แบบจำลองการตัดสินใจเลือกรูปแบบความสัมพันธ์ของผู้รับเหมารายย่อยในโครงการก่อสร้างประเทศกัมพูชา

นายไพศาล นอฟ

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สาขาวิชาวิศวกรรมโยธา ภาควิชาวิศวกรรมโยธา
คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
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DECISION MAKING MODEL FOR SELECTING SUBCONTRACTOR RELATIONSHIP IN CAMBODIA CONSTRUCTION PROJECT

Mr. Pisal Nov

A Thesis Submitted in Partial Fulfillment of the Requirements

for the Degree of Master of Engineering Program in Civil Engineering

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By	Mr. Pisal Nov
Field of Study	Civil Engineering
Thesis Advisor	Assistant Professor Vachara Peansupap, 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
(Associate Professor Tanit Tongthong, Ph.D.)

…….……... Thesis advisor
(Assistant Professor Vachara Peansupap, Ph.D.)

…….……... Examiner
(Assistant Professor Noppadon Jokkaw, Ph.D.)

…….……... External Examiner
(Wasaporn Techapeeraparnich, Ph.D.)

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งานวิจัยมีวัตถุประสงค์เพื่อพัฒนาแบบจำลอง ที่สามารถช่วยผู้รับเหมาหลักในการประเมินผู้รับเหมาช่วงเพื่อเลือกความสัมพันธ์ระหว่างระยะสั้นและระยะยาวในโครงการก่อสร้างประเทศกัมพูชา การพัฒนาแบบจำลองนี้ถูกแบ่งออกเป็น 2 ระยะ โดยระยะแรกเป็นการระบุปัจจัย ที่ใช้สร้าง ความสัมพันธ์กับผู้รับเหมาช่วง ซึ่งวิเคราะห์โดยการสัมภาษณ์ผู้รับเหมาหลัก ที่เป็นเจ้าของและผู้จัดการโครงการจำนวน 35คน ระยะที่สองเป็นการพัฒนาแบบจำลองโดยใช้ โครง ข่ายประสาทเทียม (Artificial Neural Network: ANN) และวิธีวิเคราะห์การจำแนกกลุ่ม (Discriminant Analysis) จากนั้นแบบจำลองจะถูกพัฒนาและเลือกวิธีการที่มีระดับความถูกต้องสูง โดยเลือกวิธีการอยู่บนพื้นฐานข้อมูลที่ผู้รับเหมาประเมินคุณสมบัติของ ผู้รับเหมาช่วงจำนวน 93 บริษัท จากผลการวิเคราะห์ในส่วนแรก พบว่า 10 ปัจจัยหลักจาก 22 ปัจจัยที่ผู้รับเหมาหลักพิจารณาแล้วเห็นว่าเป็นปัจจัยที่มีความสำคัญสำหรับการเลือกความสัมพันธ์กับผู้รับเหมาช่วง ได้แก่ การควบคุมเวลาในการวางแผนงาน คุณภาพงาน การร่วมงาน ประสบการณ์ ข้อผูกมัด ทรัพยากร ความซื่อตรง การตรวจสอบ และการประสานงาน จากนั้นนำปัจจัยทั้ง 10 ดังกล่าวไปกำหนดค่าสำหรับกระบวนการเรียนรู้แบบย้อนกลับ (Back-Propagation Algorithm) โดยโปรแกรม Qnet 2000 ผลการวิเคราะห์แสดงให้เห็นว่าค่าคลาดเคลื่อนของค่าเฉลี่ยกำลังสอง (Root Mean Squared Error : RMSE) มีค่าต่ำประมาณ 0.02 และ 0.04 ในขณะที่การวิเคราะห์ด้วยวิธีการจำแนกกลุ่มร้อยละมีค่าความถูกต้องอยู่ที่ 98.7% ในขณะที่การตรวจสอบความถูกต้องอยู่ที่ 83.75% ดังนั้นผลจากงานวิจัยนี้พบว่าโครงข่ายประสาทเทียมเป็นวิธีที่เหมาะสมสำหรับการพัฒนาแบบจำลองเนื่องจากวิธีการนี้ให้ผลลัพธ์ที่ดีและคลาดเคลื่อนน้อย งานวิจัยนี้เป็นประโยชน์สำหรับผู้รับเหมาหลักซึ่งมีความตั้งใจในการจำแนกผู้รับเหมาช่วงที่ต้องการพัฒนาความสัมพันธ์ในระยะยาว

ภาควิชา.....วิศวกรรมโยธา..... ลายมือชื่อนิสิต.....

สาขาวิชา.....วิศวกรรมโยธา..... ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก.....

ปีการศึกษา.....2555.....

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The objective of this research is to develop a model that could help main contractor to evaluate subcontractor on selecting short or long-term relationship in Cambodia construction projects. There are 2 stages that need to accomplish in this model development. First, it identified the important factors for selecting subcontractor relationship by interviewing with 35 main contractors who are directors or project managers. From the analysis result, there were ten of twenty two factors that main contractor considered as the important factors for selecting subcontractor relationship namely time control in planning, work quality, cooperation, experience, commitment, resources, honesty, trust, monitoring, and coordination. Second, the model was developed by using Artificial Neural Network (ANN) and Discriminant analysis. Then, the models were developed and selected suitable method that has the high level of accuracy. The selection of method was based on 10 factors with 93 samplings that main contractor evaluated is subcontractors. The result of ANN model shows the low percentage of root mean squared error (RMSE) around 0.02 and 0.04 for training and testing data set. In discriminant analysis, the percentages of accuracy in estimation are 98.7 % whereas the validations are 83.75 %. Thus, our research takes the neural network as an optimal method for developing a model because this method has given a good result of low error. Finally, this research would be useful in main contractor decision making on selecting subcontractor for developing a long-term relationship.

Department: ……Civil Engineering..... Student's Signature …….
Field of Study:…Civil Engineering…….. Advisor's Signature …….
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STR	Short-term relationship
LTR	Long-term relationship
ANN	Artificial Neural Network
LMS	Least Mean Square
RMSE	Root Mean Square Error
MAE	Mean Absolute Error
MSE	Mean Squared Error
PG	Percent Good
BP	Back-propagation
SD	Standard Deviation
CV	Coefficient of Variation
DV	Dependent Variables
IV	Independent Variables

CHAPTER I
INTRODUCTION

1.1 Significant of Research

With the sophisticated technology and increasing size of project scale, it has raised the demand for construction product and needed the greater specialization in the construction project implementation. To gain more profit and to optimize resources efficiency, main contractor has subcontracted some parts of their works to fulfill the insufficient resources or expertise in a specific area (Tannaya, 2010). Then subcontractor becomes a specialist partner in construction project who has handled the work, supplied manpower, equipment, tools, or designs. Moreover, this subcontracting job has been significantly extended from housing and building construction projects to engineering and industrial projects (Clough and Sears, 1994). Therefore, Arditi and Chotibhongs (2005) found subcontractor is a construction company that has subcontracted some parts of main contractor works and its relationship with main contractor is believed to exist since subcontractor has been worked with main contractor in construction for many projects.

The relationship between main contractor and subcontractor is one of the important factors to ensure the construction productivity. After main contractors have subcontracted their works and try to concentrate on managing site operation rather than employing direct labor (Kumaraswamy and Matthews, 2000). So they do not need to carry out all types of works and use the externalize resources or companies to help in construction within budget. Moreover, this subcontracting work could be seen as a great method for organizing the construction activities (Beardworth et al, 1988). Then main contractors can decentralize their works and allow subcontractor to become a basic part in the construction project. Therefore, the relationship between main contractor and subcontractor was developed closely by the time and satisfaction of work.

There are three main stages that main contractors use to select a good subcontractor for working with such as subcontractor selection, subcontractor performance and subcontractor relationship. First, the objective of subcontractor selection is to choose a good subcontractor for giving the subcontracted work, so main contractor will evaluate subcontractor based on the prequalification factors (Kumaraswamy and Matthews, 2000).

Second, during the construction process, main contractor will assess the effectiveness of control and management in subcontractor work which consists of construction quality, safety and cost. Moreover, with the good performance, it also helps main contractor to choose the competent subcontractor for the future project whereas the poor performance will be not selected anymore (Kang, 2011).

Third, after the relationship between main contractor and subcontractor was developed greatly by the consistent of work in many construction projects, main contractors usually have to define the potential subcontractor in order to ensure the good productivity in the future by relationship development such as short or long-term relationship (Haksever et al, 2001).

As main contractors are the important person to coordinate and manage in many critical activities in the construction project, their perceptions and roles in establishing the relationship with subcontractors are really important. Handfield and Nichols (1999) mentioned that relationship issue is a fragile and tenuous factor and the poor relationship also has lead to shorten the business in construction between other parties. Akintoye (2000) and Dainty (2001) said that the success of the construction project would be obtained when main contractors could address the capable subcontractor for making partnership. Then, if they fail or inability to address such this issue, they would not gain the benefits that could contribute to the organization (Dainty et al., 2001). Therefore, the decision making model for selecting subcontractor relationship is really a matter of concern.

After working with each other for a while, main contractors might have known more about their own subcontractors and should choose whether which relationship they should go for and will bring the potential benefit for their companies in the future. Moreover, to gain the competitive advantage in construction market, main contractors should have an effective tool to evaluate subcontractors in relationship development. Therefore, this study of decision making model will comprehend and give some perspective ideas for main contractors in selecting subcontractor relationship.

1.2 Problem Statement

Regarding to past experiences of main contractor in mismatching subcontractor for relationship development, it has found some problems such as poor communication, distrust, and insufficient information. So it leads to of high degrees of instability and poor performance and also reduces opportunities for main contractor and subcontractor to engage in explorative work that adds more value in the future (Kumaraswamy and Mattews, 2000). Moreover, there are three causes of this problem and it will be illustrated in the following section.

First, previous research studies have found difference factors using in selecting subcontractor relationship. For example, Patrick and Benson (2006) have studied about long-term relationship development between main contractor and subcontractor in China and found some critical factors such as trust, honesty, commitment and communication. Another researcher studied about project partnering between main contractor and subcontractor relationship and also pointed out some important factors in subcontractor relationship such as trust, joint problem solving, commitment, continue improvement, and cooperation (Matthews et al., 1996). In addition, there are some other factors which have been found in selecting subcontractor relationship as shown in Table 1.1. However, these factors will be used to achieve or success in developing a good relationship with subcontractor, it still generates different result

which could make some difficulties for main contractors to determine the suitable factors in their decision makings.

Table 1.1 Factors using in selecting subcontractor relationship

Factors	Hallard (1995)	Chan el at., (2004)	Cheng et al.,(2000)	Sanders and Moore.,(1992)	Ramasesh an and Loo., (1998)	Black et al.,(2000)	ACA.,(1999)	Hampson and Kwok., (1997)	Frodell.,(2010)	Mohr and Spekman.,(1994)
Trust	✓		✓		✓	✓	✓	✓	✓	✓
Commitment	✓	✓	✓		✓	✓	✓	✓	✓	✓
Communication	✓	✓	✓	✓	✓	✓		✓		
Clear definition of responsibilities		✓								
Joint problem solving	✓		✓					✓	✓	
Mutual Objective	✓									
Continuous improvement	✓									
Sharing culture		✓								
Regular monitoring		✓								
Coordination			✓						✓	✓
Management support			✓							
Cooperation				✓				✓		
Clear understanding						✓				
Flexibility to changes						✓				
Innovation							✓			
Interdependence								✓	✓	✓

Second, based on the above studies, it also has shown that some researchers still do not think of another factor which is considered in decision making for selecting subcontractor relationship like price adjustment because main contractors might choose the subcontractors with whom they have previously cooperated (Kang, 2011). It is believed that cooperative experience could reduce uncertainties in subcontractor selection and help contractors to choose the suitable subcontractors. In this selection, main contractors often pay attention to see the subcontractor experience of cooperation that could be measured by the duration and the number of projects that subcontractors have completed for main contractors. However, the price adjustment factor in the project could be one of important factors which is used to determine on selecting the subcontractor relationship because too high or low price will convince in decision making of main contractor. Although this factor should be considered in

selecting subcontractor for relationship development, it does not have higher power if comparing with other factors. In addition, it could lead to inaccurate evaluation or estimating (Kumaraswamy and Matthews, 2000). Therefore, to select a good subcontractor for relationship development, main contractors have to consider not only the price adjustment but also the other factors in the condition of work for decision making.

Third, in practical, main contractors still have used some of the factors to judge on selecting subcontractor relationship. For example, main contractors usually choose the subcontractors for relationship development based on only their personal preferences and interests (Kang, 2011). The high-level executives of main contractors company may use their power to designate subcontractors in their decision making (Zhu et al., 2005). Thus, main contractors still do not have a clear procedure on selecting subcontractor relationship. With a lack of systematic screening in this stage, it will cause a poor selection of subcontractor relationship, and then main contractor will have to work with subcontractor who has poor performance for a long-term. Moreover, this practice will hinder the benefit which would be discovered in long-term relationship from subcontractor.

As the above issue still does not give any good decision making for main contractors on selecting subcontractor relationship, We really need a systematic tool that could evaluate subcontractor in relationship development whether short or long-term relationship and also could determine the capable subcontractor to ensure their construction business effectively. That is why this research would like to propose a decision making model for main contractor to decide before developing relationship with subcontractor. Moreover, with the right decision, main contractor will work with the subcontractor well and satisfy the client. Therefore, this type of model is a useful method that could help main constructors to choose subcontractors properly and convenience.

1.3 Research Objectives

The purpose of this research is to establish decision making model for evaluating subcontractor in relationship development whether short or long-term relationship. To achieve in this objectives, the following sub-objectives are illustrated below:

- To identify important factors that use for selecting subcontractor relationship.
- To develop a decision making model for selecting subcontractor relationship.

1.4 Scope of Research

This research is conducted in Cambodia where main contractors are handling in the building construction project. The study will focus on perception of project manager or executive manager who has many years of experience in construction work and familiar in relationship development with subcontractors as respondents. To collect the data, it also will be conducted in qualitative approach. However, regarding to the time constraint and limited budget, the study will be focused only on the scope in the following:

- Stage : During construction project
- Project: Building construction project such as apartment ,hotel, shopping mall, office building, or hospital.
- Company: Engineering or Construction Company
- Respondent: Directors and Project Managers
- Investigate Location: Cambodia

1.5 Research Methodology

In order to achieve these study goals, the design of methodology are as the following:

1. Review the relevant literature articles of relationship development between main contractor and subcontractor
2. Developing the decision making model which contains three steps:

2.1 Identify important factors that use for selecting subcontractor relationship

- Identify the factors from literature review
- Developing the question and conducting the interview to get the important level of factors that use for selecting subcontractor relationship.

2.2 Developing and testing a decision making model

- Using scale measurement with each factor like likert scale
- Conducting interview with the main contractor or expert to evaluate on each subcontractor in construction project based on the important factors that we found.
- Analyzing the result by Artificial Neural Network
- Discussion the result of model

3. Research survey of decision making model for selecting subcontractor relationship

3.1 Sampling and sample size selection

3.2 Data collection:

- Data collection by interviewing respondents

3.3 Data analysis

- Result of important factors on selecting subcontractor relationship
- Result of a model by Artificial Neural Network analysis

4. Research conclusion

1.6 Research Outline

This research study is accomplished by many steps such as:

Chapter 1 discusses about the relationship between main contractor and subcontractor in construction project. Firstly, it tells the reason of subcontractor existing and how the relationship between main contractor and subcontractor is developed. Then, it has categorized the process of selecting a good subcontractor into three stages such as subcontractor selection, subcontractor performance and subcontractor relationship. This research will focus on subcontractor relationship which consists of two components such as short or long-term relationship. Moreover, it explains precisely about the reason that main contractor need to evaluate

subcontractor in relationship development. Then the proposed decision making model would be a matter to concern in this study. This chapter is contained by many points such as problem statement, research objective, scope, methodology, and expected outcome.

Chapter 2 describes the relationship between main contractor and subcontractor in detail. First, it will go through the characteristic of main contractor and subcontractor relationship. Moreover, it also explains the definitions and the benefits and the problems of relationship between main contractor and subcontractor. Last, it will review the previous studies in subcontractor relationship in detail which leads to establish the decision making model. Finally, the research gap will lead to solve the problem in this study.

Chapter 3 explains in details of the methodology to achieve the research objective. It begins with research design by showing the research framework in this study. Then it will illustrate clearly in each section of the process including factor review, scale measurement and application development. Moreover, the data collection will be described by using qualitative approach. Finally, this proposed model is calculated and validated by Artificial Neural Network and Discriminant Analysis.

Chapter 4 explains about the important factor for selecting subcontractor relationship. First, it starts with the information of sample data which is included type, position and working experience of main contractor. Then it describes about the difference types of work using difference types of subcontractor and relationship. Last, the important factors are determined by using mean and standard deviation. Moreover, it also explains about main contractor opinion on these important factors.

Chapter 5 describes the result of model development which consists of data description, independent samples t-test and research finding. The data description in this section was type of subcontracted work, type and number of subcontractor. Then

the model needs to ensure that each factor is different in determining the subcontractor relationship by using independent sample t-test analysis. Moreover, this research compares the important factor from main contractor opinion and influencing factors from actual practice. To achieve in this model development, the Artificial Neural Network was trained and tested by using Qnet 2000 program and after that we compared the level of accuracy with discriminant analysis for determining the optimal method for the model. Last, the model was discussed further by the analysis results.

Chapter 6 explains the result findings of the research, and specifies the research contribution and the limitation of the research which leads to highlight the potential areas for future study.

1.7 Expected Benefits

After this research is accomplished successfully, main contractor is able to gain an effective tool for selecting subcontractor relationships. Moreover, with this model, it could help main contractor to choose the capable subcontractor for ensuring the good productivity in the future. Otherwise, without a good decision making model to define short or long-term relationship, main contractor will lack of chance to select a good subcontractor for long-term relationship development and identify the incapable one for short-term relationship. In conclusion, this decision making model will explore a good subcontract for working effectively with main contractor. Moreover, with the right decision and strong regulation and cooperation with the outsides such as subcontractor, main contractor will have a better chance to be success in the competitive market.

CHAPTER II

LITERATURE REVIEWS

The purpose of this chapter is to review about previous studies of subcontractor relationship. First, it explains the characteristics of relationship between main contractor and subcontractor in construction projects. There are two types of relationships such as short and long-term relationship that main contractor has used with subcontractor in relationship development. Then, it will review the benefits and problems which are happening in both relationships implementation. Previously reviews of this subcontractor relationship will lead to see the research gap in developing decision making and put forward the issues to be examined. Therefore, the research objective will be achieved by the designing of research framework.

2.2 The relationship between main contractor and subcontractor in construction projects

2.2.1 Characteristic of main contractor and subcontractor relationship

Regarding to the modernizing and accelerating change in construction industry, Matthew (1996) found that the growth of advance technology which has required a high degree of design, manufacture, installation skills in product for the client. Since some construction works, which demand higher technology and skill, still have not been readily available in the organization. Main contractors have contracted with subcontractor who will handle and accomplish the sublet works. Moreover, subcontractors also provide the construction services to main contractor with project management and control, coordination, and relationship. As competition intensifies in the construction market, subcontractor resources have also become an indispensable link in the contractors' value chain (Kang, 2011). As a result, owning a number of excellent cooperative subcontractors is now a prerequisite for main contractors, in order to achieve sustainable corporate development.

In construction project, there are many participants who have to work with the same objectives including project owners, designers, supervisors, contractors, subcontractors and suppliers. Their relationship was shown by Figure 2.1. This figure has pointed out that subcontractor has stood in the central point and played an important role in the project implementation process which is related to project quality, progress, cost and safety. Therefore, main contractors who assume general responsibility for construction project must consider such issues that how to get a rational subcontractor and could specify the subcontractor relationships.

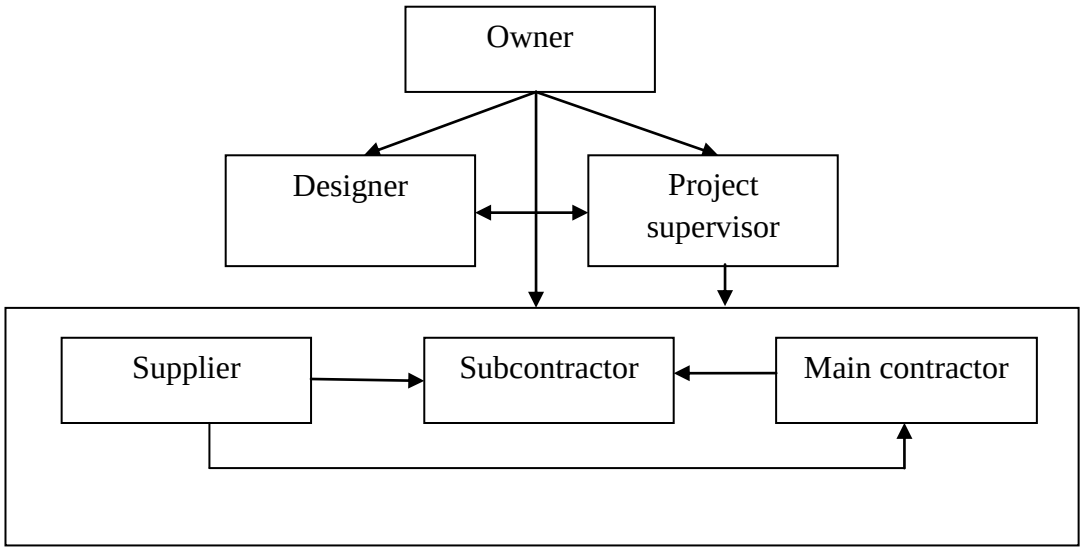

Figure 2.1 Typical relationships in construction project (Kang, 2011)

Normally, there are a large number of subcontractors who have dominated in construction project whereas a few main contractors are at the upper side. So main-constructors need to develop the core competency which responses to both environments and internal resources. In addition, the relationship between main contractor and subcontractor is one of the key factors to any successful construction project. Previous study carried out in relation to construction has suggested that main contractor should change from traditional relationship toward cooperative and collaborative relationship (Adekunle et al., 2009). Moreover, this relationship was categorized into two types including short and long-term relationship which main contractor usually uses in partnering with subcontractor. Table 2.1 shows about the

previous and modern approaches of relationship that used between main contractor and subcontractor in construction project. These relationships are differentiated not only the price adjustment but also consists of other factors that could understand clearly.

Table 2.1 A summary table of main differences between traditional and modern approach (Dornier et al., 1998)

Traditional Approach	Modern Approach
Primary emphasis on price or profit	Multi factors like profit, trust, commitment…etc
Short-period of contracts	Long-period of contracts
Selecting many subcontractors	Having few subcontractor
Try to gain more benefit only one part	Sharing benefit with each other
Subcontractor solves the problem when alone	Subcontractor and main contractor try to joint problem solving
Information barrier	Sharing information with each other

2.2 Types of subcontractor relationship development

After the relationship was strengthened by time and cooperative work, main contractor would like to see the potential subcontractor who is a key person to ensure a good productivity in the future (Patrick and Benson, 2006). Then main contractor need to determine the qualify subcontractor in this relationship development. There are two types in developing subcontractor relationship such as short or long-term relationship and both relationships could distinguish clearly based on the objective of main contractor work.

