultant)..

Which in this contract, will be called as “**The Consultant**”

The Client and the Consultant agree as follow:

1. DEFINITIONS

1.1 The Agreement is the undertaking by the parties to perform their respective duties, responsibilities, and obligations as prescribed herein, and represents the entire agreement between the parties.

1.2 The Work means the total assignment and related services required by the Agreement.

1.3 The Client means ABC Company limited or their authorized Representative(s).

1.4 The Client's Representative(s) shall mean the person(s) designated by the Board of Directors to carry out all or any functions authorized or permitted to be performed on the Client's behalf under this Agreement. The Client's Representative(s) for this agreement are as follows:

1.5 The Consultant means the person contracted with the Client to provide the consulting services as described in this Agreement.

1.6 Disbursements means all expenses directly related to travel, long distance telephone and FAX transmissions, printing/plotting and reproduction costs, postage, and courier charges.

1.7 Additional Services are those services listed under Article 4 of the Agreement - CONSULTANT’S SERVICES, and agreed to by both parties herein, but not previously described in a Request For Proposals or other such document outlining the scope of requested services.

1.8 Cost of the Work is the amount stipulated in Article 5 of the Agreement - COST OF THE WORK.

1.9 Value Added Taxes means such sum as shall be levied upon the Cost of the Work by the Federal or any Provincial Government and is computed as a percentage of the Cost of the Work and includes the Goods and Services Tax, the Quebec Sales Tax and any similar tax, the payment or collection of which is by the legislation imposing such tax an obligation of the Consultant.

2. THE WORK

Part A: Improvement of existing Architectural Plan and Design System.

- **Improvement and correction of any possible architectural plans of prefabrication houses**
- **Improvement and corrections of any shop drawing of the prefabrication houses**
- **Improve and consult the designing system and process, along with training the in-house architect in charge in ABC Company Limited**
- **Improve and Review the method and process of information flow from designing process to manufacturing process of the prefabrication houses**

Part B: Consultation and Control of Factory Operations and Construction Operations at site.

- **Improve and consult the Quality Control standard of product at factory and on site**
- **Consult and control on site construction operations**
- **Improve and consult the efficiency of foremen and labor working method**
- **Trouble shooting any problems occurred at the Factory or Construction site**

The Working period agreement of The Work from the consultant shall begin on: ....**20 October 2009**....and shall complete The Work within.....**31 March 2010**..........

****Note**** Construction project ends on 31 January 2010 (End of Part B), however from 1 February 2010 to 31 March 2010 (End of Part A) shall be used for consultation on operating systems at ABC Company Limited Factory for further projects.

The Consultant shall:

2.1 Perform the Work required by this Agreement for ABC Company Limited

2.2 Do and fulfill everything indicated by this Agreement, and

2.3 Commence the Work upon receipt of required documents, subject to adjustment as subsequently agreed to by both parties.

3. AGREEMENTS AND AMENDMENTS

3.1 The Agreement supersedes all prior negotiations, representations, or agreements, either written or oral, relating in any manner to the Work, including any Request for Proposals, submitted Consultant Proposals, or parts thereof which are not included in Appendix A.

3.2 The Agreement may be amended only by written adjustment and agreed to by both parties.

4. CONSULTANT'S SERVICE

4.1 The Consultant's basic services consist of those services performed by the Consultant, the Consultant's employees, and any sub-consultants, for the preparation of the Work.

4.2 The Work, as described in Article 2 of the agreement – THE WORK

4.3 The cost of Additional Services not listed above, either requested by the Client or suggested by the Consultant and agreed to by the Client, after this Agreement has been executed, are not included on the Cost of the Work, and shall be negotiable.

5. COST OF WORK

5.1 The Cost of the Work, which excludes Value Added Taxes, is:

Part A: ....[redacted] Million Baht.............

Part B: ....[redacted] Million Baht.............

TOTAL: ....[redacted] Million Baht.............

5.2 The Client agree to pay the COST OF WORK for each part in the following:

Part A: Lump sum payment on ....31 October 2010..... or any other point in time within the Contract Agreement duration that is agreed from both parties.

Part B: The Client has agreed to pay The Consultant proportional to the completion percentage as follow:

LOT 1: Account to be ....**30%**.... of the total Cost of Work for Part B, in the Sum of ....[redacted]...Baht

(...[redacted].................)

The Client shall only in condition of: ....Completion of Foundation Phase..........

LOT 2: Account to be ....**30%**.... of the total Cost of Work for Part B, in the Sum of ....[redacted]...Baht
(....[redacted].................)

The Client shall only in condition of: ....Completion of Structuring Phase..........

LOT 3: Account to be ....**40%**.... of the total Cost of Work for Part B, in the Sum of ....[redacted]...Baht
(....[redacted].....)

The Client shall only in condition of: ....Completion of Finishing Phase..........

5.3 All amounts are in THAI BAHT.

5.5 These amounts shall be subject to adjustments as agreed to in writing by both parties.

6. PAYMENT DETAILS

6.1 Subject to the provisions of the Agreement, the Client shall:

6.1.1 Make progress payments to the Consultant on account of the Cost of the Work when due together with such Value Added Taxes as may be applicable to such payment, and

6.1.2 Upon final acceptance of The Work, pay to the Consultant the unpaid balance of the Cost of the Work when due together with such Value Added Taxes as may be applicable to such payment.

6.2 Should either party fail to make payments as they become due under the terms of the Agreement or in an award by arbitration or court, interest at one percent (1%) per annum above the bank rate on such unpaid amounts shall also become due and payable until payment. Such interest shall be compounded on a monthly basis. The bank rate shall be the rate established by the Agreed Bank by both Parties as the minimum rate.

7. CLIENT'S RESPONSIBILITIES

7.1 The Client shall authorize a person or persons to act on their behalf, and define that person's scope of authority with respect to the Work.

7.2 The Client shall periodically review the Work, and give the Consultant prompt decisions and approvals necessary for the orderly progress of the Work.

7.3 The Client shall be the sole judge as to the acceptability of the Work.

7.4 The Client shall immediately notify the Consultant in writing if the Client observes, or otherwise becomes aware of, any non-conformity with the Agreement.

8. CONSULTANT'S RESPONSIBILITIES

8.1 The Consultant shall engage any and all services performed by employees and sub-consultants as necessary for the proper performance of the Work.

8.2 The Consultant's services involve full responsibility for the content and quality of the Work.

8.3 The Consultant shall allow the Client to examine the Work or portions thereof for periodic review or approval.

9. COPY RIGHT

9.1 All completed Work, and copyright thereto, becomes the property of the Client.

9.2 The Client retains the right to utilize the Work as it sees fit, including, without limitations to the generality of the foregoing, to make additions, alterations, modifications, and to reproduce, publish, and sell the Work.

9.3 The Client retains the right to enter into future agreements, with the intent of updating or modifying the Work, without the further involvement of the Consultant.

9.4 The Consultant is prohibited from any re-use or reproduction of the Work, in whole or in part, without the express written consent of the Client. The Consultant retains the right to personal use, or to further research and development of the Work, however any reproduction thereof is also prohibited without the express written consent of the Client, nor does said research and development obligate the Client to enter into any new agreement with the Consultant.

10. INDEMNITY

10.1 The Consultant shall save harmless and fully indemnify the Client, its successors, assigns, officers and employees from and against all losses, damages, liability, judgments, costs and expenses which they may sustain or be put to resulting from any error, omission, copyright violation, or failure to exercise reasonable care, skill or diligence on the part of the Consultant or any sub-consultant, respecting the performance of any part work or service in connection with the completed Work.

11. TERMINATION OF SERVICES

11.1 The Client, in addition to the right of dismissal for cause reserves the right to dispense with the services of the Consultant at any time. The Consultant shall accept payment for work done and costs incurred in accordance with provisions of Article 5 – COST OF WORK, based upon the percentage of Work completed as of the date of termination, in full satisfaction of any and all claims under this agreement.

11.2 The Work may only be terminated upon receipt from the terminating party of a registered Letter of Termination, addressed to the other affected party and stating the reason for termination. The Date of Termination will be the date the affected party receives the Letter of Termination.

11.3 If the Work is abandoned, or services terminated, payment for partial services shall only be made on receipt of all Work performed to date of termination.

This contract agreement is made in duplicate with the same content agreed by both parties. Both of the parties have read and understood all details in the contract agreement, therefore signing this contract agreement as a binding contract in front of a witness. The Client and the Consultant each hold a contract.

________________________________ THE CLIENT

(....President of [redacted] Company limited......)

________________________________ THE CONSULTANT

(..................The Consultant........................)

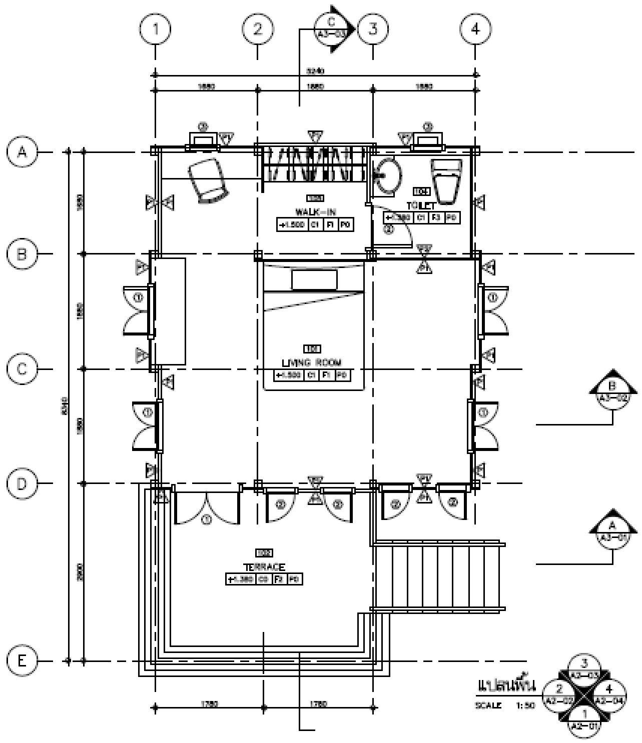
________________________________ WITNESS