2.2.1 Definition of long-term relationship development

Long-term relationship (LTR) is defined as a consistency of organization interaction between main contractor and subcontractors. So it could understand that the long-term relationship is used when main contractor commits or maintains this relationship with subcontractor regularly in order to achieve the expected result as an outcome. With the long-term period and expectation in the relationship, it gives the organization stability and leaded to develop the interdependent outcome (Haksever et al., 2001). To increase the profit, many companies have been trying to extend their businesses relationship into the long-term perspective. Moreover, the meaning of long-term relationship is not only considers in term of duration but it also consists of collaborative activity which has long-term orientation (Mehmet, Ismail, and Omer, 2001). This long-term orientation has been defined by various authors. Kelly and Thibaut (1978) have explained the long-term orientation as the interdependence of mutual benefits opinion among each party that is expected to be gained in the future. Anderson and Weitz (1989) found long-term orientation in a relationship as mutual commitment that work together to increase the profitability. Moreover, Dwyer, Schurr, and Oh (1987) agreed the long-term orientation is a commitment to lose the benefit for a short-period of time in order to obtain the relationship stability and long-term benefit. Next, Ganesan (1994) said that the long-term orientation is the joint profit when they trust one another in business transaction. Totally, this long-term orientation is to improve the performance of the company outcome by focusing on the relationship (Noordewier, John and Nevin, 1990). Therefore, LTR is a mutual commitment in transaction work between main contractor and subcontractor to achieve expected outcome in the future.

Actually, sometimes many main contractors have hardly found to compete in construction business. One solution that some companies will try to remain in the future competition is to develop long-term relationship (LTR) with the other companies and it will not only improve the outcome of work but also sustain the organization benefit (Patrick and Benson, 2006). Moreover, this LTR is also one of

the important aspects in subcontractor management which has provided maintenance and enhancement of long-term productivity for main contractor. Spekmann, Kamauff, and Spear (1999); Underhill (1996) suggested main contractors should not only depend on their own internal capabilities but also create the relationship network with the outside companies in the competitive market nowadays. Moreover, they also call for a new system of LTR where main contractors can manage subcontractors and business efficiency. Therefore, main contractor should be able to determine the potential subcontractor in LTR development which could give a lot of benefits for the company.

The LTR practice between main contractor and subcontractor has been characterized and found more in partnering work that is hardly to distinguish (Baden, 1995, Stephenson, 1996, Smyth, 1999). Partnering was established for the benefit of the organization and increased the productivity, so it leads to develop the LTR as the outcome. The meaning of partnering was defined by Construction Industry Institute (CII) in 1987 as a long-period of corporative work for achieving the objective in specific problem or business by improving the productivity for each party. Black et al. (2000) added that the aim of partnering is to avoid serious problem in relationship and encourage each participant to work for the same objective. Therefore, this partnering is a system that integrated each participant to work tightly for achieving the best result in a long-run.

2.2.2 Definition of short-term relationship development

Short-term relationship is explained when main contractor uses subcontractor in an essential occasion or no choice at that time and it is an inconsistency of work between main contractor and subcontractor. The reason that main contractor chooses to practice short-term relationship with subcontractor because they have seen subcontractor still lack of some factors such as lack of trust, mutual understanding, and no commitment in the construction work. So it leads to dissatisfy main contractor for giving the continuous work. Moreover, this practice was leaded to the

dissatisfaction in the objectives and discovered by various authors in their investigations of the relationships between contractors and subcontractors (Gray and Flanagan, 1989; Winter and Preece, 2000). Finally, this short-term relationship was chosen by main contractor when it is necessary to add more profit for construction project.

2.2.3 Benefits from developing suitable/appropriate subcontractor relationship

The importance benefit of subcontractor relationship is when main contractor choose a good subcontractor for long-term relationship development which will maintain the profit intensively. Bennett, Flanagan, and Norman (1987) found that almost all building constructions in Japanese were undertaken by subcontractors who have worked for particular contractors in many projects for decades. That is why those Japanese contractors could have a great success and overcome many problems such as bankruptcies, poor performances, high levels of disputes, and claims by working tightly together with their subcontractors. Moreover, this implementation has given many benefits such as trust, risk and uncertain reduction, product and quality improvement, and cost reduction (Imai and Komiya, 1995). Haksever (2001) have focused on the benefits of long-term relationship between main contractor and subcontractor in UK, the result shows that most of the UK contractors have perceived indirect benefits such as less conflict, risk and better communication rather than direct outcomes such as quality, time, and cost. Based on these benefits of long-term relationship, many authors suggested that long-term relationship has played an important role to enhance the company performance and quality standard (Doz and Hamel, 1998; Kale, Dyer, and Singh, 2001). Therefore, main contractors will gain a lot of benefits, if they have chosen to make the LTR with the right subcontractor.

Short-term relationship is also one of the relationships that focus more on profit margin based in construction project. Moreover, to obtain the short-term benefits, it has reduced the opportunities for main contractor and subcontractor to engage in explorative work that adds more value in the future (March,1999). In addition, it has

pushed subcontractor away from long-term learning by main contractor because of short-term productivity in construction project (Dubois et al., 2000; Miozzo and Ivory, 2000).

2.2.4 Problems from developing wrong/inappropriate subcontractor relationship

Regarding to the wrong selection of subcontractor in relationship development, it has caused the adverse controversy which leads to contractual dispute, ligation and distrust among other parties. (Kumaraswamy and Mattews, 2000). Moreover, based on the relationship with subcontractor in construction work, we have raised some statements from main contractor point of view in the following.

"When the competitive market has only focused on the price over other features, it influenced the relationship between main contractor and subcontractor and made the instability of regular business" (Gray and Flanagan, 1989)

This statement has explained the short-lived of relationships between main contractors and subcontractors and the lost benefits of each party. These impacts are from the underestimation of subcontractor selection in relationship development. So main contractor should place subcontractor in high consideration and develop some potential tools that will help main contractor to judge subcontractor at initial stage before developing long-term relationship.

2.3 Review of previous studies in subcontractor relationship

Regarding to previous researches, it still does not have any decision making tool for evaluating subcontractor in relationship development because there is a little number of research studies which focuses on subcontractor relationship comparing to supplier, client or customer relationship. For example, Patrick and Benson (2006) have studied about long-term relationship development between subcontractor and main contractor in China and found some critical factors such as trust, honesty,

commitment and communication. Moreover, they found some majors barriers in this relationship such as lack of mutual trust, inconsistent performance, commitment and understanding. Then they also have suggested some proactive strategies to solve in these problems such as well structured documentation, organize regular meeting and constant contract.

Next researcher has studied about main contractor and subcontractor relationship in project partnering and divided into two types such as short-term relationship as project partnering and long-term relationship as strategic partnering. In addition, he also have pointed out some important factors in subcontractor relationship such as trust, joint problem solving, commitment, continue improvement, and cooperation (Matthews et al., 1996). Winter and Preece (2000) have compared the relationship marketing of main contractor and subcontractor between UK and German and found trust as a critical factors that main contractor should think of. Faisal et al., (2006) explored in business relationship of main contractor and subcontractor with other organizations like client or supplier and they found the result showed that the important of developing good relationship with their partners could increase their financial performance and solved many barriers too. However, these research studies that try to prove the relationship between main contractor and subcontractor are really significant to improve the productivity in construction project, there is not any method to help main contractor for evaluating subcontractor in relationship development. Therefore, this research will propose a decision making model for indentifying subcontractor in relationship development.

2.4 Research gaps

Main contractors are the important person who response and manage with many activities in construction project, so they need the suitable and capable subcontractors to handle the sublet works. The relationship with subcontractor is an important factor that main contractor should consider even short or long-term relationship in order to

maintain the company benefit. However, previous researches have suggested some difference factors, main contractors are still not able to define the suitable factors for subcontractor relationship evaluation (Patrick and Benson, 2006; Cheng et al., 2000). In addition, main contractors usually use their preference and interest in subcontractor selection as a basic tool for judgment in relationship development which increases the degree of unreliability (Ruiqing, 2009). Then many problems have occurred between main contractor and subcontractor as mentioned before. Therefore, main contractors really need an effective method in subcontractor selection which will give more accuracy for their decisions making and also could prevent or avoid the problems in selecting wrong subcontractor for relationship development

Moreover, this study on main contractor decision will also solve the problem such as:

- Main contractors are still underestimating in subcontractor selection for relationship development because they sometimes use their perception and familiarity for judgment.
- Main contractors do not have any decision making tool for selecting subcontractor relationship. They cannot choose the potential person to work with and sustain their construction business effectively.

2.5 Research framework

To fulfill these gaps, a framework of decision making model is designed and arranged as shown in Figure 2.2. First, the problems of subcontractor relationship are described and the objectives are also defined in the research. Next, the factors of these relationships were identified in the current practice of main contractor evaluation. Then, the model will be developed by using likert scale measurement. Moreover, the model will be developed by Artificial Neural Network. This model is also checked to

see its validity and verified if it is still not accuracy. Last, this model is going to study in building construction project.

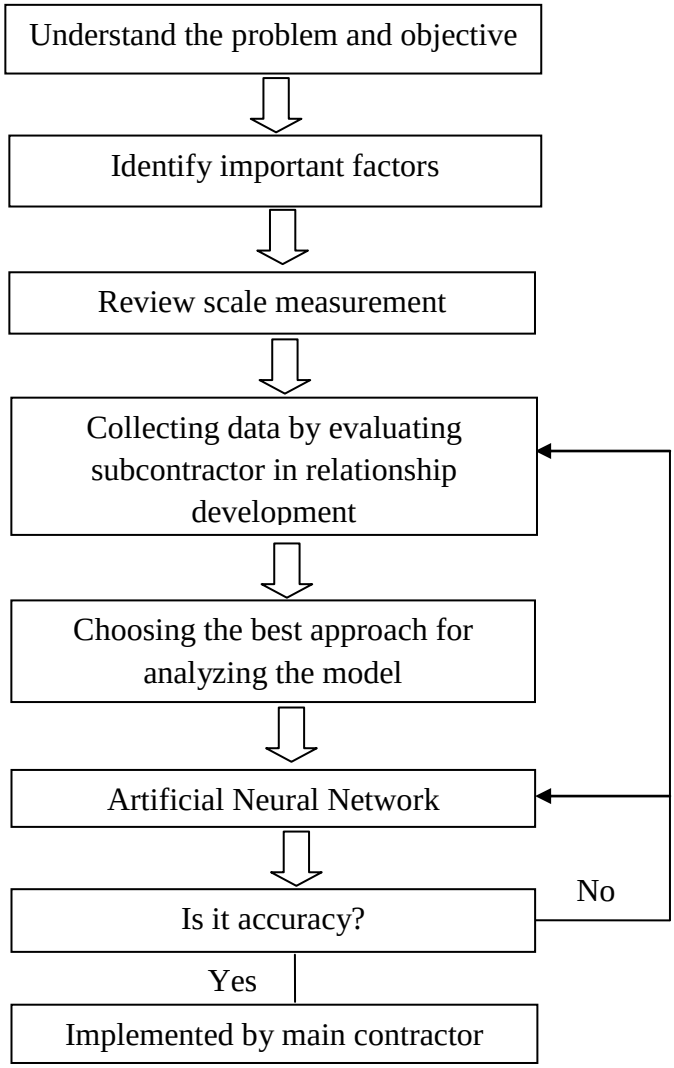

Figure 2.2 Research framework of decision making model

2.6 Summary

In summary, this chapter will describe and review subcontractor relationship in construction project. First, it starts from characteristics of main contractor and subcontractor relationship. From the subcontractor relationship, there are two elements such as short or long-term relationship. Then, it will explain about definition

of each relationship and also illustrate the benefits and problems which main contractors have perceived and experienced with subcontractor. Moreover, previous reviews related to subcontractor relationship still have not shown any tool to solve in the problem. Thus, there is still a research gap to propose a new decision making model for selecting subcontractor relationship. To cope with the gaps, the research framework is designed as presented in Figure 2.2. Then the research methodology is discussed in the following chapter.

CHAPTER III

RESEARCH METHODOLOGY

The objective of this chapter is to explain the proposed methodology in developing of decision making model for selecting subcontractor relationship. First, this chapter will describe the classification of types and approaches in this research. Then it shows a framework of research methodology (Figure 3.1) with the clear information in this process. After that the section will be explained in detail of model development which consists of factors review and scale measurement study. Last, the model was developed by using Artificial Neural Network (ANN). Under section 3.4, research describes application of decision making model which is included data collection and data analysis.

3.1 Research type and approach

Since many methods have been conducted to define the best result in decision making, one of them was well known by authors as Artificial Neural Network (ANN). This method is a mathematical model that uses to simulate the structure and functioning of biological nervous system (Shuklal, 2010). Moreover, the meaning of biological nervous system is included brain and spinal cord that is managed by a group of specialized cells called Neurons or Nerve Cells. So it came from the examination of central nervous systems. There are many purposes of using this Artificial Neural Network such as:

- Generalizing the knowledge learnt and apply to new data
- Capturing complex relationships in a relatively easier way than other computational methods.

As above mention in chapter 1 and 2, this research tries to develop decision making model for selecting subcontractor relationship whether should choose short or

long-term relationship with subcontractor in construction project. Moreover, many data collections are necessary for constructing this model in order to achieve the research goal. The model is mainly developed by face to face interview technique to understand the problems and objective clearly. Then, the result of the model was discussed by Artificial Neural Network. Therefore, this research can be classified into qualitative research approach.

This research is mainly conducted by qualitative approach. The object of using qualitative is to explain the social phenomena by understanding the world in which we are living and why something happens (Hancock, 1998). The data collection could be obtained by observation, interviews, taped information, and documents. The important steps of the qualitative research consist of defining the problem to be studied, taking into account contextual factors of research participant, collecting data from a small number of participants, interpretive approaches to provide descriptions of the participant contexts. Related to this research, qualitative approach is used to identify influencing the variable or factors of subcontractor relationship development between main contractor and subcontractor. Moreover, the research used face to face interview to ask main contractor perception of important factors for selecting subcontractor relationship subcontractor in their decision making practice and it could get the answer from 35 respondents or main contractors. Then, the second stage the research study will contact main contractor for interviewing again by asking them to evaluate each of their own subcontractor on selecting subcontractor relationship and it could get around ninety and three of subcontractor evaluation by main contractors in construction project. Therefore, this research could be success by main contractor help and cooperation in sharing about their practice of continuing relationship with subcontractor.

3.2 Research design

Research is commonly conducted by scientific and systematic investigation with various information to solve the problem. Moreover, research is an important tool to

answer the question on specific issue and reach for a new conclusion. With the stated problem, research methodology is designed at the initial stage. There are various types of research design and each process is explained clearly based on the research objective. The research of developing decision making model for selecting subcontractor relationship was defined through each step as shown below:

1. Review of previous literature in order to gain knowledge of subcontractor relationship practice between main contractor and subcontractor in construction project.
2. Development of decision making model which consists of two stages such as:
    - Identification important factors for selecting subcontractor relationship from main contractors opinion
        - Collecting all factors from literature review
        - Conducting interview for determining the important factors for selecting subcontractor relationship from main contractor
    - Development of a decision making model
        - Constructing scale measurement of each factor by using likert scale
        - Interviewing with main contractor again to ask them for evaluating their own subcontractors on selecting subcontractor relationship.
        - Using Artificial Neural Network to calculate in the model

3. Application of decision making model

    3.1 Selection of sample size

    3.2 Data collection

    - Data collection by using face to face interview

    3.3 Data analysis

    Result of decision making model in selecting subcontractor relationship Will:

    - Identify important factors of subcontractor relationship
    - Category each subcontractor in short or long-term relationship by ANN

To achieve the research objective, the design methodology about the process was illustrated as guide in Figure 3.1. This research process was divided into two parts which consist of important factors identification and model development. Moreover, the proposed model was developed with the clear objective in order to solve the research gap by the relevant information and knowledge. Therefore, this research aims to develop the decision making model for selecting subcontractor relationship.

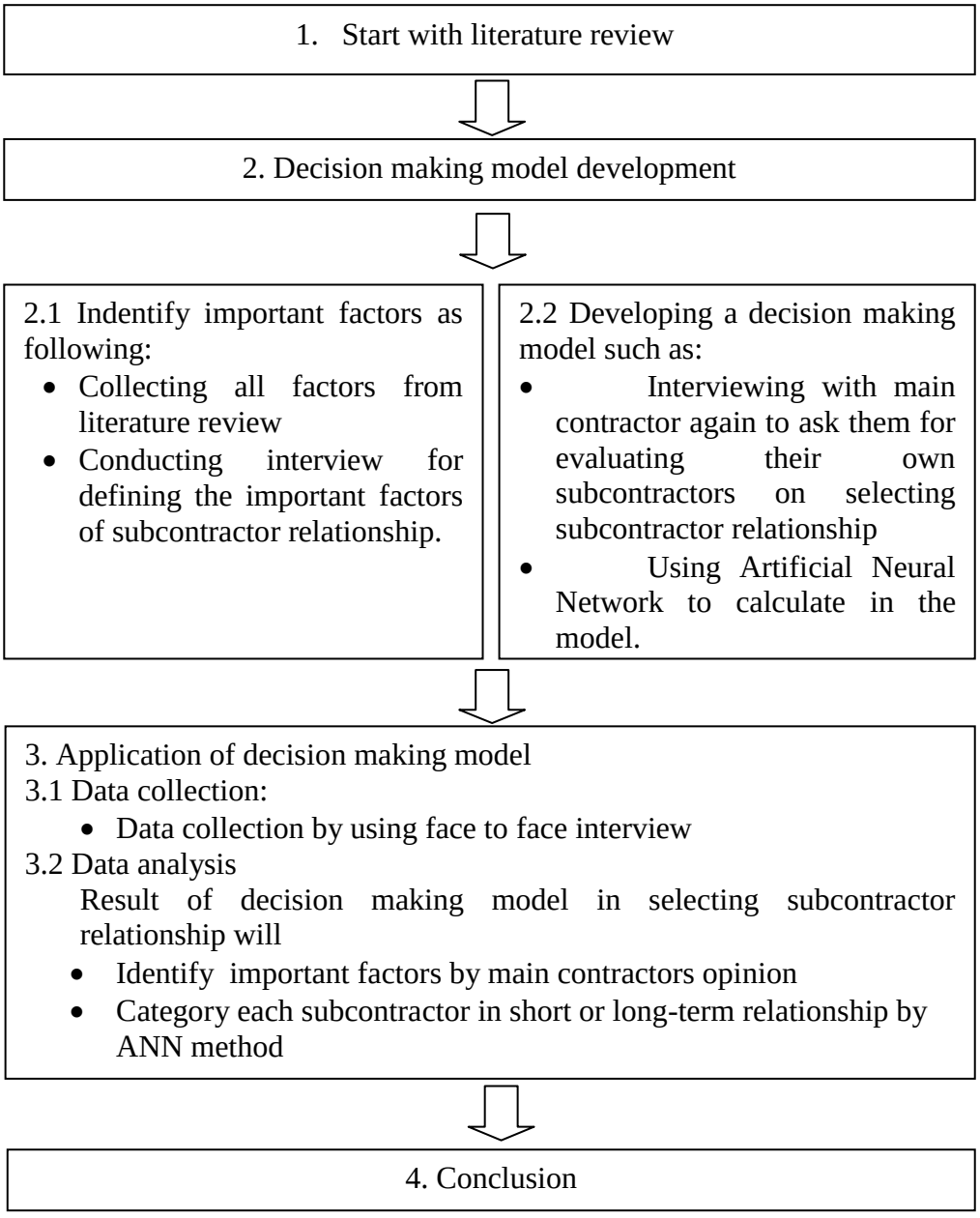

Figure 3.1 Research methodology

3.3 Decision making model development

The objective of model development process is achieved by many stages and the final result will be implemented by end user like main contractor. The model was developed into two stages namely (1) identifying important factors and (2) establishing and testing the decision making model by Artificial Neural Network. The overview of each stage is explained as shown below.

3.3.1 Review of factors for selecting subcontractor relationship and scale measurement

The section focuses on a review of factors for selecting subcontractor relationship and scale measurement. First, the review of factors seeks to define the element of subcontractor relationship development that main contractor currently used to evaluate subcontractor. In this subcontractor relationship, it is established by two main factors such as subcontractor performance factors and subcontractor relationship factors. Then, review of scale measurement will lead to choose suitable scale for putting on each factor in subcontractor relationship. This scale measurement is considered by using various types of scale such as nominal, ordinal, interval, ratio and likert scale. Finally, this research decided to use likert scale.

3.3.1.1 Review of factors for selecting subcontractor relationship

The decision making model will begin with review of factors for subcontractor relationship development. These factors that main contractors use to evaluate each subcontractor should be gotten from two main factors namely subcontractor performance factors and subcontractor relationship factors. The term of subcontractor performance is defined by main contractor who examines subcontractor own factors and past project performance (Kang, 2011). Another term is subcontractor relationship and it is understood as personality of subcontractor who has been worked with main contractor as partnership. It helps main contractor to see

how subcontractor behave in construction project and mostly focus on main contractor perception. These factors will be used to develop the suitable factors for selecting subcontractor relationship.

3.3.1.1.1 Subcontractor performance

Subcontractor performance is one of important factors used by main contractors to select the optimal subcontractor for future work. There are many sub-factors that have influenced in this performance investigation. For example, Shash (1998) found some factors influencing in subcontractor performance such as management ability, worksite condition and subjective assessment. Then, Wu (2001) found the other 12 factors by using a questionnaire survey for asking main contractor perspective in Taiwan as shown in Table 3.1. Moreover, Chung and Ng (2006) found a dozen of factors that main contactors have used for measuring the subcontractor performance by interviewing such as the workmanship, progress, health and safety, relationship and communication. Last, Kang (2011) proposed three main factors in subcontractor performance namely subcontractors' financial capability, experience and qualification, enterprise and project manager knowledge of subcontractors. These factors were also divided into sub-factors as shown in Figure 3.2 below.

Table 3.1 Evaluation factors of subcontractor performance (Wu, 2001)

No	List of factors
1	Construction technique
2	Time control
3	Material wastage
4	Cooperativeness
5	Collaboration with other subcontractors
6	Service after work completion
7	Safety and protection

8	Tool usage habit
9	Workspace cleanliness
10	Management ability
11	Financial status
12	Subcontractor personality

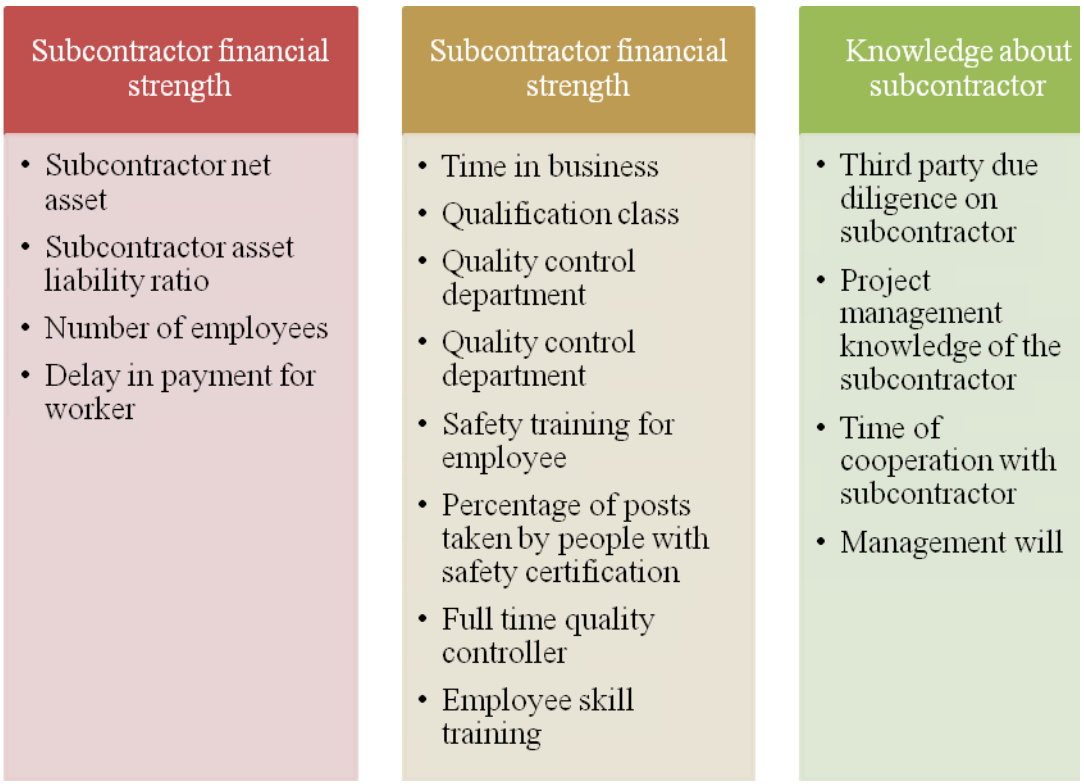

Figure 3.2 Three main factors of subcontractor performance (Kang, 2011)

3.3.1.1.2 Subcontractor relationship

There are many sub-factors for selecting subcontractor relationship which are defined by many researchers in relationship development between main contractor and subcontractor. Chan (2004) and Hellard (1995) have founded the key important factors in partnering. According to Hellard (1995), subcontractor should equip with key elements for successive partnering such as commitment, effective problem

solving, trust, mutual objectives, equity, timely communication, and continuous improvement. Chan (2004) identified the five critical factors for selecting subcontractor relationship including communication, commitment, clear responsibilities, sharing culture, and monitoring. Spekman and Sawhney (1990) found ten key factors of subcontractor characteristics such as trust, honest, communication, commitment, joint problem solving, coordination, interdependence, innovation, flexibility to change, and clear understanding. Thus, the other researches about subcontractor relationship factors are listed in Table 3.2.

Table 3.2 Summary of subcontractor relationship factors (Patrick and Benson, 2006)

Authors	Subcontractor relationship factors
Cheng et al., (2000)	Management support, Mutual trust, commitment, coordination, Creativity Effective Communication
Sanders and Moore (1992)	management team, Cooperation, Open communication, problem solving group working
Patrick and Benson (2006)	Trust, honesty, commitment, communication, integrated information system, culture
Black et al., (2000)	Mutual trust, Effective communication, Clear understanding, commitment, Flexibility to changes
ACA (1999)	Commitment, trust, respect, innovation, fairness, enthusiasm
Ramaseshan and Loo (1998)	Trust, Commitment, inter-organization trust and communication
Hampson and Kwok (1997)	joint problem solving, commitment, Trust, interdependence, communication, and cooperation
Frodell (2010)	Trust, coordination, interdependence, communication, problem solving, commodity
Mohr and Spekman (1994)	Coordination, interdependence, trust commitment

3.3.2 Scales of measurement for each factor

The scale measurement was proposed by Stanley Smith Stevens in 1946 on the article name “On the theory of scales of measurement”. There are four difference

types of scale that all measurements in science were conducted. These scales are nominal, ordinal, interval, and ratio. Moreover, there is another scale called likert scale which was developed by Rensis Likert in 1932 for measuring the respondent's attitudes and opinions. Last, each type of scale does have its own characteristic.

3.3.2.1 Nominal scale

The definition of nominal scale is a collection of categories which object in the relevant domain is classified. The key feature of nominal scales is that their categories do not topological features – which mean no up-down, or right-left, or bigger-smaller, or in between; there is only difference and mutually exclusive and exhaustive category. It is not relative to ordering. For example, the gender study is categorized by male and female. Moreover, nominal scale is also known as binary variable that has only two possible outcomes such as buy or not buy, yes or no. Some variables with 3 or more categories are known as multi-way term and characterized by a categorical distribution (Hardegree, 1980).

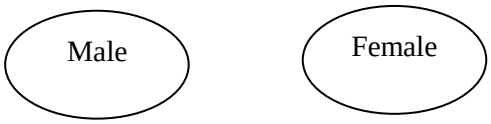

Figure 3.3 Nominal scale of gender (Hardegree, 1980)

3.3.2.2 Ordinal scale

Ordinal measurement scales is designed to gain information on variable whether greater or lesser. For example, 1=low, 2=moderate and 3=high. Another explanation of ordinal scale indicates something about the rank-ordering of objects or event like 1^{st}, 2^{nd}, 3^{rd}, 4^{th}…etc. For example, you might be interested to understand about customer satisfaction on food service in a restaurant, their feeling will be ranked on a scale of 1 to 5. A score of 5 presents more satisfy than 4, and 2. Thus, the values are simply expressed by an order (Hardegree, 1980).

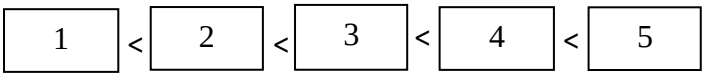

Figure 3.4 Ordinal scale of customer satisfy on food service in restaurant (Hardegree, 1980)

3.3.2.3 Interval scale

Interval scales give us about the quantitative information. When a variable is measured on an interval scale, the distance between numbers on the scale is equally. An example of an interval scale is 1 to 100. With interval scales, there is no absolute zero point and negative values can be used. Moreover, it could be understood from another example of time in day that 1 and 3 pm is the same as 10 and 11 am (Hardegree, 1980).

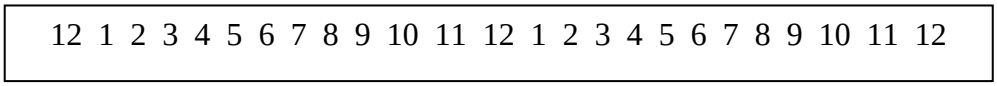

Figure 3.5 Interval scale of time (12-hr) (Hardegree, 1980)

3.3.2.4 Ratio scale

Ratio scale has all the properties of an interval variable, and a clear definition of 0.0. The ratio scale is used to measures the variables like height, weight, time, length, and energy. The scale is the estimation of the ratio between a magnitude of a continuous quantity and a unit magnitude of the same kind (Michell, 1997). Not only are numbers or units on the scale equal over all levels of the scale, but there is also a meaningful zero point which allows for the interpretation of ratio comparisons. For example of time, we can say that difference between three hours and five hours is the same as the difference between eight hours and ten hours (equal intervals), or we can also say that ten hours is twice as long as five hours. Therefore, this is a ratio comparison (Hardegree, 1980).

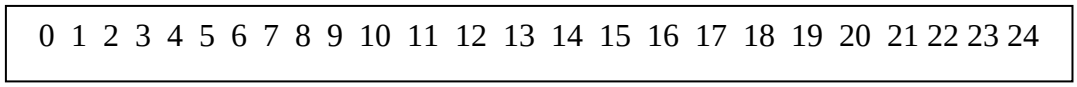

Figure 3.6 Ratio scale of time (24-hr) (Hardegree, 1980)

3.3.2.5 Likert scale

With the likert question, the respondent will ask to answer with the level of agreement and disagreement measurement. Usually, it was created with five or seven order response levels with the equivalent of positive and negative response in agree or disagree scale. For example, the common five level likert item is known such as (1) Very important, (2) important, (3) Neutral, (4) No important,(5) Not very important. In likert scale measurement, it has considered in two aspects. First, the value assigned to a likert item does not have in the measurement theory or scale and it is arbitrary. So the researchers assign the value of this likert item for providing the important detail for their research. The value is most commonly chosen with 5 or 7 point scale. Second, the distance of each likert item is equal. For example, for 5-point scale, the distance between items 1 and 2 is the same as between items 4 and 5. In addition, the term of equidistant is essential to consider for preventing bias in analysis. Thus, it would lead to bias for the outcome. Finally, likert scale is widely used to rating scale in survey research and also has given more accuracy for the result which is not contained bias and inequality (Hole, 2011).

Table 3.3 Summary types of scale measurement

N	Type of scale measurement	Short definition	Example
1	Nominal scale	categories which object in the relevant domain is classified	Man and female
2	Ordinal scale	is the order matters but not the difference between values. Present greater or lesser	1=low and 5=high

N	Type of scale measurement	Short definition	Example
3	Interval scale	is related to quantitative attribute and numbers or units on the scale is equal over all levels of the scale.	1,2,3….100
4	Ratio scale	has all the properties of an interval variable, and also has a clear definition of 0.0.	0.5
5	Likert scale	answers with the level of agreement and disagreement measurement.	5 or 7 point of scale

Finally, the scale that uses in this research study is likert scale because this research is mostly focused on main contractor perception and experience in their works, so it tries to avoid the bias of respondent answers and get more accuracy for data analysis. Moreover, in neural network, likert scale was also popular to use by some researchers in model development. Deng (2008) used five-point likert scale with neural network (1 = very unsatisfied to 5 = very satisfied) to improve customer satisfaction for hotel service in Taiwan. Moreover, Saberi (2010) used 5-point likert scales to evaluate AMT implementation in Small and Medium size Enterprises (SMEs) by using an Artificial Neural Network (ANN). Therefore, this likert scale is suitable for using in this study.

3.3.3 Important factors for selecting subcontractor relationship

The purpose of this section is to define the important factors for selecting subcontractor relationship. Participants were given by five-point likert scale to evaluate on each factor (5= very agree to 1= very disagree). So after having a deeply interview with both project managers and directors of main contractors companies, the data will be analyzed into three stages including reliability analysis, mean and standard deviation and T-test analysis. Each method was explained clearly in the following.

3.3.3.1 Reliability analysis of scale

This research attempts to establish a validity and reliability of questionnaire in order to improve the accuracy of the analysis. Both elements are the basic in the determination of an instrument. Instrument is some kinds of skill, knowledge, simulation or questionnaire that uses to test or measure concept, skill or affective value. Validity focuses on the applying of instrument in measurement. Reliability focuses on the ability of an instrument to assess consistently. Usually, the reliability is closely associated with the validity. Moreover, an instrument cannot be valid unless it is reliable but the reliability of an instrument does not depend on its validity (Tavakol and Dennick, 2011). As reliability allows us to study the properties of measurement scales and the items that compose the scales, it is determined by many methods like Cronbach Alpha, Split-half, Guttman, Parallel and Strict parallel. Among of them, Cronbach's alpha is the most widely used objective measure of reliability and this method evaluates the internal consistency (Cronbach, 1951), so Cronbach's alpha increases as the inter-correlations among the items included in the analysis increase. Cronbach's alpha formula is shown in the following.

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum \sigma_i^2}{\sigma_i^2}\right) \tag{3.1}$$

Where:

k is number of components

σ_i^2 is variance of each component

$\sum \sigma_i^2$ is a total variance

The Cronbach's alpha coefficient is ranged between 0 and 1 and the higher score of the coefficient alpha, the better scale is reliable. Previous study determined the accepted value for reliability at 0.70 (Nunnaly, 1978).

3.3.3.2 Mean and Standard deviation

Previous studies have been used mean value to present the critical or important index in the research. Akintoye and MacLeod, (1997) determined management and risk analysis in construction by using standard deviation and mean. Ogunlana (2002) evaluated the factor used in selecting project manager to work ing construction project in Thailand by using standard deviation and mean too. Raz and Michael (2001) analyzed the important index of benefits and uses of tools for risk management by using above the overall average of mean. Thite (2000) used mean and standard deviation to analyze the leadership styles in information technology projects. Kamin (1998) analyzed reliability and discussed the productivity problems by using mean and standard deviation. Therefore, after seeing the significant use of mean and standard deviation, this study also takes both approaches as a method to identify the important factors that are used to select subcontractor relationship.

Many of the questions were asked for main contractor opinion on subcontractor relationship by rating scales. This will require calculating means and standard deviations for data analysis. The mean value was calculated by summation of respondent scores divided by number of respondents. This method was used to see the central tendency. Moreover, it should remember that the purpose of using the mean values for various factors is to study the relative trends rather than unnecessarily emphasising one particular numerical value against the other. The mean was calculated using the following formula.

$$M = \frac{\sum x_i}{N} \qquad (3.2)$$

Where Σx_i = Sum of each respondent scores

N = Sample size (number of respondents)

i =1, 2, 3, 4, 5…..

Another method that was used to analyze the dispersion of data and it is known as standard deviation. This method has measured the spread of the data set and the relationship of the mean to the rest of the data. If the data scores are close to the mean, it explained that the response scores are fairly uniform and then the standard deviation will be small. In contrast, if the data scores are far from the mean, it means that there is a wide variance in the response scores, so the standard deviation will be large. In addition, if all the data scores are equal, the standard deviation will be zero. The formula of calculating standard deviation is shown in the following.

$$SD = \frac{\sum (x_i - x)^2}{N - 1} \tag{3.3}$$

Where x_i = respondent score

x = Mean of all scores

N = Sample size (number of respondents)

i=1, 2, 3, 4, 5…..

However, to confirm about dispersion of data by standard deviation value alone is not particularly useful, this research has used coefficient of variation (CV) for understanding about the meaning of standard deviation related to the mean. The coefficient of variation is a uniform method that could help to determine the relevance of the standard deviation and what it indicates about the responses of the sample. If the value of CV is close to 0, the greater the uniformity of data. Conversely, if the value of CV is close to 1, the greater the variability of the data. The formula of CV is shown in the following.

$$CV = \frac{SD}{M} \tag{3.4}$$

Where SD = standard deviation value

M = Mean value

Based on the objective of the survey questionnaire in first part, it was intended to explore the important factors on selecting subcontractor relationship. Mean and

standard deviation values should be an appropriate statistic tools in this study, so we could identify the important factors by average value of mean. The result analysis will be illustrated in section 4.3.4.

3.3.3.3 Independent samples T-test analysis

T-test analysis method was calculated in order to ensure the differences of data sets. There are two types of t-test namely independent-samples t-test and paired-samples t-test. The objective of using independent-samples t-test is when we would like to compare the two different groups of people by using mean scores whereas paired-samples t-test is determined by comparing in the same group of people with mean value on two different occasions. Because our data is the answer of project manager and director for identifying the important factors for selecting subcontractor relationship, the independent-samples t-test is an appropriate method when there are two independent groups of samples, so it will compare different means score of both samples. Previous research also used this independent samples t-test analysis approach in evaluating the product and service management (Papastathopoulou and Avlonitis, 2006).

To analyze the data, the dependent variables (DV) which were group 1 indicated project manager opinion of important factors on selecting subcontractor relationship and group 2 referred director opinions of important factors on selecting subcontractor relationship too. The independent variables (IV) were 22 factors derived from subcontractor relationship. Moreover, we created hypothesis of samples as shown in the following and then the calculation of independent samples t-test was used by SPSS program.

Ho: m1 = m2 means there is no significant difference in answering of project manager and director on important factors on selecting subcontractor relationship.

H1: m1 $\neq$ m2 means there is significant difference in answering of project manager and director on important factors on selecting subcontractor relationship.

Before the analysis, we should check the homogeneity of variance assumption. This assumption means the variance of dependent variable should be the same with the other groups being compared. The homogeneity assumption is checked by Levene's test. If the significant score is greater than 0.05, it is not violate the assumption and we should use the first line in the table, which refers to Equal variances assumed. Moreover, if the significant level is equal or less than 0.05, it is violate the assumption. However, SPSS still gives another choice which provides us an alternative t-value by second row called Equal variances not assumed

Last, to assess the differences between the project manager and director group opinions, we have to see Sig. (2-tailed) column under the t-test for equality of means. The meaning of this result is that if the significant value (2-tailed) is equal or less than 0.05, it means that there is a difference in the mean scores of two group opinions. On the other hand, If the score is larger than 0.05, it refers that there is no significant difference between the two group opinions.

3.4 Application of decision making model

Supposing, the model was fully developed for main contractor to use in building construction projects. The following section explains about the procedure of data collection and data analysis of decision making model for selecting subcontractor relationship.

3.4.1 Data collection

Data collection could influence the reliability and validity of research study. The objective of data collection is to gather enough data for analyzing the model and testing. The data collection of this research is using interview technique. In this research, it is conducted by interviewing main contractor during building construction projects. This interview is implemented to find out the effective or accuracy of the

model in decision making on each subcontractor selection in relationship development.

3.4.1.1 Data collection by interview

Interview is consisted of asking questions, listening and recording the respondent answer. This technique is conducted to have in-depth understanding in the problem and carried with less number of respondents if comparing to the survey questionnaire. The interview is classified into four types which range from more formal and less formal which are such as in-depth interview, structured interview, focused group discussion, and semi-structured interview. Structured interview was prepared already including question and time setting, so interviewer will meet the respondent as on schedule. Moreover, interviewer can choose hand over the questionnaire paper or just read it out to respondent. Then the research needs to provide the explanation in each question if it is vague. Semi-structure interview allow the interviewer to control over the interviewee and it begins with less formal in order to catch up the interviewee point of view and get inside information. In-depth interview is used for collecting the complex information and the small number of sample was selected for detail interview. The interviewer needs more effort and skill in conducting this interviewing. Focused group discussion is conducted with a group of people rather than with individual. Its purpose is to remove bias of individual perception and improve the quantity and quality of information needed. Therefore, this research will use structured interview with project managers or directors of main contractor company to evaluate on each subcontractor in relationship development.

3.4.1.2 Data analysis

There are two selected methods that use to develop a decision making model including Discriminant Analysis and Neural Network. The model is developed from 10 important factors which were gathered by the above average score of main contractor opinion. These factors are likely to help main contractor on selecting the

mode of relationship development with subcontractors. After getting these 10 important factors, the questionnaires were designed by asking main contractor to evaluate on each subcontractor for relationship development. The objective of using discriminant analysis is used to categorize the predicted group. The analyzing of this method is determined when factors and dependence variables are showed in group like nominal and predictor and independent variables are interval scale. Moreover, this predicting group membership is based on two or more independent variables. Neural network is another analyzing method which uses for classification in decision making because it is able to reduce the level of error and maximize the accuracy of the training and testing data. In addition, it does not need to concern about the assumptions in the model. Last, by comparing the result of these methods, the model determines the optimal method which has the high level of accuracy. The detail information of discriminant analysis and neural network were discussed in the following.

3.4.2 Artificial Neural Network

3.4.2.1 Introduction

Artificial Neural Network is sometimes known as neural network, was developed by McCulloch and Pitts in 1943. This method tries to follow the process of nervous system in the brain's networks. So it is a mathematical method used to simulate the information processing as the human brain (Hinton, 1992). Many researchers tried to develop the neural network which represents the computational processing ability of the brain as a sophisticated modeling technique and it would be able to deal with the complicated problem in some research fields.

Basically, this method was followed by three components such as input unit, output unit, and fixed activation threshold. This network consists of an interconnected group of artificial neurons and processes information using a connectionist approach. Cybenko (1989) and Hornik et al., (1989) mentioned that ANN could be a universal

function approximator because it could automatically approximate whatever functional form a desired degree of accuracy the data. Therefore, this network has become a popular method which could perform a wide range of complex tasks especially in decision-making issues.

3.4.2.2 Architecture of neural network

Artificial Neural Network (ANN) could be seen often as visible units and hidden units. Visible units have seen by the external world including input and output nodes whereas the hidden nodes do not directly interact with the outside world (Shukla, 2010). Moreover, the input and output nodes usually are grouped into layers called input layer and output layers in the ANN. Then a layer has the hidden nodes is known as hidden layer. Figure 3.7 shows about each layer of input, output and hidden units.

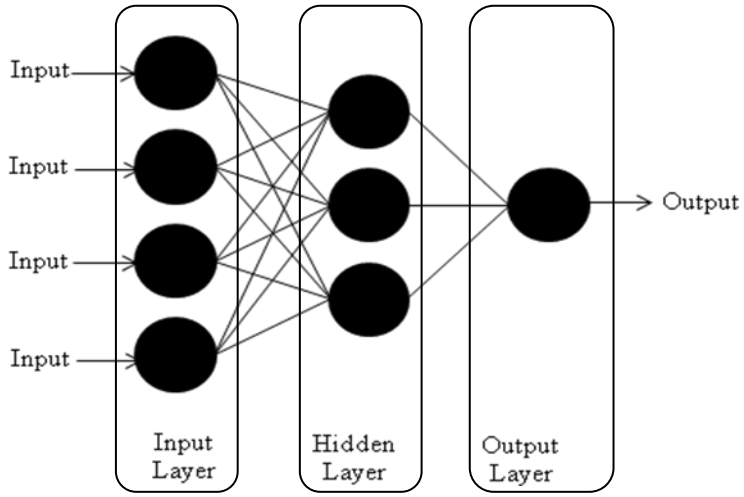

Figure 3.7 layers of input, output and hidden units

3.4.2.2.1 The number of input nodes

In our model, we have only one input layer which consists of many input nodes. The number of variables in the input layer was considered the same as the number of input nodes. For our study, the input nodes numbers are equal to the

number of factors using on selecting of subcontractor relationship such as time control in planning, work quality, cooperation, experience, commitment, resources, honesty, monitoring, coordination, and trust. Moreover, these 10 variables were shortlisted among 22 factors and also known as the important factors that main contractor used in decision making for selecting subcontractor relationship. Therefore, in short, we have 10 input nodes in the layer for developing the model in ANN.