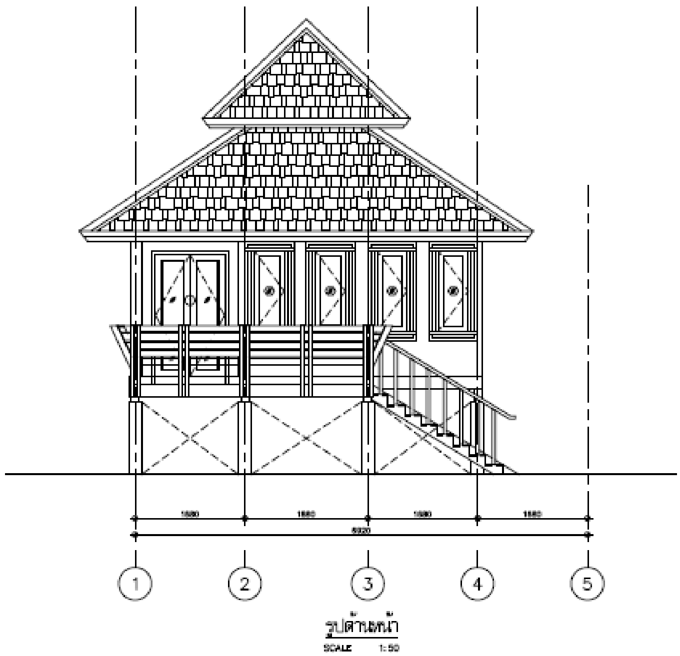
(..........WITNESS from Client....................)

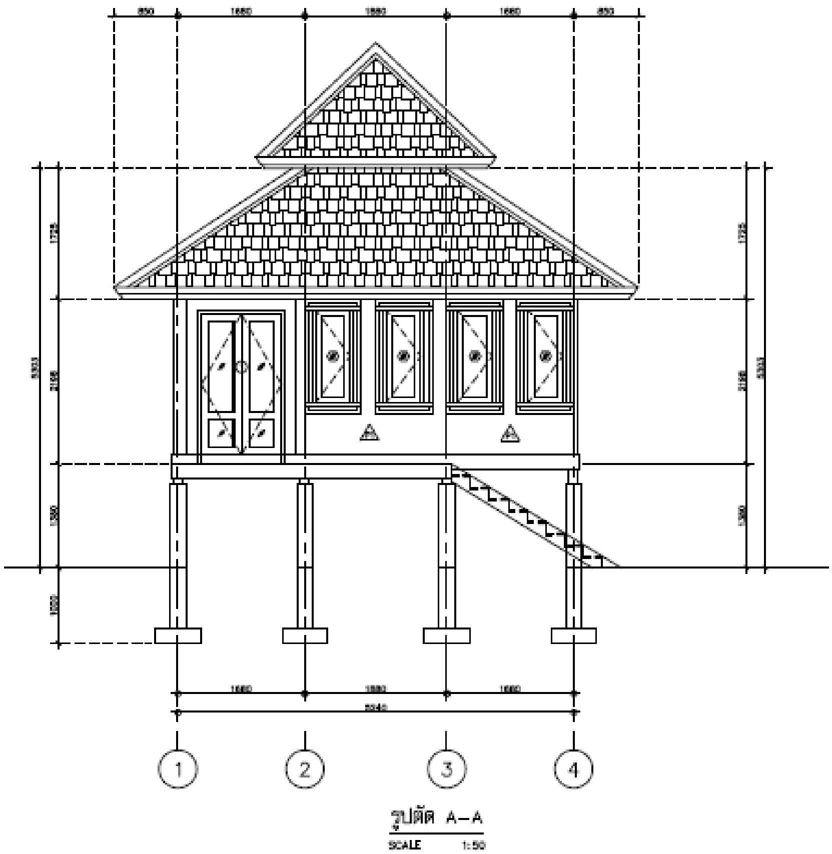
________________________________ WITNESS

(..........WITNESS from Consultant.............)

Floor Plan


WALK-IN
TOILET
LIVING ROOM
TERRACE
แปลนพื้น
SCALE 1:50


รูปด้านหน้า
SCALE 1:50



Photos of Prefabricated Classical Thai House

BIOGRAPHY

Navin Grueneberger was born in Hamburg, Germany 1986. He graduated from Sirindhorn International Institute of Technology, Thammasat University, Thailand in 2007 with a Bachelor’s degree in Electrical Power Enginering. He continues to study in Engineering Business Management for Master’s degree at Regional Centre for Manufacturing Systems Engineering, Chulalongkorn University (Thailand) and University of Warwick (United Kingdom). He had been working on a construction project during his Master’s degree.