3.4.2.2.2 The number of hidden layers and nodes

The hidden nodes and layers have become the essential parts in the neural networks structure. It does not yet have any guideline for specifying the number of hidden nodes and layers. Some authors suggested to use a hidden layer in the study because it is enough for ANN to give a desired accuracy in the complex problem (Hornik et al., 1989; Cybenko, 1989). However, the other researchers found increasing the number of hidden layers (usually 2hidden layers) may provide more benefits their problems. Srinivasan et al., (1994) obtained a higher accuracy in the data training by two hidden layers. Moreover, Zhang et al., (1997) found the model with two hidden layers has given better result in accuracy for some type of problems. To solve the problem of number in hidden nodes and layers, Chang et al., (2006) performed a sensitivity analysis and also found a hidden layer could improve the result. Therefore, to achieve a good model, our research has chosen a hidden layer for developing the model.

Next, the number of hidden nodes has become an important issue because it could capture and detect the pattern in the data, and compute the nonlinear function from input to output nodes (Zhang et al., 1997). Moreover, many researchers have provided several practical guidelines to specify the number of hidden nodes. Hecht-Nielsen (1990) and Lippmann (1987) mentioned the number of hidden nodes about 2n+1. Then Wong (1991) proposed the number of hidden nodes should be only 2n. Moreover, Kang (1991) and Tang and Fishwick (1993) found the number of hidden nodes were n/2 and n respectively, where n is the input nodes number. Based on Tang and Fishwick finding, in forecasting the time series by neural network, the number of

hidden nodes does not affect quite significant on forecast performance. Moreover, it is noticed from many studies that the network has the number of input nodes equal with the number of hidden nodes produced the desirable result (Sharda and Patil, 1992; Tang and Fishwick, 1993; Chakraborty et al., 1992; De Groot and Wurtz, 1991). Finally, we could conclude that this research study uses one hidden layer and 10 hidden nodes.

3.4.2.2.3 The number of output nodes

The output nodes quantity is usually easily to determine that it is depended on the problem of study (Zhang et al., 1997). For our decision making problem, the output nodes are short-term relationship and long-term relationship. Thus, in our research study, only one output node was needed.

3.4.2.3 The activation function

Normally, ANN consists of artificial neuron and it was established by following three parts. First, it is called multiplication, the input is multiplied by the associated connection weight between the neurons. Next, at the middle part, it is summation that means the sum of all bias and inputs weight. Then, at the last part, the summation of bias and inputs is going through the transfer function. Artificial neuron model simplicity is shown in the Figure 3.8.

$$y(k) = F(\sum_{i=0}^{m} w_i(k).x_i(k) + b) \quad (3.5)$$

Where

$x_i(k)$ is input score of k where i is from 0 to m

$w_i(k)$ is weight score of k where i is from 0 to m

b is bias score

F is an activation or transfer function

$y_i(k)$ is output score of k.

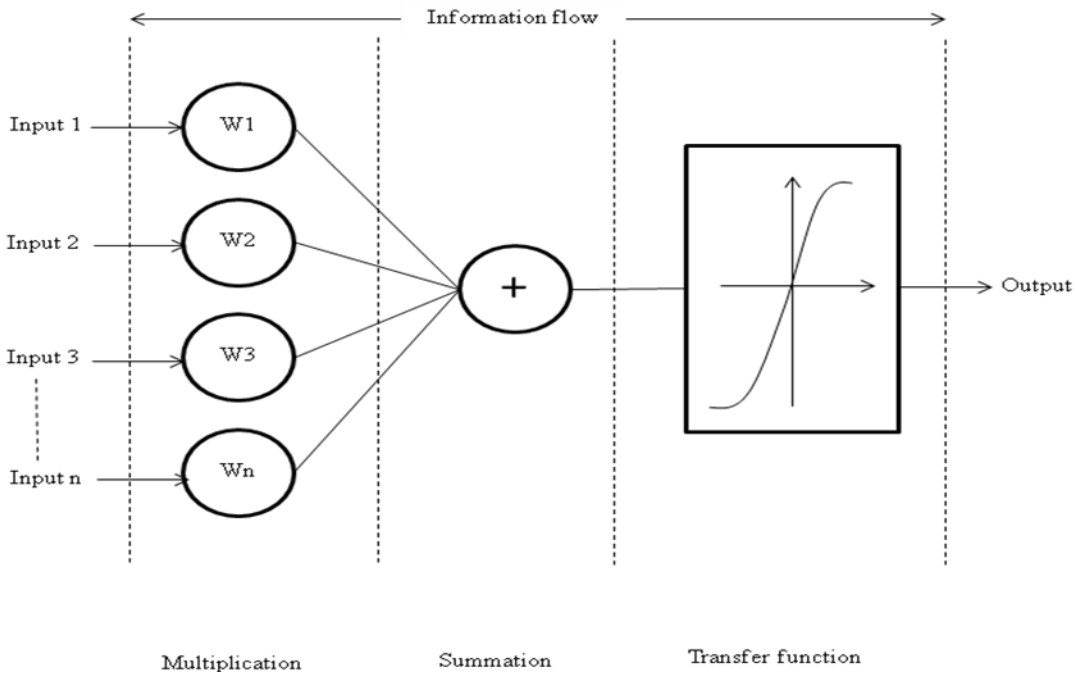

Figure 3.8 Artificial Neural Network process (Krenker et al., 2011)

The activation function, called as a transfer function, was used to determine the relationship between inputs and outputs in the network. Mostly the transfer functions used the nonlinear function, known as a sigmoid function. This function use to calculate the weight update by derivation in the Neural Network. Equation 3.6 shows about sigmoid function.

$$f(x, w) = \frac{1}{1 + e^{-(\sum xw + w_o)}} \tag{3.6}$$

Where w_i is weight value, x_i is input value and w_o is the bias value and this function is ranged from 0 to1.

There is a majority of neural networks that used the same transfer functions among each layer (Schoneburg, 1990). Usually, several researchers apply sigmoid functions for hidden nodes. Moreover, sigmoid function also seems provide a good result in classification of many problems at the output nodes (Zhang et al, 1997).

Therefore, this research will use sigmoid activation function into both hidden node and output node.

3.4.2.4 Training algorithm

After choosing the topology, we need to train the input node for learning the knowledge among each data. There are two types of training process namely unsupervised and supervised learning. Each learning process was explained in the following section.

Supervised learning sets the parameters value from training data after calculating the output value. So each output unit is told what its desired response to input signals ought to be. In addition, one issue that supervised learning has concerned is the problem of error convergence like the minimization of error between the desired and computed unit values. One well-known method, which is common to many learning paradigms, is the least mean square (LMS) convergence.

On the other hand, unsupervised learning is used to minimize a cost function and given data. Cost function is calculated by the task formulation. Moreover, mostly, this learning is used to solve problems in applications like statistical or clustering modeling. Unsupervised learning normally tries to organize data into different group. For example, self-organization is one of popular issues that used the unsupervised learning. Finally, unsupervised learning is performed on-line whereas supervised learning is performed off-line.

According to our study, we will use supervised learning because we would like to see the error of data which is occurred in the model and minimize this error to the acceptable level. Based on the supervised learning, there are many steps of solving the problem. First, we need to specify the type of training process. Second, we have to collect the data set for training. Third, we explain the training data set into understandable form in Artificial Neural Network. Last, after we do the learning, we

could validate the performance of learned Artificial Neural Network with the data set. Test data set consists of data that has not been introduced to Artificial Neural Network while we use in learning.

3.4.2.4.1 Back-propagation algorithm

To obtain a good model, we need to adjust the weights of each unit and the error between the desired output and the actual output is reduced. This process requires that the neural network compute the error derivative of the weights (EW). In other words, it has to calculate how the error changes as each weight is increased or decreased slightly. There are two ways that we could define the EW. First, we calculate the EW by perturbing a weight slightly and observing how the error changes. This method is seem not efficient because it requires a separate perturbation for each of the many weights. Next, we could calculate the EW by use the back-propagation algorithm. Moreover, this method has become one of the most important tools for training neural networks recently.

Back-propagation (BP) algorithm is a supervised learning method, and is most useful for feed-forward networks. This algorithm would like to reduce the error of output (Rumelhart, Hinton, and Williams, 1986), so it means that when the computation of the error changes as the activity of an output unit is changed. Usually, in ANN calculation, we select the parameters randomly and process the inputs to generate a predicted output. After the error derivative is the difference between the actual and the desired outcome, the network tries to reduce the error by adjusting the parameters again and again until the network brings a specific error. Finally, the detail of this BP calculation will explain in section 3.4.2.8. Moreover, although this back-propagation algorithm consists of many calculations in practice, we could use some software that could allow us to solve the problem and enable to determine the optimal result in Artificial Neural Network. One of the most popular software that we use for calculating in back-propagation algorithm is known as Qnet 2000. The process of using this qnet 2000 program will be illustrated in Chapter 5.

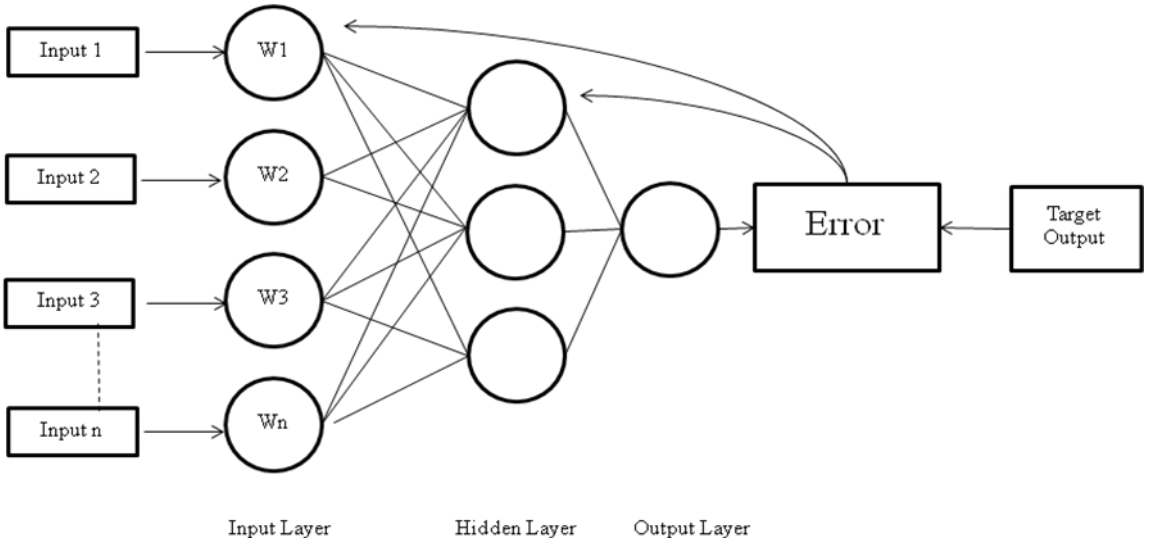

Figure 3.9 Back-propagation algorithm processes

3.4.2.5 Input data transformation in the networks

The input data needs to transform before using in the modeling because it involves with scaling data issue in neural network. Mostly, the accepted data in the neural network is ranged from -1.0 to +1.0 or 0.0 to 1.0 because it depends on the transfer functions used in the model. The majority of neural network models use a sigmoid transfer function (Rajkumar and Bardina, 2003). A sigmoid function is known as a non-linear function. In addition, when we use this function, the scale value the input data was transferred over the range from 0 to 1 by using linear transformation formula (Lapedes and Farber, 1988). Regarding to our study, we also use sigmoid function so the likert scale of input data was transferred before using the training algorithm. Before we begin the training process, the output data was transferred by using 0 and 1 to represent short term relationship and long term relationship respectively. Last, equation of linear transformation formula which uses to calculate of input data transformation is shown in the following.

$$x_n = \frac{(x_i - x_{mini})}{(x_{max} - x_{mini})} \tag{3.7}$$

3.4.2.6 Training sample and test sample

Training and test sample were required to build an ANN model. The training sample was used to develop the ANN model whereas the test sample is used for checking the predictive accuracy of the model. Sometimes, we also need another external sample besides training and test sample to validate the model again because it improves the accuracy of the model (Weigend et al., 1990). However, if the data set is small, it is commonly to use one test set for both validation and testing purposes. The division of the data into the training and test sets is an important issue to consider in developing ANN. There are no clear solution on specify the number of the training and the test sample. Previous studies suggested some rule of 90% vs. 10%, 80% vs. 20% or 70% vs. 30%...etc. Nam and Schaefer (1995) studied the effect of different training sample size and found that when the training sample size is increased, the ANN result performs better and better. Granger (1993) mentioned at least 20 percents of samples should keep for testing for non-linear models. Chang (2006) has divided training and test set and verification samples into 85%, 10% and 5%. Moreover, based on Qnet program, the minimum requirement of test set number is around 10%. Therefore, although our sample is around 93, we could divide it into 79, 9 and 5 for training, testing and verifying respectively.

3.4.2.7 Performance measurement

After we have trained the data of model, we need to evaluate the predictive accuracy based on the error value between the predicted and actual value. Generally, four performance measures is used by various authors including mean squared error (MSE), mean absolute error (MAE), percent good (PG) classification, and root mean squared error (RMSE). However, each of this performance measure could use to explain the error of performance in the network (Twomey and smith, 1996). When the actual outputs are continuous and the output targets are binary variables, MAE or RMSE is the most popular method that uses to determine the error in classification networks. Therefore, based on the calculation of back-propagation algorithm by using

qnet program, this program has used RMSE as a tool for checking the error of training and testing sample. The meaning of Root Mean Square Error (RMSE) often use to measure of the difference between actual and predicted value by a model. Last, the formula of RMSE is given in the following equations, where n is the number of observations, X_{pre} is a predicted value and X_{obs} is an observed value for ith observation.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_{pre} - X_{obs})^2}{n}} \tag{3.8}$$

3.4.2.8 Steps of calculating back-propagation algorithm in neural network

As we know the objective of using back-propagation algorithm before, the calculation of this method would give some more perceptions to reader in understanding BP algorithm. There are many steps to achieve in this calculation. So we would describe this method step by step. First, we calculate the activation function by a summation of multiplying between the inputs (x_i) and their respective weights (w_{ji}). Then we use the above result to calculate the output by sigmoid function $O_j(\bar{x},\bar{w})$. Moreover, this sigmoid function is ranged from 0 to 1.

$$A_j(\bar{x},\bar{w}) = \sum_{i=0}^{n} x_i w_{ji} \tag{3.9}$$

$$O_j(\bar{x},\bar{w}) = \frac{1}{1+e^{A_j(\bar{x}\bar{w})}} \tag{3.10}$$

Now, when the inputs are given into the training process, we will get a desired output. Since the error between the desired and actual output is the difference, we could minimize the error by adjusting the weights. So we could determine the error of each neuron output by using the equation below.

$$E_j(\bar{x},\bar{w},d) = (O_j(\bar{x},\bar{w}) - d_j)^2 \tag{3.11}$$

Where d_j is desired target, we take the square of the difference between the desired target and actual output for making it positive. Moreover, the error value of output will be lesser or greater is depended by the different value whether it is small or big. The error value in the network is calculated by the sum of error of all the neurons in the output layer. After that, the calculation of back-propagation algorithm follows the error of inputs, weights and outputs. Last, we use gradient descendent method to adjust the weight.

$$E_j(\bar{x}, \bar{w}, d) = \sum_j (O_j(\bar{x}, \bar{w}) - d_j)^2 \tag{3.12}$$

$$\Delta w_{ji} = -\eta \frac{\partial E}{\partial w_{ji}} \tag{3.13}$$

Where Δw_{ji} is the adjustment of each weight

η is constant

$\frac{\partial E}{\partial w_{ji}}$ is the derivative of E in respect to wji

Based on the equation 3.13, we could understand that if the contribution of weight a smaller error, the adjustment will be lower. This calculation is determined until reach the satisfied weights which mean the error is minimal. Next, we do the same for calculating the error by the output using derivative of E in respect to O_j.

$$\frac{\partial E}{\partial O_j} = 2(O_j - d_j) \tag{3.14}$$

Then, we need to know the output result from transfer function based on the weight of equation 3.9 and 3.10.

$$\frac{\partial O_j}{\partial w_{ji}} = \frac{\partial O_j}{\partial A_{ji}} \frac{\partial A_j}{\partial w_{ji}} = O_j(1 - O_j)x_j \tag{3.15}$$

We can see that from equation (12) and (13):

$$\frac{\partial E}{\partial w_{ji}} = \frac{\partial E}{\partial O_{ji}} \frac{\partial O_j}{\partial w_{ji}} = 2(O_j - d_j)O_j(1 - O_j)x_j \tag{3.16}$$

Thus, the adjustment of each weight in equation 15 into equation 12 will be changed into this equation below.

$$\Delta w_{ji} = -2\eta(O_j - d_j)O_j(1 - O_j)x_j \tag{3.17}$$

We can use the result from equation 16 for training an ANN with two layers. Moreover, if we want to add one more layer, we need to adjust the weights of a previous layer (v_{ik}). So we have to change x_i with w_{ji} in (14), (15), (16). In addition, we still have to see the result of the network error bases on the adjustment of previous layer.

$$\Delta v_{ik} = -\eta \frac{\partial E}{\partial v_{ik}} = -\eta \frac{\partial E}{\partial x_i} \frac{\partial x_i}{\partial v_{ik}} \tag{3.18}$$

Where:

$$\frac{\partial E}{\partial w_{ji}} = 2(O_j - d_j)O_j(1 - O_j)w_{ji} \tag{3.19}$$

Then, the equation 14 will be changed to the equation below.

$$\frac{\partial x_i}{\partial v_{ik}} = x_i(1 - x_i)v_{ik} \tag{3.20}$$

Finally, when we would like want to have another extra layer, we could do it the same by determining the error regarding to the weights and inputs of the first layer. Moreover, we have to look closely with value of the indexes because there are many difference numbers of neurons in each layer of ANN that could make us confusion.

3.4.3 Sensitivity analysis

To determine the influencing factor of subcontractor relationship in the current practice of main contractor evaluation, sensitivity analysis is an efficient tool. It is used to apply in a trained feed forward neural network for automatically identifying

all input parameters that influences on the output. This method an optimal method that used to provide the contribution percentage of input to the model outputs (Gevrey, 2003 and Shojaeefard, 2012). Moreover, in neural network, the sensitivity method could be determined the contribution percentage of each input by the result of input node interrogator option in the software Qnet 2000. This option is used to determine the sensitivity by repeating the training patterns process again and again with each input and computing the result of the network's output. In addition, we should remember the interpretation of this sensitivity result has assumed that the value of input is independent. Therefore, the result of influencing factor of subcontractor relationship is determined by sensitivity approach in neural network.

3.4.4 Discriminant analysis

There are two purposes that we use discriminant analysis in this research. First, we would like to identify the influencing factors for selecting subcontractor relationship from the current practice in main contractor decision. Moreover, based on the result of influencing factors which we could get from the discriminant analysis and sensitivity analysis of neural network and, we compared these results and make some discussions with the important factors of subcontractor relationship that we got from main contractor opinion by mean value. Next, we will compare the degree of error between discriminant analysis and neural network. Thus, we could determine the optimal method which has lower error than another as a model for selecting subcontractor relationship.

Discriminant analysis is used to calculate a linear equation of the interval variables to predict group outcome (Hair et al., 2010). It analyses the data when factor and dependence variables are showed in group like nominal and predictor and independent variables are interval in nature. Moreover, this predicting group membership is based on two or more independent variables. In discriminant analysis case, the dependent variable must be mutually exclusive and exhaustive such as making a profit or not, employed/ unemployed, buy a product/not buy and so on. In addition, the independence variable is identified based on the previous research or the

experience or knowledge of the researcher and it is the quantitative variable and rated by score. All in all, the discriminant analysis is defined by a linear equation that will predict the groups of dependent variable belong to and the calculation in this study could be helped by using SPSS programming.

3.4.4.1 Steps in calculating two-group discriminant analysis

This research is considered in two-group discriminant analysis which it has two dependent variables such as short or long-term relationship. Moreover, one discriminant function is considered and the predictor variables in these relationships are identified. There are many stages of calculating two-group discriminant analysis which showed as in Figure 3.10 and each step was explained clearly in the following section.

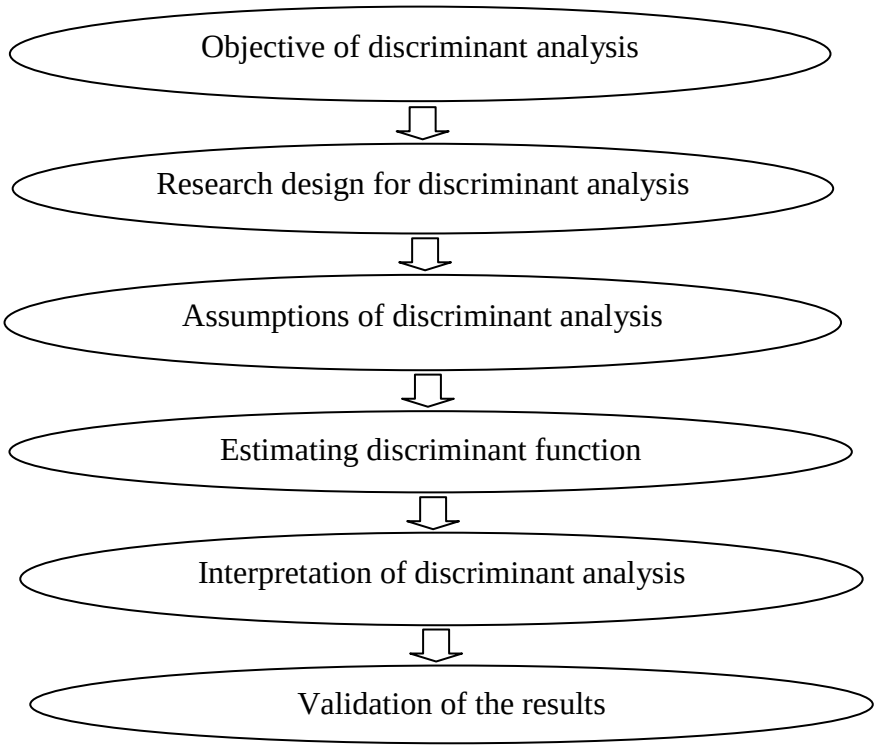

Figure 3.10 Discriminant analysis process (Hair et al., 2010)

3.4.4.1.1 Objective of discriminant analysis

Firstly, the discriminant analysis needs to define the objective of its study. As main constructors take a great responsibility in construction management, they need to sublet some parts of their works to many subcontractors in each project. Moreover, after the relationship between main contractor and subcontractor is developed by time and corporative work with each other, main contractor has seen subcontractor as a good companion who could improve the construction work and profit in the future. Regarding to this reason, main contractor is interested to see the type of relationship whether short or long-term relationship that they should place on each subcontractor. The inquiry follows the obvious need by management to always strive to better understand in decision making. As the result, main contractors will be able to identify the subcontractor who is capable and suitable for them to make the long-term relationship whereas the bad one is in short-term relationship.

To answer in main contractor decision making, discriminant analysis is selected as a tool to identify the evaluation of short or long-term relationship with subcontractor.

3.4.4.1.2 Research design for discriminate analysis

There are three stages that discriminant analysis concerns in research design. First is about selecting the dependent and independent variables. Second, it focuses on deciding the sample size needed to determine in discriminant function. last, it is division of sample for validation purpose.

3.4.4.1.2.1 Selecting of dependent and independent variable

To determine discriminant analysis, the researcher has to specify the dependent and the independent variables. The independent variables are metric

whereas the dependent variables are nonmetric. In this research, the independent variables were known as 10 important factors of subcontractor relationship which was perceived by main contractor opinion. In addition, the dependent variables were grouped as in short and long-term relationship. The research will use the rating score on each independent variable of subcontractor evaluation. After the dependent variables were known as short or long-term relationship, the independent variables can be found into two ways such as:

- First, the variables are identified by literature review in previous research
- Second, the variables that were underlying in the main contractor knowledge and experience were understood by face to face interview.

3.4.4.1.2.2 Sample size

In the discriminant analysis, it is like the other multivariate techniques that influenced by the sample size being analyzed. So the smaller sample is, the more error will be occurred. Moreover, the sample size of discriminant analysis will consider from the overall sample size and sample size per category. In addition, the minimize size of the overall sample is recommended five observation per independent variable whereas the size of small group in the category must exceed the number of independent variables. The guideline of each group recommends having at least 20 observations (Hair et al, 2006, 2010). After data collection, we could get the sample size around 93 to use in this method.

3.4.4.1.2.3 Division of sample

The sample is classified into two groups known as analysis or estimation sample and hand out or validation sample. The discriminant function is determined by analysis sample whereas the validation sample is reserved for testing the discriminant function. Moreover, this sample uses to validated is known as cross-validation or the split-sample approach (Cooley and Lohnes, 1971). There is no definite guideline for

determining the relative size of analysis and validation sample. Mostly, the total sample is divided into one-half for analysis sample and the other half for testing sample. Some authors have suggested using 75-12 or a 60-40 split (Hair et al, 2006). Although the sample size seems to be small, we also have to divide the sample into estimating and testing samples. The result of validation is more focused than increasing the number of sample in analysis sample. The research has chosen to split the sample into 79 and 14 of analysis and hold out samples which are the same the samples size in training and testing of neural network. In addition, each group of sample size in estimation which is 30 and 49 for short and long-term relationship exceeds the minimum size of 20 observations per group. Therefore, we pass the sample requirement and could continue in this analysis.

3.4.4.1.3 Assumptions

In discriminant analysis, the assumptions concerns with the sample size that independent variable is normality of. It also uses Box's M test to evaluate the significance differences between dependent variables (Green and Carroll, 1978). Moreover, the researcher wants no significant result in this Box's M test (>0.01) so it will indicate that there was not difference between the group covariance matrices (Agresti, 1996). On the other hand, if the research design increases in the sample size or independent variables number, it will be acceptable even the value is significance. If the assumption is violated, the researcher has to examine again by finding the other method available like logistic regression. In addition, it would cause a problem if the data does not meet the multivariate normality assumption.

3.4.4.1.4 Estimating the discriminant function

At this stage, researcher has to determine the method and number of discriminant functions. There are two methods for obtaining the discriminant function such as simultaneous/direct method and the stepwise method. The direct method is determined by taking account the independent variable simultaneously with regardless

of its discriminating power. This method would include all independent variables and select the variable that has the most discriminant power. The stepwise discriminant analysis is derived by considering the independent variables one by one, regarding their ability to discriminate among groups. The stepwise method is used to determine the function with a large number of independent variables (Hair el at., 2006, 2010). Regarding to the large number of independent variables, this research should use stepwise method and this method will explain in the following step.

First, the research must evaluate the overall significance of discriminant function and the significance of each separate discriminnant function. The assessment of the overall significance in stepwise method was usually defined by the value of Mahalanobis (D^2). Moreover, Mahalanobis (D^2) procedure becomes critical as the number of predictor variables increase because it does not result in any reduction in dimensionality. A loss in dimensionality would cause a loss of information because it decreases the variability of independent variables. Thus, normally the researchers prefer the largest Mahalanobis distance (D^2) between the groups which they could use of available information in a stepwise process. Next, the researcher will look at the significance in separate discriminnat function. As this study is two groups, it will have one discrimination function and the significance factor of 0.05 or less required for entry is often used (Hair et al., 2006). Finally, after researchers know the significance of the overall and separate discriminant function, they could select the qualify independent variables to calculate in the stepwise process.

Next, the stepwise approach defined the discriminant function by following a sequential process of adding or deleting variables in the following manner:

1. Choose the variable that has the most discriminating power.
2. Compare each independent variable with the other by one at time, and choose the variable that has improved the discriminant power in the function by combining with the first variable.

3. Select additional variables in a like manner. Some previously selected variables may be removed when we include additional variables.
4. Consider the process completed when the variable is no longer contribute the power with further discrimination study.

Third, to define the discriminant function, the basis for calculating the discriminant Z scores were established. The discriminant Z score gives a direct means of comparing observation on each function. Moreover, the discriminant function can be expressed with both standardized or unstandardized weights and values. The discriminant Z scores of any discriminant function are determined by linear combination and could be calculated by the formula below.

$$Z = a + w_1X_1 + w_2X_2 + w_3X_3 + \ldots\ldots\ldots + w_nX_n \quad (3.21)$$

Where Z = Discriminant function

w_n = Discriminant coefficients or weights

X_n = Predictors or independent variable

a = a constant

Fourth, the research will assess the classification accuracy by following three steps. First is calculation of the cutting score. The factor against which each observation's discrimination Z score is used to define the classified group. Next we will develop the classification in both estimating and the testing samples. Last, it assesses the levels of predictive accuracy from the classification matrices for both the statistical and practical significance. These three steps will be explained more in the below section.

1. In order to calculate the cutting score, we have to know the prior probabilities

through the use of group size. The optimum cutting score will be half way between the two group centroids and become simply the average of the two centroids.

$$Z_{CE} = \frac{Z_A + Z_B}{2} \qquad (3.22)$$

Where Z_{CE}= effective cutting score value of group A and B

Z_A , Z_B = Centroid for group A and B

Then, to test the classification of discriminant function, the sample is divided randomly. One group is used to calculate the discriminant function by the analysis sample. The other group is developed the classification by testing sample. The calculation procedure in discriminant function is determined by multiplying the raw variable measurement with the weights generated by the analysis sample. Then the discriminant scores for the testing samples are compared with the optimal cutting score value and classified in the following.

- Classify an individual into group A if Zct<Zn

Or

- Classify an individual into group B if Zct>Zn

Where Zct= optimal cutting score value

Zn= discriminant Z score for the nth individual

2. The establishing standards of comparison for the hit ratio are calculated to

understand the percentage that is classified properly by chance and without the aid of the discriminant function. Because our research study is unequal group sizes, the researcher has to determine the maximum chance factor and proportional chance factor. First, with the greatest probability of occurrence in the group for all observation, the percentage correctly classified is determined by the maximum chance factor. It reflects our most conservative standard and assumes no difference in the cost of misclassification as well. Second, the proportional chance factor assumes that the costs of misclassification are equal. For example, we want to identify members of equal group well. The proportional chance factor is shown in equation 3.23.

$$C_{PRO} = p^2 + (1-p)^2 \quad (3.23)$$

Where C_{PRO} = proportional chance factor

P = proportion of firms in group A

1-P = proportion of firms in group B

In addition, the researcher would like to know the classification accuracy. if the percentage of classification accuracy is no greater than the expected by chance, it will have little or no interpretation. However, if the classification accuracy is bigger than the expected value by chance, the researcher can continue to interpreting the discriminant functions and group profiles. Therefore, if the achieved classification accuracy (analysis sample, validation sample and cross-validation) must exceed the selected comparison standard (maximum chance factor and proportional chance factor) plus 25 percent, it will indicate the classification accuracy is acceptable.

Next, the measurement of classification accuracy is Press's Q statistic. This method compares the number of correct classifications with the total sample size and the number of groups. If it exceeds the optimal value of 6.63, the result of classification indicates better than the classification by chance. The formula of Press's Q statistic is determined below.

$$\text{Press's Q} = \frac{[N - (nk)]^2}{N(K-1)} \quad (3.24)$$

Where N = Total sample size

N = Number of observation correctly classified

K = number of groups

3. This calculation determines the result of misclassified of each case in analysis and testing sample. Moreover, it also performs the additional analysis profiling for misclassified cases.

- The misclassified group (analysis and holdout samples) could identify not only those cases with classification errors, but also a direct representation of the type of misclassification error.

- This analysis could determine the characteristic of misclassified cases for improving the level of accuracy in prediction. This analysis could take form of profiling the misclassified cases on either independent variables or other variables not included in model. The form of profiling on the independent variables could be seen as a graphical presentation of observation. It is the discrimiant Z scores and portrays the overlap among group and the misclassified cases. This plotting shows not only the general group characteristics in the centroids, but also the variation in the group members. Another assessment of observation could be made by evaluating the Mahalanobis D^2 distance in each case with the group centroid. So when the the value of independent variables is closer to the centroid, it will have a smaller Mahalanobis D^2. Last, with this profiling of misclassified cases, the research encourages to identify new possible variables that may relate uniquely to the misclassified cases and increase the overall perspective accuracy.

3.4.4.1.5 Interpretation of discriminant analysis

The interpretation of discriminant function is explained by the relative influencing of independent variable in group membership discriminating. To achieve this interpretation, there are three available methods to choose for determining the relative importance such as:

First, the standardized discriminant weights or discriminant coefficient of each independent variable should be taken into account for consideration. The independent variables with the smaller weights contribute less to the discriminating power than the variables with greater weight. Moreover, the small number of weight of coefficient is also indicated the irrelevant to relationship determination because of a

high degree of multicollinearity. These problems suggest caution in using weights to interpret the results of discriminant analysis.

Second, discriminant loading is known as the structure correlation measures the linear correlations between each predictor variable and the discriminant functions, so the variable which is higher number is related to the function. It is popularly use as a basis for interpretation because of the deficiencies in using weight. In stepwise, this loading is less affected by multicollinearity and more useful in interpretation purpose that it calculated for all variables, so it will provide a relative effect of every variable on a common measure even some variables are not included in discriminant function. An earlier rule of thumb indicated loadings above ±.40 should be used to identify substantive discriminating variables.

Last, it is examined the independent variable by partial F values. The greater value of F are calculated and ranked. So the higher F values of particular variable, the greater discriminatory power will be obtained.

3.4.4.1.6 Validation of the discrimination results

In this stage, it involves with the validation of the discriminant result. This process provides the assurance that the result has the validity both internal and external. There are two validities of discriminant analysis such as internal and external. Internal validity is known as testing sample. It is established to assess whether the discriminant function in classifying observations passes the acceptable level or not and it is not used in the estimation process.

External validity is defined as cross-validation approach is performed with multiples subsets of the total sample. It is from another separate sample perhaps from another population use to assess of hit ratios. The cross-validation is depended on the “leave-one-out” principle by estimating k-1 case, so it will eliminate one observation at a time from a sample of k cases. After all of the group membership predictions have been made one at time and a classification matrix is constructed and hit ratio

calculated. This validity is supported when the hit ratio of the selected approach exceed the comparison standards that represent the predictive accuracy expected by chance.

Another validation technique is to profile the groups on the independent variables to ensure heir correspondence with the conceptual bases used in the original model formulation. This profiling is based on the group means and enable the researcher to understand the character of each group according to the independent variables.

3.5 Summary

The methodology of the research is explained in detail in this chapter. To gain the research objective, this research has two main parts. First, it tries to identify the important factors of subcontractor relationship from main contractor opinion. Next, we explore the suitable method for developing the model. Neural network and discrimimant analysis are compared the level of accuracy and determined the influencing factors from actual practice. By using the ANN, back-propagation algorithm is determined in order to get the minimum error and high accuracy of model. On the other hand, discriminant analysis used stepwise method to determine the categories of the dependent variable. Then, we choose the method that has lower error and the result is discussed in the chapter 5. In addition, sensitivity analysis of neural network is used to determine the influencing factor from input to output node. Later on, we compare the finding of factor from main contractor opinion and current practice with subcontractor.

CHAPTER IV

IDENTIFICATION OF IMPORTATNT FACTORS FOR SELECTING SUBCONTRACTOR RELATIONSHIP

This chapter mainly explores about contractor perception of important factors on selecting subcontractor relationship. First, it starts with description of survey data information including background and experience of respondents working with subcontractor. Then, it discusses about the main contractor practice in decision making for selecting subcontractor relationship. The analysis presents the nature of using subcontractor and percentage of subcontractor relationship implementation. In addition, it also explains about the types of work that main contractor used with different types of subcontractor and relationship such as short or long-term relationship. Next, the analysis method has determined nine important factors for selecting subcontractor relationship and each factor was explained in detail in section 4.3.5. Finally, this chapter will be a primarily stage that uses to develop a model for selecting subcontractor relationship at last.

4.1 Description of survey data

The survey question aims to achieve the research objective by conducting a depth interview with main contractor who has experienced in relationship development with subcontractor. This data collection took place from November until January 2012 in Cambodia. In this survey, 35 respondents were contacted for having in-depth interview plus with questionnaire and all of them are local companies and working in building construction at Phnom Penh, a capital city of Cambodia. It took around 20 and 40 minutes for each respondent who is willing to share their work experience or opinion.

4.1.1 Positions of respondent

Position of respondents is considered as a key factor for selecting subcontractor relationship. With the high position as project manager or director of main contractor company, they are persons who have the ability to decide by relationship development with subcontractor. In this research, the respondents have been targeted to people who have high position in main contractor company. The result is illustrated in Table 4.1 and Figure 4.1. From the result of this research, 62.86 % of respondents are holding the position as project manager in the company whereas 37.14% of main contractor companies are directors. So they are qualified for answering in the interview request.

Table 4.1 Position of respondent in main contractor company

Position of main contractor	Number of respondent	Percentage	Cumulative Percentage
Project manager	22	62.86	62.86
Director	13	37.14	100.00
Total	35	100.00	

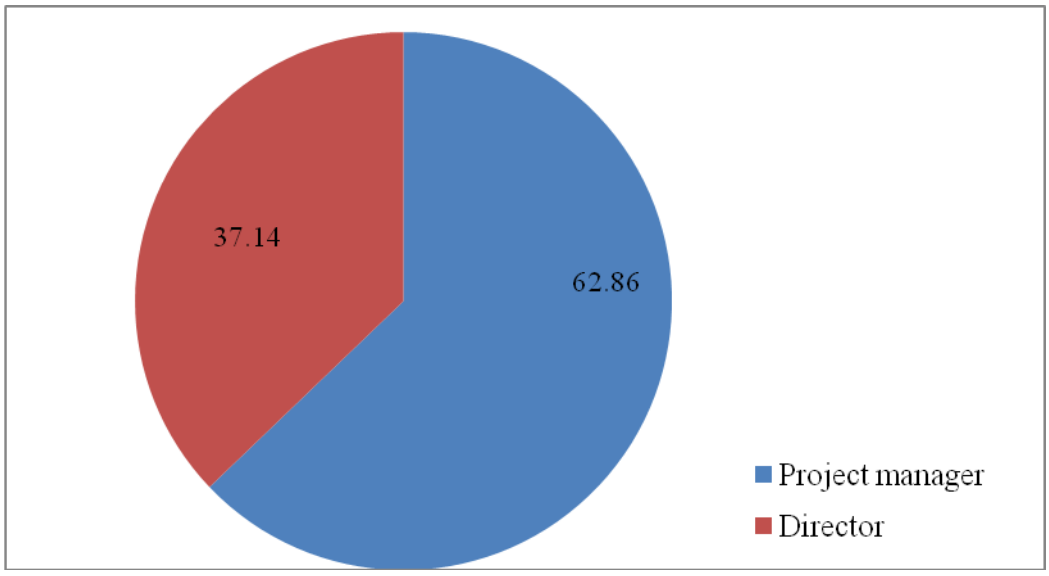

Figure 4.1 Position of respondent in main contractor company (N=35)

4.1.2 Working Experience of respondent

Experience is one of the important factors that have influenced main contractors' perception on selecting subcontractor relationship. Usually personal experiences are obtained by understanding from the past performance with subcontractor works. So main contractors have come across with many types of subcontractor in construction field and understood about their behaviors which are suitable for performing the construction work. With a clear understanding of subcontractor, main contractors have determined the types of relationship development with subcontractor and this experience is classified into three groups. The analysis result shows in Table 4.2 and Figure 4.2.

Respondents who are decision maker on selecting subcontractor relationship are categorized into three groups of experience. Regarding to the result, 8.57% of respondents who have experience in work less than 5 years, 42.86% of respondents who have experience in work around 5-10 years whereas 48.57% of respondents who have experience in work more than 10 years. In general, the experience of respondent presents the period that main contractors have been working with subcontractor in building construction.

Table 4.2 Experience of main contractor working with subcontractor

Experience of subcontractor relationship	Number of respondent	Percentage	Cumulative Percentage
Less than 5 years	3	8.57	8.57
From 5 to 10 years	15	42.86	51.43
More than 10 years	17	48.57	100
Total	35	100	

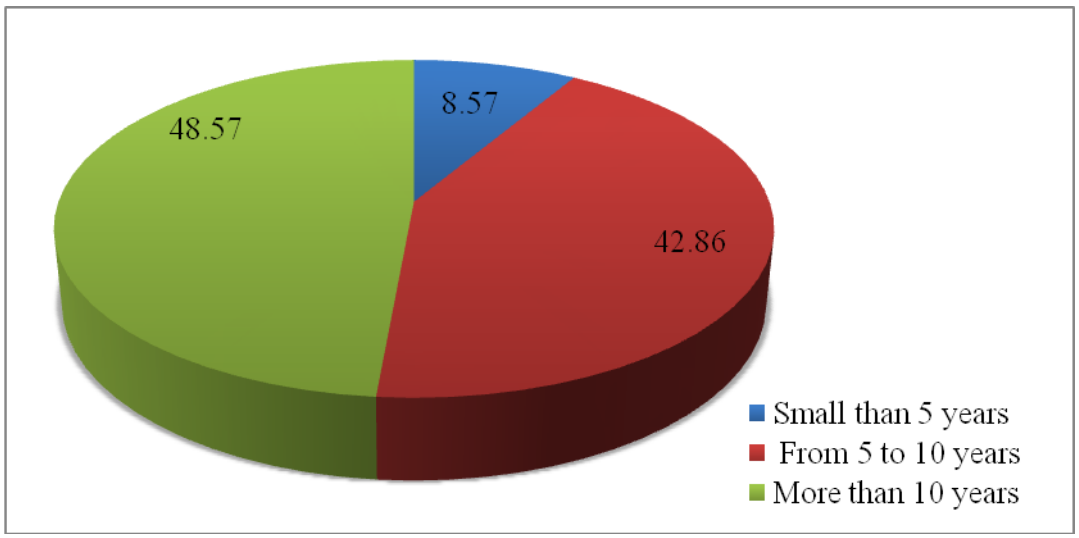

Figure 4.2 Experience of main contractor working with subcontractor (N=35)

4.2 Current practice of selecting subcontractor relationship

4.2.1 Nature of using subcontractor

Most of main contractor companies agreed that they have been experienced by working with subcontractor as a partner. There are three cases of using subcontractor that main-contractors have been experienced in construction project namely using only labor subcontractor, using labor and material subcontractor and employing both types of them. First, some main contractors preferred to work with subcontractor who has only labor because their companies possess of some equipments to handle the construction work already. Next, the other main contractors used subcontractor who has both labor and material because if it has any problems in construction work, they could contact only that subcontractor for solving the problem and main contractor could share some parts of the work responsibility too. Last, with the condition of work and size of construction project, main contractor may have to consider using both conditions of subcontractor. Result from the analysis shows in Table 4.3 and Figure 4.3.

Respondents who have participated in this research have shared the idea of using subcontractor in different cases. From the result, 42.86% of respondents have been using only labor subcontractor to work with main contractor. In addition, 57.14% of main contractors have experienced working with both types of subcontractor such as only labor subcontractor and labor and material subcontractor. Therefore, main contractor has used both types of subcontractor to adjust with the working condition and time and improve the construction work.

Table 4.3 Different cases of using subcontractor

Types of subcontractor	Number of respondent	Percentage	Cumulative Percentage
Only labor subcontractor	15	42.86	42.86
Labor and material subcontractor	0	0.00	42.86
Both types above	20	57.14	100.00
Total	35	100.00	

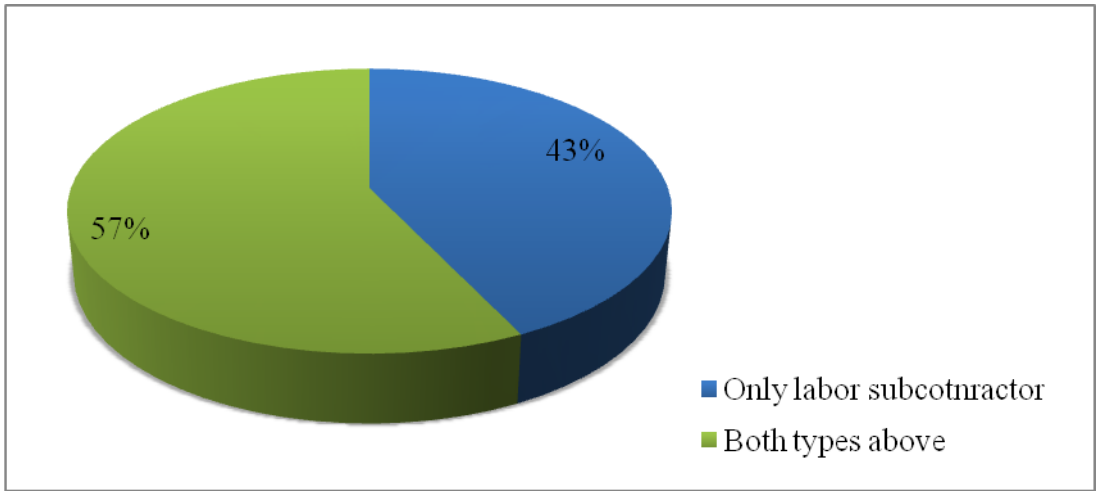

Figure 4.3 Different cases of using subcontractor

4.2.2 Percentages of using subcontractor relationship

Subcontractor relationship is one of critical factors that respondents have come across in construction work. Usually there are two types of subcontractor relationship that main contractors have used in decision making namely long-term relationship and

short-term relationship. The meaning of these subcontractors relationship has been explained as in chapter 2. In this research, respondents are required to tell about their working experiences on using subcontractor relationship. The analysis result is shown in Figure 4.4 and Table 4.4.

The result shows that 2.86% of the respondents have experienced in using short-term relationship with subcontractor in their works. Moreover, 5.71 % of respondents have practiced long-term relationship with subcontractor whereas 91.43 % of main contractors have used short and long-term relationship together.

Table 4.4 Different types of subcontractor relationship

Types of subcontractor relationship	Frequency	Percentage	Cumulative Percentage
Short-term relationship	1	2.86	2.86
Long-term relationship	2	5.71	8.57
Both types	32	91.43	100.00
Total	35	100.00	

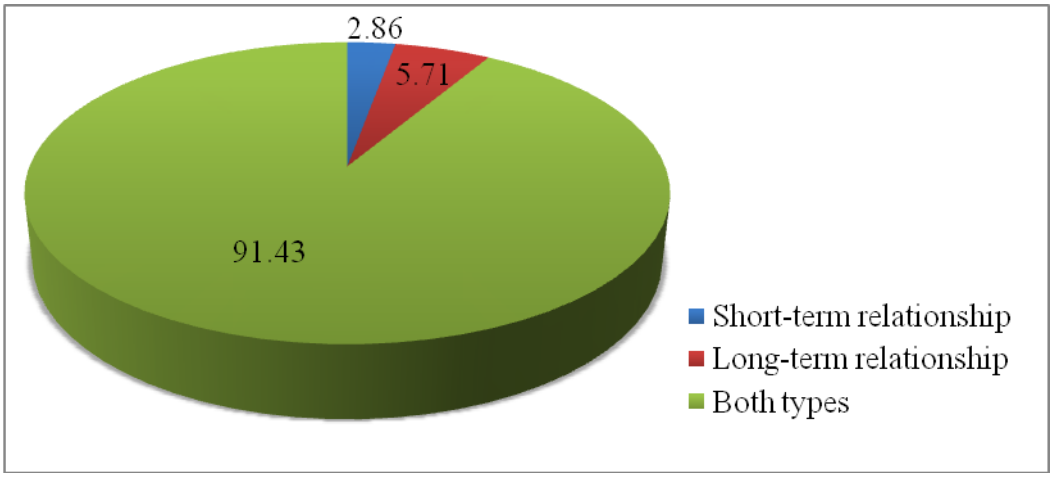

Table 4.4 Different types of subcontractor relationship

4.2.3 Main contractor perception on selecting subcontractor relationship

There are some reasons that main contractors have experienced on selecting subcontractor relationship. First, most of respondents have agreed that their companies created subcontractor relationship because they would like to ensure the quality of productivity and make sure that construction project completed on time. Moreover, respondent like $C_{2,3,4,8,11}$ have said that they developed subcontractor relationship because the work requirement is required resources more than their company abilities. So they are lack of man power or skill to handle in the construction work. In addition, labors in Cambodia are not skillful and some of them usually come to work in the city only after farming season. This is a problem to maintain the labor force in construction project and main contractor seeking other man powers to fulfill the position. On the other hand, one of respondents like C_9 is interested to explain more detail of his company practice developing subcontractor relationship. First, he described that the development of long-term relationship aims to control the company budget and he also known subcontractor clearly so if the problem has occurred in the construction project, he can only contact with subcontractor to solve the problem faster and easier. In contrast, the short-term relationship is happened because his company is lack of experience in doing some types of work and to fulfill the progressive of work while more workers are required.

Most of respondents have the same trend of selecting subcontractor relationship by using their experience in construction work. They said that working experience has given them the perception of understanding about the work and also connecting with the other subcontractors who have worked with them. Moreover, usually main contractors have met some problems in the project implementation. For example, if main contractors have many projects, they will try to find some more subcontractors for starting the construction project. In this case, it is an urgent situation and they may trust their connection. However, this situation could sometimes cause to select the wrong subcontractor. Moreover, other respondents have mentioned about some problems of selecting wrong subcontractor in long-term

relationship such as insufficient equipment, skilled workers, rework for improper productivity, misunderstanding each other and facing with owner dissatisfaction. Therefore, determination of subcontractor selection for relationship development whether short or long-term relationship is still a problem in main contractor decision making.

4.2.4 Types of work that using subcontractor and subcontractor relationship

In building construction, there are many types of construction work that main contactors have used with different types of subcontractors and relationship. As the research focuses on building construction, it has divided into four sections such as earth works, structural works, finishing works and miscellaneous works. Each section is categorized into subsection. Moreover, the result is divided into two parts separately. First, it shows about the percentage of different types of work that main contractors have given contract to different cases of using subcontractor. Then another result tells about the percentage of different types of work that main contractors have used within different types of subcontractor relationship. The analysis result is shown in the following section.

4.2.4.1 Different types of subcontractor work

With the different types of subcontractor, main contractors have used them to apply with different types of work in construction project. So it means that main contractors have used each type of construction work with one of subcontractor types whether only labor subcontractor or labor and material subcontractor or both types. The analysis result shows in Table 4.5, Table 4.6 and Table 4.7.

Three categories of subcontractor types were studied and respondents were asked to answer in each group. From the result, it focuses on different types of work that main contractors have used with only labor subcontractor. 80-90% of works such as concrete work, formwork work, reinforcing bar work and brick work of structural

section are used by only labor subcontractor, 60-80% of concrete work, masonry work, floor finishing work, and color paint work are used by only labor subcontractor, 50-60% of toilet partition work is used by only labor subcontractor, 40-50% of gypsum board work, ceiling work, steel structure work are used by only labor subcontractor, 30-40% of Gravel compaction, excavation work, polyethylene sheet, electrical work and plumbing work are used by only labor subcontractor, 20-30% of backfill work, lean concrete work, hand rail work and insect work are used by only labor subcontractor, 10-20% of soil treatment work (anti termite), door and window works are used by only labor subcontractor. Therefore, we could define the important works that main contractors have used with only labor subcontractor.

Table 4.5 Using different types of work with only labor subcontractor

Section	Subcontractor	Frequency	Percentage
I	**Earth Works**		
1	Excavation	14.00	40.00
2	Backfill	10.00	28.57
3	Gravel Compaction	11.00	31.43
4	Lean Concrete	10.00	28.57
5	Polyethylene Sheet	11.00	31.43
6	Soil Treatment (Anti Termite)	5.00	14.29
II	**Structural Works**		
1	Concrete	28.00	80.00
2	Formwork	31.00	88.57
3	Reinforcing Bar	31.00	88.57
4	Brick	30.00	85.71
5	Steel Structure	16.00	45.71
III	**Finishing Works**		
1	Masonry work	26.00	74.29
2	Floor Finishing	24.00	68.57
3	Gypsum Board	14.00	40.00
4	Ceiling	16.00	45.71
5	Color Paint	26.00	74.29
IV	**Miscellaneous Works**		
1	Hand rail	10.00	28.57
2	Insect net	8.00	22.86
3	Door and Window	4.00	11.43

Section	Subcontractor	Frequency	Percentage
4	Toilet Partition	19.00	54.29
5	Electrical work	14.00	40.00
6	Plumbing work	11.00	31.43
Total respondents		35	

Second, the result shows the different types of work that main contactors have used with labor and material subcontractor. 40-60% of plumbing work, door and window work, insect net work, floor finishing work, gypsum board work, ceiling work are used by labor and material subcontractor, 30-40% of soil treatment work (anti termite), steel structure work and hand rail work are used by labor and material subcontractor, 10-20% of brick work, color paint work, backfill work, polyethylene sheet work, and excavation work are used by labor and material subcontractor, 0-10% of gravel compaction work, lean concrete work, concrete work, formwork, reinforcing bar work, masonry work, and toilet partition are used by labor and material subcontractor. Thus, we could see the part of works that is mostly used by labor and material subcontractor in construction project.

Table 4.6 Using different type of work with labor and material subcontractor

Section	Subcontractor	Frequency	Percentage
I	**Earth Works**		
1	Excavation	4.00	11.43
2	Backfill	5.00	14.29
3	Gravel Compaction	2.00	5.71
4	Lean Concrete	2.00	5.71
5	Polyethylene Sheet	5.00	14.29
6	Soil Treatment (Anti Termite)	14.00	40.00
II	**Structural Works**		
1	Concrete	2.00	5.71
2	Formwork	1.00	2.86
3	Reinforcing Bar	1.00	2.86
4	Brick	4.00	11.43
5	Steel Structure	12.00	34.29
III	**Finishing Works**		
1	Masonry work	2.00	5.71

Section	Subcontractor	Frequency	Percentage
2	Floor Finishing	16.00	45.71
3	Gypsum Board	16.00	45.71
4	Ceiling	15.00	42.86
5	Color Paint	5.00	14.29
IV	**Miscellaneous Works**		
1	Hand rail	13.00	37.14
2	Insect net	16.00	45.71
3	Door and Window	21.00	60.00
4	Toilet Partition	2.00	5.71
5	Electrical work	17.00	48.57
6	Plumbing work	19.00	54.29
Total respondents		35	

Third, there is not much type of works that was used into both cases like only labor subcontractor and labor and material subcontractor. First, around 22% of door and window work that used both types of subcontractor, then 5.71% of masonry work is used of both types of subcontractor, 2.86% of lean concrete work, steel structure work, gypsum board work, and ceiling work are used of both types of subcontractor.

Table 4.7 Using difference types of work with only labor subcontractor and labor and material subcontractor

Section	Subcontractor	Frequency	Percentage
I	**Earth Works**		
1	Excavation	0.00	0.00
2	Backfill	0.00	0.00
3	Gravel Compaction	0.00	0.00
4	Lean Concrete	1.00	2.86
5	Polyethylene Sheet	0.00	0.00
6	Soil Treatment (Anti Termite)	0.00	0.00
II	**Structural Works**		
1	Concrete	0.00	0.00
2	Formwork	0.00	0.00
3	Reinforcing Bar	0.00	0.00
4	Brick	0.00	0.00
5	Steel Structure	1.00	2.86

Section	Subcontractor	Frequency	Percentage
III	**Finishing Works**		
1	Masonry work	2.00	5.71
2	Floor Finishing	0.00	0.00
3	Gypsum Board	1.00	2.86
4	Ceiling	1.00	2.86
5	Color Paint	0.00	0.00
IV	**Miscellaneous Works**		
1	Hand rail	0.00	0.00
2	Insect net	0.00	0.00
3	Door and Window	8.00	22.86
4	Toilet Partition	0.00	0.00
5	Electrical work	0.00	0.00
6	Plumbing work	0.00	0.00
Total respondents		35	

4.2.4.2 Different types of subcontractor relationship

There are three groups of subcontractor relationships such as long-term relationship, short-term relationship and both relationship that main contractors have used with difference types of construction work. This result shows in the following Table 4.8, 4.9, 4.10.

First, short-term relationship is one of subcontractor relationship that main contractors have used with different types of construction work. From the result, 50-60% of insect net and toilet partition works are used in short-term relationship, 30-45% of excavation work, backfill work, polyethylene sheet, gravel compaction work, soil treatment work (anti termite) and hand rail work are used in short-term relationship, 20-30% of lean concrete work, gypsum board work, ceiling work, color paint work and door and window work are used in short-term relationship, 10-20% of masonry work, floor finishing work, brick work are used in short-term relationship, 0-10% of concrete work, formwork, reinforcing bar work, steel structure work, electrical and plumbing works are used in short-term relationship with subcontractor in construction project.

Second, long-term relationship is used by main contractor with different type of construction work. The result shows that 60-80% of concrete work, formwork reinforcing bar work, brick work, steel structure work, electrical and plumbing works are used by long-term relationship subcontractor, 40-50% of floor finishing, gypsum board and ceiling works are used by long-term relationship subcontractor, 30-40% of masonry work and color paint work are used by long-term relationship subcontractor , 20-30% of hand rail work, insect net, door and window and are used by long-term relationship subcontractor, 10-20% of soil treatment work (anti termite), work, and toilet partition are used by long-term relationship subcontractor, 0-10% of excavation work, backfill work, gravel compaction work, lean concrete and polyethylene sheet work are used by long-term relationship subcontractor.

Third, sometimes main contractors selected short and long-term relationship with subcontractor. The result shows 20-30% of floor finishing work, masonry work, painting work, and door and window installation work are only used both types of subcontractor relationship whereas 10-20% of gypsum board work, ceiling work, and hand rail work are used with short and long-term relationship, 0-10% of excavation work, backfill work, gravel compaction work, lean concrete work, polyethylene sheet work, soil treatment work (anti termite), concrete work, formwork, reinforcing bar work, brick work, steel structure work, , electrical and plumbing works are used with short and long-term relationship.

Table 4.8 Using different types of work with short-term relationship

Section	Subcontractor	Frequency	Percentage
I	**Earth Works**		
1	Excavation	15.00	42.86
2	Backfill	13.00	37.14
3	Gravel Compaction	11.00	31.43
4	Lean Concrete	9.00	25.71
5	Polyethylene Sheet	12.00	34.29
6	Soil Treatment (Anti Termite)	11.00	31.43
II	**Structural Works**		
1	Concrete	2.00	5.71

Section	Subcontractor	Frequency	Percentage
2	Formwork	2.00	5.71
3	Reinforcing Bar	2.00	5.71
4	Brick	4.00	11.43
5	Steel Structure	1.00	2.86
III	**Finishing Works**		
1	Masonry work	6.00	17.14
2	Floor Finishing	6.00	17.14
3	Gypsum Board	9.00	25.71
4	Ceiling	8.00	22.86
5	Color Paint	9.00	25.71
IV	**Miscellaneous Works**		
1	Hand rail	14.00	40.00
2	Insect net	19.00	54.29
3	Door and Window	10.00	28.57
4	Toilet Partition	19.00	54.29
5	Electrical work	3.00	8.57
6	Plumbing work	3.00	8.57
Total respondents		35	

Table 4.9 Using different types of work with long-term relationship

Section	Subcontractor	Frequency	Percentage
I	**Earth Works**		
1	Excavation	2.00	5.71
2	Backfill	2.00	5.71
3	Gravel Compaction	2.00	5.71
4	Lean Concrete	3.00	8.57
5	Polyethylene Sheet	2.00	5.71
6	Soil Treatment (Anti Termite)	6.00	17.14
II	**Structural Works**		
1	Concrete	29.00	82.86
2	Formwork	28.00	80.00
3	Reinforcing Bar	29.00	82.86
4	Brick	26.00	74.29
5	Steel Structure	29.00	82.86
III	**Finishing Works**		
1	Masonry work	12.00	34.29
2	Floor Finishing	15.00	42.86

Section	Subcontractor	Frequency	Percentage
3	Gypsum Board	14.00	40.00
4	Ceiling	15.00	42.86
5	Color Paint	12.00	34.29
IV	**Miscellaneous Works**		
1	Hand rail	8.00	22.86
2	Insect net	8.00	22.86
3	Door and Window	9.00	25.71
4	Toilet Partition	6.00	17.14
5	Electrical work	23.00	65.71
6	Plumbing work	23.00	65.71
Total respondents		35	

Table 4.10 Using different types of work with short and long-term relationship

Section	Subcontractor	Frequency	Percentage
I	**Earth Works**		
1	Excavation	2.00	5.71
2	Backfill	1.00	2.86
3	Gravel Compaction	1.00	2.86
4	Lean Concrete	2.00	5.71
5	Polyethylene Sheet	1.00	2.86
6	Soil Treatment (Anti Termite)	3.00	8.57
II	**Structural Works**		
1	Concrete		0.00
2	Formwork	1.00	2.86
3	Reinforcing Bar		0.00
4	Brick	3.00	8.57
5	Steel Structure		0.00
III	**Finishing Works**		
1	Masonry work	10.00	28.57
2	Floor Finishing	8.00	22.86
3	Gypsum Board	6.00	17.14
4	Ceiling	6.00	17.14
5	Color Paint	8.00	22.86
IV	**Miscellaneous Works**		
1	Hand rail	4.00	11.43
2	Insect net		0.00
3	Door and Window	8.00	22.86

Section	Subcontractor	Frequency	Percentage
4	Toilet Partition	0.00	0.00
5	Electrical work	1.00	2.86
6	Plumbing work	1.00	2.86
Total respondents		35	

4.3 Discussion result of important subcontractor relationship factors

4.3.1 Reliability of scale

Respondents were asked about their perception in decision making of important level on each factor when they would like to develop the relationship with subcontractor as a partner for a long-term. Each factor was developed based on subcontractor performance and relationship. When each factor uses with scale (likert scale), Cronbach's alpha method calculates the internal consistency for each scale. The result has shown the value of Cronbach's alpha is 0.701 which is still equal the acceptable value of 0.70. So the scale is considered to be reliability. Moreover, from Table 4.11 that shown the value of Alpha if item deleted, it was understood that these 22 factors could represent for main contractor opinion were valid and not remove from the study. Last, all of these 22 factors provided the most reliability scale for measuring main contractor perception on important level of subcontractor relationship.

Table 4.11 Cronbach's Alpha for main contractor scale (N=35)

Cronbach's Alpha=0.701 N of Items=22	Cronbach's Alpha if Item Deleted
Trust	.736
Honesty	.697
Commitment	.697
Work experience	.713
Flexibility to change	.691
Clear understanding	.677
Innovation	.699
Communication	.665

Cronbach's Alpha=0.701 N of Items=22	Cronbach's Alpha if Item Deleted
Coordination	.691
Joint problem solving	.676
Cooperation	.688
Monitoring	.692
Time control in planning	.683
Safety training for employees	.666
Work quality	.704
Safety control system	.664
Wastage disposal control	.675
Employee skill training	.656
Financial Status	.706
Price adjustment	.741
Resources	.681
Knowledge	.688

4.3.2 Result of mean and standard deviation

After having a deeply interview with 35 respondents both project managers and directors of main contractors companies, the data is analyzed to determine mean and standard deviation of factors using to select short or long-term relationship. The result could identify 10 important factors are greater than the average mean value (mean=4.010). Moreover, the CV value of all factors is closer to 0, so it means that the respondent answers are uniformity. From Table 4.12, subcontractor relationship factors were ranked in the descending order of mean scores including (1) time control in planning (mean=4.514), (2) work quality (mean=4.457), (3) cooperation (mean=4.257), (4) experience (mean=4.171), (5) resources (mean=4.143), (6) honesty (mean=4.114), (7) commitment (mean=4.114), (8) monitoring (mean=4.114), (9) trust (mean=4.057) and (10) coordination (mean=4.029). Therefore, these factors are important in decision making of main contractor on selecting subcontractor relationship and are described in the next section.

Table 4.12 Result of mean and standard deviation of subcontractor relationship factor

Factor	Mean	Standard deviation	SD/M	Rank
Time control in planning	4.514	0.612	0.136	1
Work quality	4.457	0.561	0.126	2
Cooperation	4.257	0.561	0.132	3
Work experience	4.171	0.747	0.179	4
Resources	4.143	0.601	0.145	5
Honesty	4.114	0.530	0.129	6
Commitment	4.114	0.530	0.129	7
Monitoring	4.114	0.471	0.114	8
Trust	4.057	0.725	0.179	9
Coordination	4.029	0.618	0.153	10
Clear understanding	4.000	0.542	0.136	11
Joint problem solving	3.971	0.664	0.167	12
Innovation	3.943	0.591	0.150	13
Communication	3.943	0.639	0.162	14
Price adjustment	3.943	0.639	0.162	15
Flexibility to change	3.914	0.612	0.156	16
Safety training for employees	3.914	0.853	0.218	17
Employee skill training	3.914	0.562	0.144	18
Safety control system	3.771	0.690	0.183	19
Knowledge	3.714	0.572	0.154	20
Wastage disposal control	3.657	0.639	0.175	21
Financial Status	3.571	0.778	0.218	22
Average	4.01039			

4.3.3 Result of independent samples t-test analysis

The research also aims to determine whether the opinion of project managers and directors on the important factors of subcontractor relationship are the different or not. This analysis used independent samples t-test and the result was shown by the Appendix D.

In Table D.2 of appendix D, we begin to see the table of Levene's Test for Equality of Variances and the significant value of many factors were greater than 0.05 including honesty (Sig = 0.416), commitment (Sig = 0.122), experience (Sig = 0.703),

flexibility to change (Sig = 0.07), clear understanding (Sig = 0.276), coordination (Sig = 0.271), joint problem solving (Sig = 739), cooperation (Sig = 0.303), monitoring (Sig = 0.08), time control in planning (Sig = 0.794), safety training for employees (Sig = 0.162), work quality (Sig = 0.499), wastage disposal control (Sig = 0.591), employee skill training (Sig = 0.572), financial status (Sig = 0.056), price adjustment (Sig = 0.181), resources (Sig = 0.888), and knowledge (Sig = 0.493). So it means that equal variance assumption is not violated. Next, in the column of t-test for Equality of Means, we get the value in the first row of sig (2- tailed) , the result showed that all the factors value are greater than 0.05, so we can conclude that both two groups opinions are the same.

On the other hand, when the value of significance in Levene's Test is less than 0.05 like trust (Sig = 0.002), innovation (Sig = 0.03), communication (Sig = 0.026), and safety control system (Sig = 0.015), it means the assumption of equal variance is violated. Then we could understand the value of t-test result by the second row of sig (2- tailed). The result of these factors were larger than 0.05, so we can conclude that both two groups opinions are also the same.

4.3.4. Respondent perception of important factors on selecting subcontractor relationship

4.3.4.1 Time control in planning

With an overall mean of 4.514, time control in planning is the most essential factor on selecting subcontractor relationship with subcontractor. Most of main contractors consider timing as money, so they concern with the time management in the project after given the work to subcontractor. Moreover, as time planning is one of key factors in construction management for main contractor company, many respondents would be willing to work with subcontractor who could finish the work on time. Most main contractors mentioned that if subcontractor has a poor time planning in construction work, it will cost them severely because they will be fined by

owner and also need to spend more budgets on the unfinished work. Therefore, main contractor would like see any subcontractors who have an effective time planning and could finish the given work fast with the quality standard too.

4.3.4.2 Work quality

Work quality, an overall mean is 4.457, is an important factor in main contractor decision for selecting subcontractor relationship. This factor is found in second rank and has given significant consideration for main contractor. Moreover, the most of respondents were agree that if subcontractor could not produce a high or acceptable quality of work, they will consider to give the work for subcontractor in the next project or not. Thus, main contractor also needs to check the quality of subcontractor work which has to match with the standard requirement. From the result, some of respondents especially project manager have placed this factor as the most important factor for selecting subcontractor relationship because it will reflect their achievement of work for the company and they are afraid that if project owner does not satisfy with their work, it will affect their reputation in the company. In addition, the company also loses the reputation in the competitive market. So they would like to select the subcontractor who has a good working performance in construction. Last, this factor is not only satisfying the main contractor but also fulfill the client need as mentioned in the contract.

4.3.4.3 Cooperation

Cooperation is listed in the third rank and has overall mean of 4.257. Many respondents have agreed that this factor is important on selecting subcontractor relationship. Eighty percentages of respondents require subcontractor who is willing to join or participate in the work requirement. Respondent C_9 has shared his experience on this factor with subcontractor in the past. He was working in one project with a business man as a project owner. Main contractor was really hard to fulfill owner requirement. After owner saw the progress of work, he always insists to

see the result of finishing some parts of works in the project like structural and floor fishing works. During that time, he could understand his subcontractor well by seeing their cooperation in the work like adding some more workers and working overtime without complaint. So from his opinion, this cooperation factor would influence to his perception on selecting a subcontractor for long-term partner. Other respondents like C_{14} and C_{22} mentioned cooperative work of subcontractors in construction will bond the relationship and it also illustrates the characteristic of subcontractor with them whether those subcontractors are reliable or not. Therefore, subcontractor who tries to participate and help main contractor as the cooperation for finishing the project successfully will be noticed in the future.

4.3.4.4 Work Experience

Work experience has an overall mean of 4.171 and was ranked at fourth among other factors for selecting subcontractor relationship. Many respondents prefer the subcontractor who has many years of experience in construction work because they believed that subcontractor will bring them with a good productivity. With high experience, main contractor also think that the subcontractor may have a better skill and come across in many situations in the construction project. For example, respondent C_{35} and C_{28} mentioned quite similar with other main contactor opinions that usually a high experience subcontractor in working requirement could provide a good quality of finishing work better than the less experience one. Therefore, the experience factor has important role in main contractor consideration for given the work or contract to subcontractor because main contractor will not worry about the work like working with the fresh working subcontractor. In addition, they will not be headache because the experience subcontractor usually has created few problems in the work whereas the one who is lack of experience will be difficult to work together and produce many problems. In addition, respondent C_{14} and C_{16} mentioned that some experience subcontractors could give a better suggestion for problem solving in construction project sometimes.

4.3.4.5 Resources

Resources have an overall mean of 4.143 and are ranked at fifth among important factors. Many main contractors have considered this factor as essential point for avoiding future problem. For example, many main contractors would like to know about subcontractor resources including quantity of workers, quantity of small or big equipments, and projects that subcontractor is handling. Moreover, some respondents like C_6, C_9, C_{16} and C_{24} were interested to understand whether the subcontractor has many projects while working them or not. The purpose of wondering is to prevent the lack of resources especially workers to carry out the construction work, it will prolong the project progress and impact the other activities. Therefore, subcontractor who equips with enough resources will also build a confident for main contractor and create less concern about the resources problem in the progressive work of construction project.

4.3.4.6 Honesty

Honesty is ranked as sixth important factors with an overall mean of 4.114. This factor is still an important factor for selecting subcontractor relationship in main contractor decision. Many main contractors wants subcontractor to say about the true thing in construction work especially if it has a problem in construction work. For example, if one action is delay, the reason is either money or man power problem. So this factor is really important that main contractors would like to get among other subcontractors. Moreover, some main contractors mentioned the need of having an honest subcontractor, they perceived less headache in controlling the work especially about cheating issue like work quality, material quantity and so on. So main contractor would like to have a good subcontractor who does not cheat, lie and corrupt with main-contractors.

4.3.4.7 Commitment

With an overall mean of 4.114, commitment is ranked at seventh among factor explored on selecting subcontractor relationship. Moreover, one of respondent (C_{14}) prefers to explain about this factor clear that first he would like to see the result of subcontractor work in the project whether it is acceptable or not, If subcontractors are work hard, they could still not produce the satisfied work for the client or reach the standard requirement, his company is willing to help for accomplishing the work successfully at last. In his perception, he would like the subcontractor who commits to work hard in the project and not leave their responsibility to main contractor. On the other hand, some main contractors expect to get a subcontractor who could understand about main contractor situation and could help them to finish the work on time in any circumstance, they still think that if subcontractors do not commit to finish the work before deadline of the project, they also receive the bad perception for their companies. So it is not only the factor that main contractors but also subcontractor who have to concern when they were working together. Finally, one of the respondents (C_{19}) mentioned that subcontractor who is work hard and careful in construction work would give main contractor a good productivity. Therefore, the commitment of work that subcontractor is carrying will make main contractor a feeling that the project will be completed on time.

4.3.4.8 Monitoring

With an overall mean of 4.114, monitoring ranks eighth among twenty two factors. This factor is one of important factors in main contractor decision making on selecting subcontractor relationship. This factors has attracted main contractor perception by considering on subcontractor could handle the work effectively and finish on time. Moreover, some respondents (C_6, C_{34}, C_{32} and C_{21}) have evaluated subcontractor on this monitoring factor too because their objective is to find a capable subcontractor who could control and manage the progressive work in construction everyday and contact with main contactor if it has any problems. In addition, two

respondents (C_7 and C_{14}) have mentioned that a project success must be monitored the progressing of work all the time, so if subcontractor has monitored the subcontracted work effectively, they will become one of partner for the future project.

4.3.4.9 Trust

With an overall mean of 4.057, trust ranks ninth among factor explored and this factor is an important factor for selecting short or long-term relationship in main-contractor decision. Main contractor would look to find a subcontractor who is a trusted person for giving the work and become a good partner in the future. Moreover, main contractor would see the trusted person after they have worked with subcontractor for many projects already. However, some of them still have mentioned that they could not trust those subcontractors for 100 percents because they are afraid that subcontractor will sometimes run away from them and cause more troubles in construction with this subcontractor irresponsibility. So they still need to take some parts of subcontracted work for considering especially related to budget controlling. In addition, a few of respondents (C_4 and C_{14}) has said that this factor should consider as in the middle level because although main-contractors would like to have a trusted subcontractor, they are also one of factors that could change the subcontractor to become a trusted person. For example, in term of payment for subcontractor, if main contractor are late, subcontractor may not happy to work with us any more because they need money to give their labors and other issues in their companies. So this trust factor is caused by main-contract behavior toward subcontractor too.

4.3.5.10 Coordination

Coordination is ranked as tenth factor with an overall mean of 4.029. This factor is the last most important factors that influence main contractor decision for selecting subcontractor relationship with subcontractor. This factor is needed by main contractors like C_{21}, C_{27} and C_{34} to reduce their working pressure and problem by subcontractor ability in managing work and time requirement on time, so main

contractor do not have to deal with all the issues by themselves every time. Moreover, one respondent C_1 has explained about his opinion in this factor that subcontractor should be able to coordinate the given work effectively especially when problem is occurred. If the problem of subcontractors is small, it should be solved by subcontractors whereas main contractors will solve large problem. Therefore, if subcontractors could coordinate the work well by managing the progressive work smoothly and has solved some problems in the construction work for main contractor, they will likely to be selected as a partner in the next project.

4.4 Summary

This chapter mainly focuses on determining the important factors on selecting subcontractor relationship by main contractor opinion. To illustrate about these important factors, this research has reached the persons who have the responsibility in subcontractor selection such as project manager or director from main contractor companies. Moreover, the interview session has conducted carefully by asking the respondents with the design questionnaire before. Then, the result has discovered top ten important factors that are important in main contractor decision as shown in above section. Finally, these important factors will be used to develop a model for categorizing subcontractor in short or long-term relationship.

CHAPTER V

MODEL DEVELOPMENT FOR SELECTING SUBCONTRACTOR RELATIONSHIP

This chapter objectively establishes a decision making model for helping main contractor on selecting subcontractor relationship. The process of model establishment is accomplished by many steps as mentioned in chapter 3 already. There are two methods that can be applied to develop a model for selecting subcontractor relationship. These two methods are discriminant analysis and artificial neural network (ANN). The model is based on the important factors from main contractor opinion which was determined in chapter 4. The survey questionnaire in this stage was designed to assess the current practice of subcontractor and the current type of subcontract too. Moreover, data for developing model were gathered from questionnaire with 11 project managers and 4 directors. They evaluate on the current practice of 93 subcontractors and also their current relationship with subcontractors. The result of this chapter is divided into 3 main parts namely data description, data screening (Independent t-test) and model development. First, the paper will begin with the data description which is included types of subcontracted work that main contractors are using in current construction project. In addition, the analysis describes types and number of samples in the model. Then section 5.2 will test the differences of 10 important factors by using independent samples t-test. Last, to develop a decision making model, Artificial Neural Network (ANN) is determined by using a computer program called Qnet 2000 for calculating back-propagation algorithm. After that we use sensitivity analysis with neural network to determine the influencing factors of subcontractor relationship in current practice by main contractor evaluation. Moreover, to choose the optimal method, we have selected another method called discriminant analysis which compares with the level of accuracy with neural network. Last, some discussions are made by the result of both methods.

5.1 Data description for developing model

The description of data in this model attempts to explain about the information of sample in the model. First, it describes about the types of sub-work in construction project currently. Then, the types and number of subcontractors that are evaluated by main contractor are described for a better understanding of data before analysis. Last, each part of data description will described in the following section.

5.1.1 Types of subcontracted work in construction project

As the scope of this study focuses on building construction project and many different types of subcontracted works have been used by main contractor around the capital city. This finding will help us to perceive the types of work that main contractor are using in construction project nowadays. After data collection of 15 main contractors, we could get 93 subcontractors who have been evaluated. Based on main contractor evaluation, we could see that 16.92% of finishing work was contracted with subcontractors. In structural work, main contractors have contracted with subcontractors around 12.31%. Therefore, this finding shows that the subcontractors, who are specialist in structural works such as concrete work, rebar work, masonry work, and brick work whereas in finishing works including color painting work, plumbing and electrical work, air condition work and ceiling work were popular to get the contract with main contractor. Thus, those subcontractors should strengthen their skills to compete with other subcontractors too.

Table 5.1 Percentage of each subcontracted work

N	Subcontracted work	Frequency	Percentage
	Structure work	16	12.31
1	Concrete work	16	12.31
2	Rebar work	9	6.92
3	Masonry work	9	6.92
4	Brick work	8	6.15
5	Formwork	3	2.31

N	Subcontracted work	Frequency	Percentage
6	Steel frame work	3	2.31
	Finishing work	22	16.92
1	Plumbing and electrical work	8	6.15
2	Color painting work	8	6.15
2	Air condition work	7	5.38
3	ceiling work	7	5.38
4	Mirror work	4	3.08
5	Flooring work	4	3.08
6	Door and window work	4	3.08
7	hand rail work	1	0.77
8	Furniture and décor work	1	0.77

5.1.2 Types of subcontractor in model

The types of samples aim to describe the information of subcontractors who are used for developing the model. Based on Cambodia construction project, it is noticed that there are two types of subcontractor namely a group of workers and a construction company. First, they are a group of workers who have been working with main contractors and they also have some skills in construction work. Moreover, those people do not have a specific company and they work for main contractor by subcontracting some parts of construction project with negotiation price. Second, subcontractor is a construction company who has been registered in Ministry of Commerce for running a business and the company also has clear regulation and policy of leadership. In addition, this subcontractor usually has more budget and specific location. So they could have a chance to become one of candidates of the bidding event. From the result, 33.33% of samples are belonging to a group of works whereas 66.67% of them are working with main contractor as construction companies. Moreover, this model will be developed by considering both groups have no difference for main-contractor. Therefore, this study could apply to select subcontractor who is either a group of works or a company for relationship development. Table 5.2 and Figure 5.1 show about types of subcontractor in the samples.

Table 5.2 Result of difference subcontractor groups

N	Type of subcontractor	Frequency	Percentage
1	A group of workers	31	33.33
2	Company	62	66.67
Total		93	

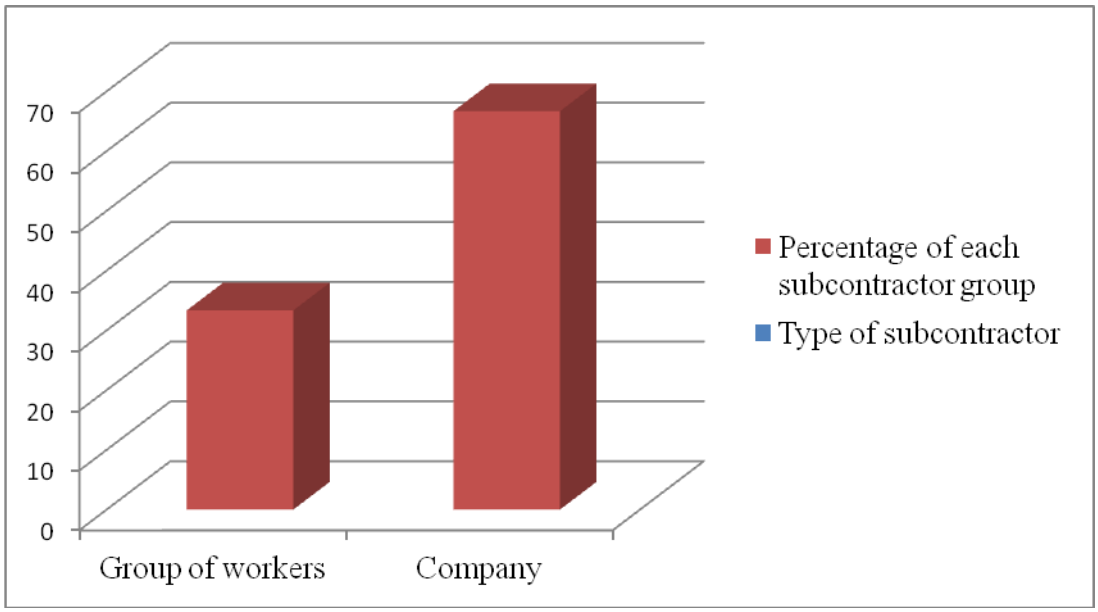

Figure 5.1 Percentage of difference subcontractor groups

5.1.3 Number of samples for developing model

The size of samples refers to the quantity of subcontractors who have been evaluated by main contractor. The evaluation is based on the important factors on selecting subcontractor relationship. Based on the result of data collection, we could get 93 evaluations of subcontractor. Although the sample size seems to be small, we also split these samples of 79, 9 and 5 into training, testing and verifying samples respectively. Therefore, the sample size in this study is used to develop a model on selecting subcontractor relationship by Artificial Neural Network (ANN).

5.2 Independent samples T-test

Before we could develop the model for selecting subcontractor relationship, we need to ensure the differences of data set by using independent samples t-test analysis. The analysis of this section is difference from the t-test analysis in chapter 4 because the data set of this analysis is gotten by main contractor opinion on evaluating subcontractor for relationship development currently and it uses to ensure each important actor is deference to specify the short or long-term relationship whereas the t-test analysis in chapter 4 was used to specify the difference of 22 factors which used to determine the important factors of subcontractor relationship based on main contractor and director perception and experience. Therefore, the t-test analysis in this chapter will ensure that these 10 important factors are not the same for using to develop a model on selecting the subcontractor relationship.

Based on the result of independent sample t-test in Appendix E, we could confirm about the difference of data set. First, from the table of Levene's Test for Equality of Variances, we could see the significant value of some factors were greater than 0.05 including work quality (Sig = 0.194), time control in planning (Sig = 0.271), experience (Sig = 0.108), cooperation (Sig = 0.623), honesty (Sig = 0.207), commitment (Sig = 0.540), resources (Sig = 0.352), monitoring (Sig = 0.871), trust (Sig = 0.529). So it means that assumption of equal variance is not violated. Next, we could understand the value of t-test result from the first row of sig (2- tailed) in the column of t-test for Equality of Means. The value of all the factors is less than 0.05, and it means that both two group opinions are significantly difference.

On the other hands, there is only coordination factor that has the significance value around 0.001 which is less than 0.05, so it has violated the assumption of equal variance. Then, we use the second row of sig (2-tailed) to check the result of t-test. Moreover, this factor still has the t-test value less than 0.05, so it means that both two group opinions are also significantly difference.

5.3 Model development for selecting subcontractor relationship

The model development is constructed by interviewing with main contractor companies and asked them to evaluate each of their own subcontractors on selecting short or long-term relationship. After the data collection, it is analyzed and validated by Artificial Neural Network (ANN) consequently. Moreover, we also use another method called discriminate analysis to compare the level of accuracy on model development. Therefore, the expected user of this model mainly refers to main contractor and other companies who would like to use this model for developing relationship with subcontractor in the future. Last, the following section will explain about the result of back-propagation algorithm that we got from the analysis of Qnet 2000 program.

Qnet 2000 is developed by Vesta service as a powerful tool for calculating the back-propagation algorithm. This program could be effectively applied to every complicated problem or lacking of modern statistical models. Moreover, this program has some key features that made it become easy to use in neural network. First, this program is easy to put the data into the training file by using DataPro. This DataPro is one of the options that uses ASCII file format with support for space, comma and tab delimited format. Next, we could select transfer functions from one layer to layer by characteristic of network. Usually, Auto train of this program is used by setting up a single runs and then it will optimize any number of models in a batch style in the automated mode. After training, we could see the information result by Netgraph. This Netgraph creates the graphs of all key networks and training information. Moreover, in this option, it also has AutoZoom that can be used to interrogate plotted information to any level of detail required. Last it is automatic save by storing the network model during training and protects us from overtraining too.

5.3.1 Architecture of Artificial Neural Network

To develop a decision model for selecting subcontractor relationship by using ANN, we have to construct its architecture carefully because it will affect the performance of model. This architecture is included by the nodes in each layer, the number of arcs and the number of layers like input, hidden and output, transfer functions of the hidden and output nodes, the training algorithm, the input data transformation or normalization method, number of samples in training and testing data sets, and the performance measure of accuracy between actual and predicted value. To achieve the objective of this study, we will begin by considering on the architecture of model. Moreover, as in chapter 3, we have described in detail about the architecture of this model, so now we will summary the components of the model briefly.

The elements of the model architecture are summarized such as:

- One input layer has 10 variables or10 input nodes
- One hidden layer has 10 variables or 10 hidden nodes
- One output layer has 1 variable or 1 output node
- There are 110 of connected arcs between input and hidden nodes and between hidden and output node
- The transfer function of output and hidden nodes is sigmoid function
- The training algorithm was applied by using back-propagation algorithm.
- The transformation of input data was calculated by linear transformation formula
- Data normalization was used 0 to1 to represent long term relationship and short term relationship
- The number of samples in training, test set and validation was divided into 79, 9 and 5 samples respectively
- The performance measurement of accuracy was used by root mean square error (RMSE)

In our model development, we choose feed-forward in neural network and it is determined by the back-propagation training algorithm. First, the reason that we choose this feed-forward topology because it is used when the information flow from inputs to outputs in only one direction. Based on our research, feed-forward topology is used because the process of information computation flows from input node that had 10 variables to the output which was subcontractor relationship without back-loops. Figure 5.2 shows about the feed-forward topology of our model.

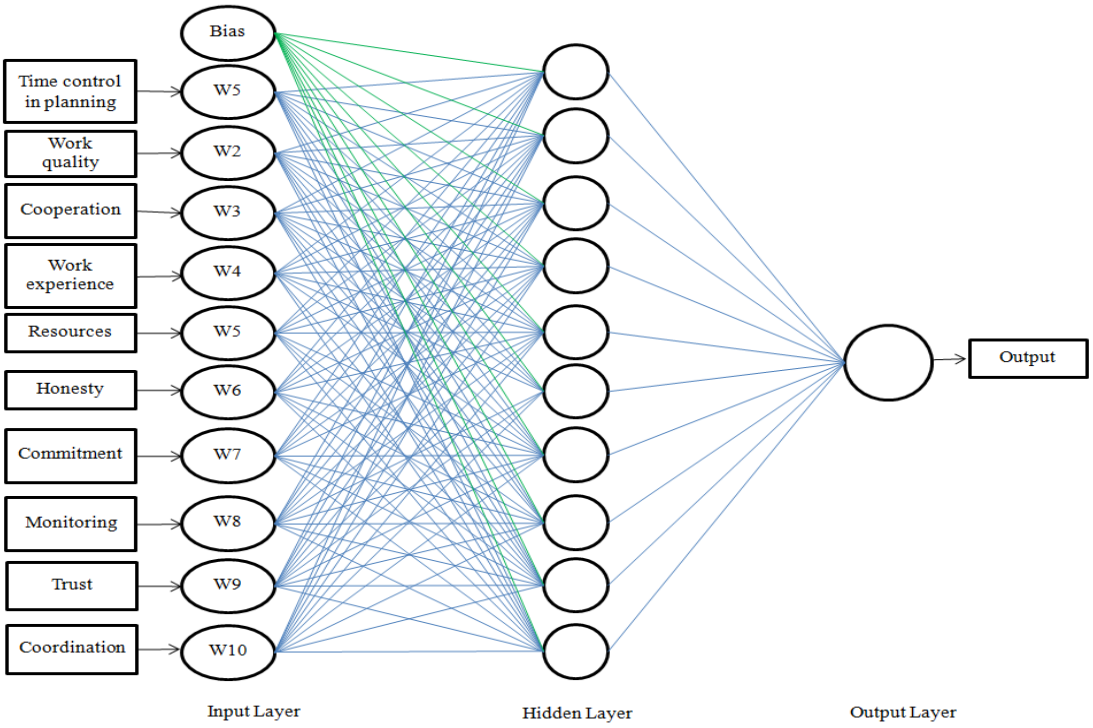

Figure 5.2 Subcontractor relationship selection model by ANN

5.3.2 Training Control Option

To gain the potential result of model, we need to determine the correct value of some key options in Qnet 2000 such as learning rate, momentum and so on. First, the learning rate coefficient calculates the size of the node for adjusting the weight during training. Moreover, the higher learning rate coefficient could provide faster learning but it leads to instability and divergence whereas the smaller value of this coefficient

would improve the numerical convergence. Usually, when the coefficient is ranged from 0.001 to 0.1 and gives a good process of training data without the risk of divergence (Change et al., 2006). Next, the momentum factor of the Qnet's training algorithms is ranged of 0.8 to 0.9. When the number of iteration is increased, it will provide the lower value of RMS error in the training. Moreover, this is no rule to select the iteration numbers and generally, the iteration numbers are increased by the complexity in problem. Last, the remained options are followed by the default of program. Finally, our model has determined the suitable value in the training control option and it is summarized in Table 5.3. Next section will be explained about the result that we obtain from the analysis of Qnet program.

Table 5.3 Summary of the training control

Network Definition		Training Controls	
Network Layers:	3	Max. Iterations:	20000
Input Nodes:	10	Learn control start:	10001
Output Nodes:	1	Learn Rate:	0.001
Hidden Nodes:	10	Learn Rate Max:	0.1
Transfer Functions:	Sigmoid	Learn Rate Min:	0.001
Connections:	110	Momentum:	0.8
Training Patterns:	79		
Test Patterns:	9		

5.3.3 Results of the Artificial Neural Network

From training data of 79 at 20,000 iterations, we could get the result of RMSE and correlation coefficient of training and testing data. First, The Root Mean Square Error (RMSE) usually uses to assess the difference between the predicted value and the actual values observed from the environment that is being modelled. Moreover, Figure 5.3 indicated that the RMSE result of network at tolerance between 0.32 and 0.02 and varied in every time of training data about ±0.02. So it means that the result

of RMSE was steadily declined to a minimum of 0.02. The result of RMSE in test set has tolerance from 0.30 to 0.04 which means that the result of RMSE was steadily declined to a minimum of 0.04. Usually the minimum RMSE often uses as a criterion for determining the best trained network. Therefore, the network trained of data at a tolerance of 0.02 would be chosen as the best performing among all those trained. Figure 5.3 and 5.4 show about the number of iterations against with RMS error for both training and test set.

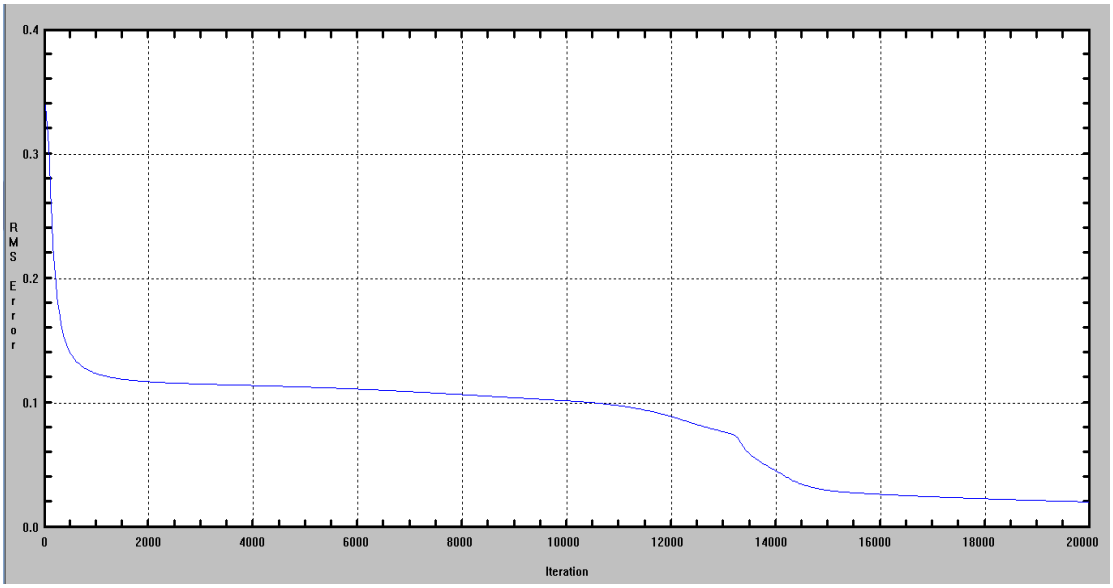

Figure 5.3 Iteration numbers and RMS error for training set

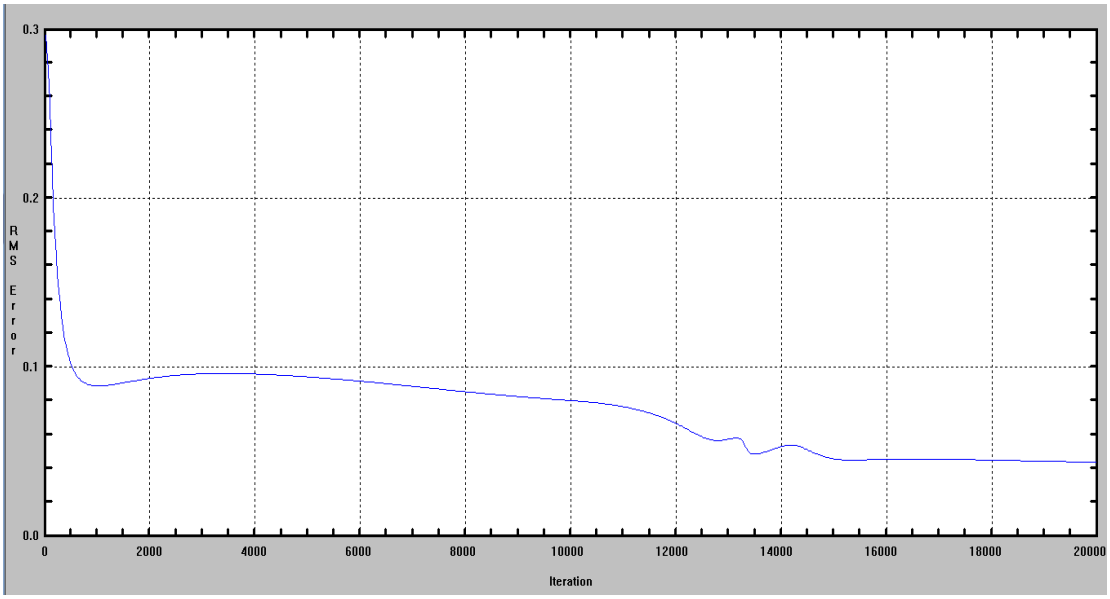

Figure 5.4 Iteration numbers and RMS error for test set

Next, the result of training data also shows about the correlation coefficient value. The correlation coefficient assesses how well the network predictions trend with the targets for the cases outside the training set. The range of correlation coefficient is between -1 and 1. From the result of Figure 5.5 and 5.6, the correlation coefficient for training and test sets are 0.998 and 0.982 respectively. Thus, it means that our network is highly correlation between the target and output data.

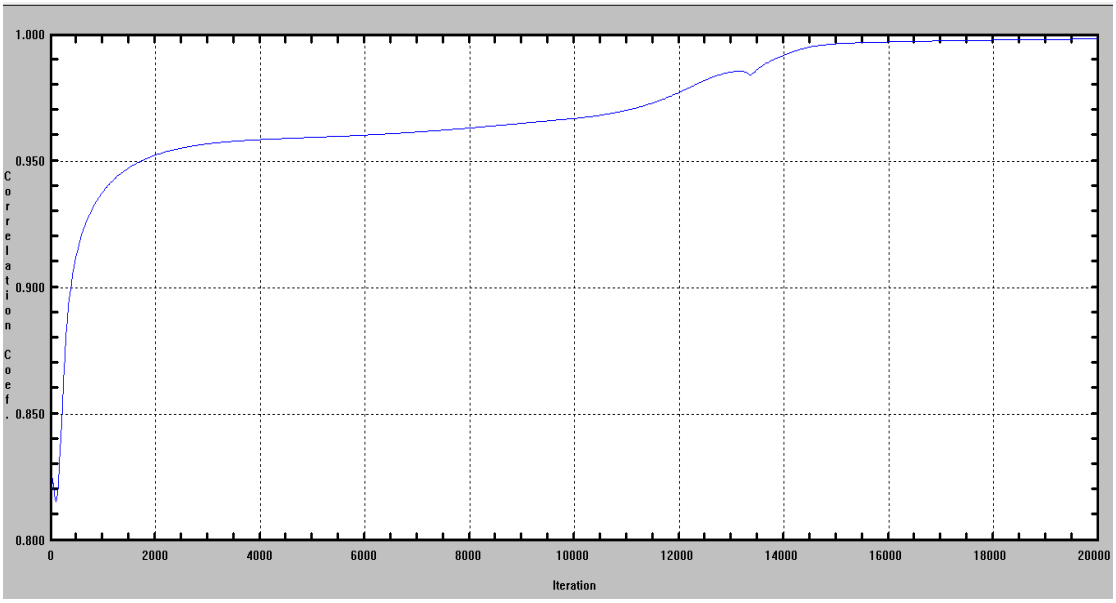

Figure 5.5 Iteration numbers and correlation coefficient for training set

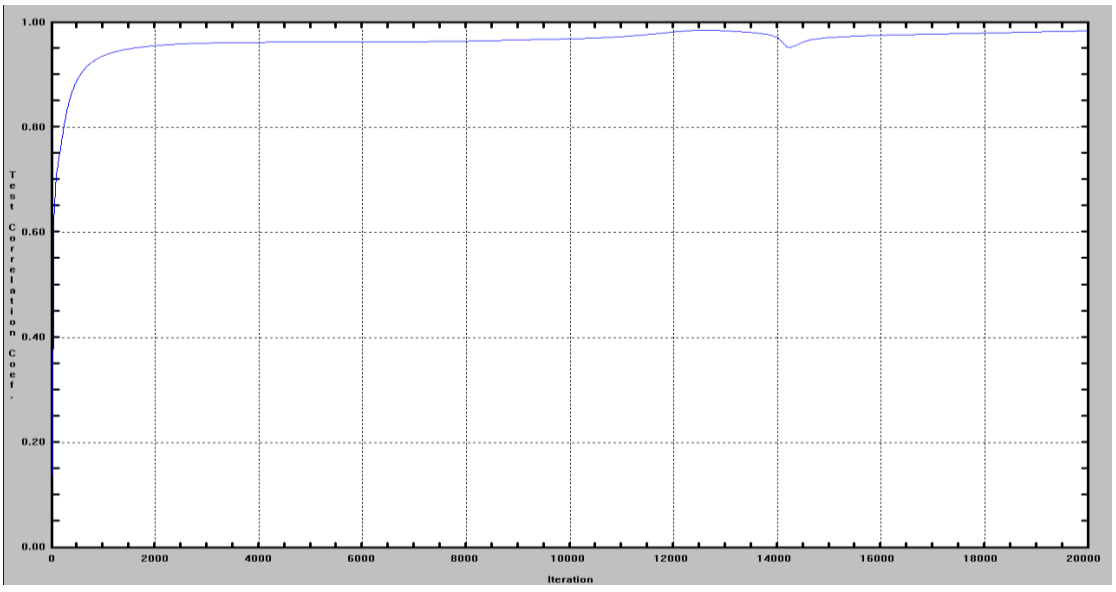

Figure 5.6 Iteration numbers and correlation coefficient for test set

On the other hand, the RMSE of the training and test set could understand the overtraining behavior. It means that when the test set error increases while the training set error continues to descend, the overtraining will be occurred. From the Figure 5.3 and 5.5, we could see the curve of number of iterations was decreasing, while the curve of the correlation of training set and the RMSE of test set was decreasing. So it means that our model is not overtraining that could hurt the predictive capabilities of the model being developed.

From the result of this model, we could plot the graph between network outputs versus the target values in Figure 5.7. The vertical line refers to the network output whereas the horizontal line indicates the training target. Moreover, in this figure, it has the red optimal agreement line, so when the point closely falls to the optimal agreement line (or called equality line), the model has a good result of the overall agreement. Next, in Figure 5.8, we also plot another graph between the target value and network output data versus the input pattern sequence number. Moreover, in the vertical line, it indicates the target values and network output data whereas the horizontal line is pattern sequence. There are three curves were shown in this figure namely the training targets, the training set network responses and the test set network responses. In conclusion, we have seen form the Figure 5.7 and 5.8 and also could conclude that between the target and output results are closely agreement.

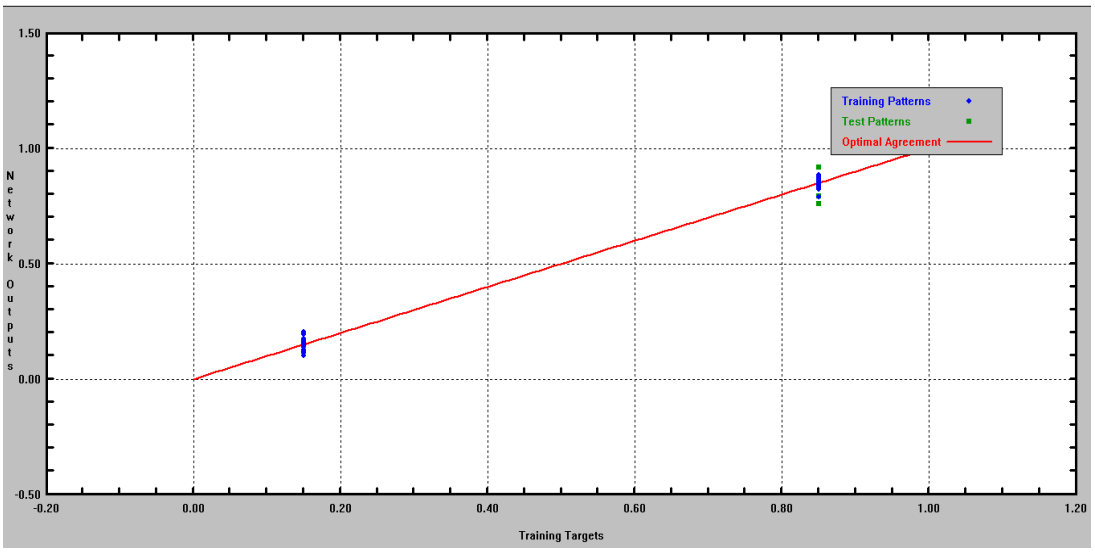

Figure 5.7 Comparisons of targets vs. outputs

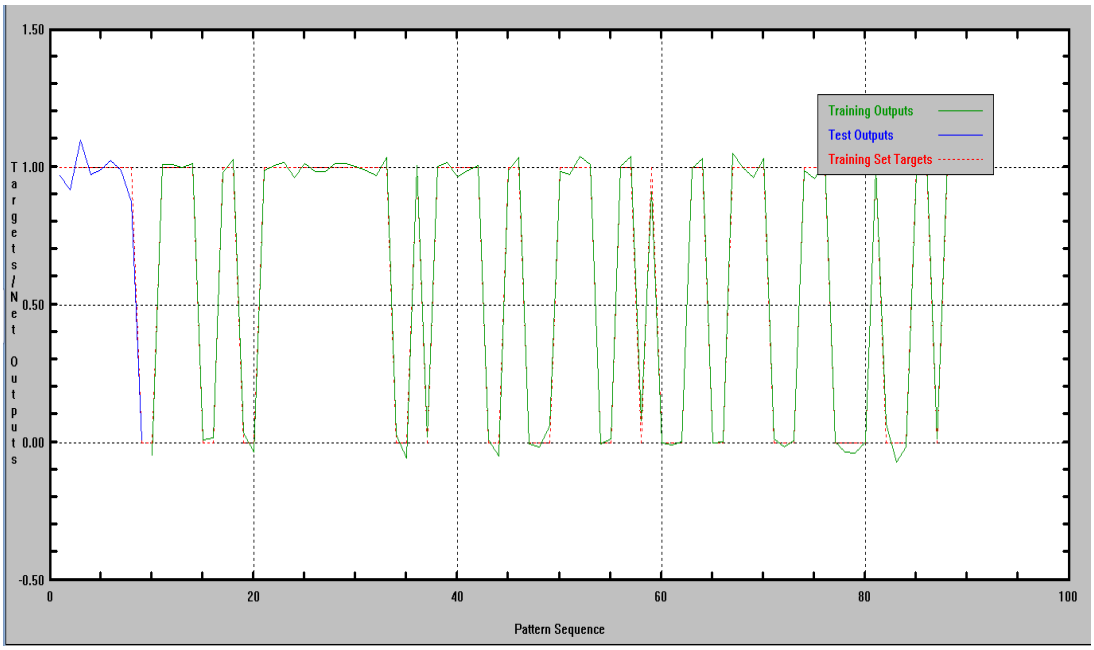

Figure 5.8 Comparisons of targets/ outputs vs pattern sequence

Last, we also keep some samples data for using in verification purpose. Moreover, there data were not used in the training and testing process. Shanker and Michael (1996) found the cut off value for two group classification by using neural network. Applying in our research, we could understand that if the output value is larger than 0.5, it is long-term relationship and if the output is equal or less than 0.5, it is short-term relationship. Furthermore, from the result of Table 5.4, we could get the error value from the 5 verification data sets is 1 answer, so the model is still highly accuracy.

Table 5.4 Comparisons of targets vs outputs of validation samples

Number of sample	Target	Output	Output
1	1.00000	0.92950	Correct
2	0.00000	0.26418	Correct
3	0.00000	0.01593	Correct
4	0.00000	0.54390	Wrong
5	1.00000	1.00827	Correct

In conclusion, ANN is a significant method that could produce the model on selecting subcontractor relationship more accuracy. Moreover, this method has reduced the error in data set to minimum and gain the weight that could determine short-term relationship or long-term relationship. Finally, the conclusion of model explains main contractor about result finding, contribution, limitation and future studying in the following chapter.

5.4 Result of Sensitivity analysis

By using input node interrogator, we could understand the inputs that has influenced to the output could be understood by the contribution percentages. From this result, we could see trust, cooperation, work quality, time control in planning and monitoring are the top five variables which have the higher percentage among the other. Therefore, this results could us about the influencing factor of subcontractor relationship that main contractor has used to evaluate their own subcontractors in actual situation.

Table 5.5 Contribution percentages of input to output

Output Node	Input Node	Node Name	Percent Contribution
1	1	Work quality	11.17
1	2	Time control in planning	9.13
1	3	Experience	4.7
1	4	Cooperation	23.17
1	5	Honesty	2.23
1	6	Commitment	4.71
1	7	Resources	5.25
1	8	Coordination	2.79
1	9	Monitoring	7.83
1	10	Trust	29.03

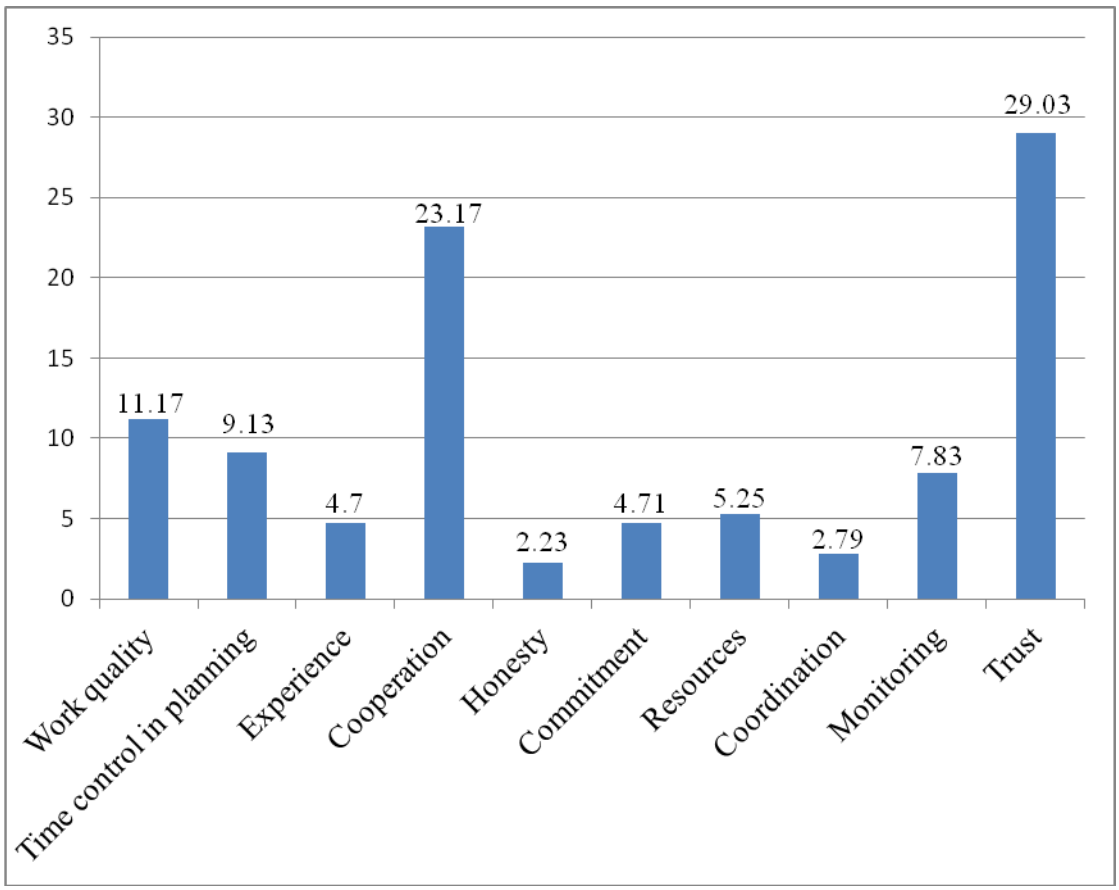

Figure 5.9 Contribution percentages of input to output

5.5 Result of two-group discriminant analysis

5.5.1 Result of assumption

As the objective and research design of discriminant analysis was explained already in chapter 3, we began with the result of assumption that was explained by Box's M test. This test checks the dispersion matrices of the independent variables among the two groups. The significance value of 0.5883 is greater than 0.05 which means the test is not significant, so we could understand that the assumption is not violated and the groups are not different. The next step can proceed with the analysis. Moreover, the value of log determinants is also almost equal to one another. The result of Box's M test and log determinant are shown by Table 5.6 and Table 5.7.

Table 5.6 Result of Log Determinants

Category	Rank	Log Determinant
1 Short term relationship	4	-3.443
2 Long term relationship	4	-2.390
Pooled within-groups	4	-2.710

Table 5.7 Test Results of Box's M

Box's M		5.883
F	Approx.	.552
	df1	10
	df2	17589.505
	Sig.	.854

5.5.2 Result of establishing discriminant function

This research determines the discriminant function by using stepwise method with 79 samples of subcontractor evaluation. First, to identify including variables in the analysis, we use two basic ideas. First, when the variable has statistically significant value across groups (0.05 or less than 0.05). Next, the variable provides the largest Mahalanobis distance (D^2) between the groups. From the result of Table 5.7, we could identify eight variables with the significance means of the independent variables for the two groups such as X_1, X_2, X_3, X_4, X_5, X_6, X_9, and X_{10}. Moreover, these variables also have the largest Mahalanobis distance. Then, this process will be continued by including variables in the discriminant function as long as they provide statistically significant among the groups beyond those differences already accounted for by the variables in the discriminant function.

Table 5.8 Group Descriptive Statistics and Tests of Equality for the Estimation Sample

Independent variables		Dependent Variable Group Means: Region		Test of Equality of Group Means				
		Group 1: Short-term relationship (n=30)	Group 2: Long-term relationship (n=49)	Wilks' Lambda	F Value	Significance	Minimum Mahalanobis D2	Between Groups
X_1	Work quality	3.17	3.98	.717	30.400	.000	1.634	1 and 2
X_2	Time control in planning	3.17	4.08	.754	25.073	.000	1.347	1 and 2
X_3	Experience	3.03	3.92	.745	26.320	.000	1.414	1 and 2
X_4	Cooperation	2.80	4.04	.587	54.176	.000	2.911	1 and 2
X_5	Honesty	2.53	3.59	.726	29.028	.000	1.560	1 and 2
X_6	Commitment	2.77	3.94	.663	39.225	.000	2.108	1 and 2
X_7	Resources	2.77	3.61	.834	15.290	.000	.822	1 and 2
X_8	Coordination	2.70	3.63	.781	21.604	.000	1.161	1 and 2
X_9	Monitoring	2.97	3.88	.741	26.876	.000	1.444	1 and 2
X_{10}	Trust	2.50	3.84	.547	63.696	.000	3.423	1 and 2

Note: Wi1ks' lambda and F ratio with 1 and 77 degrees of freedom

This estimation will begin with first variable X_{10} that has the largest significant difference between groups (63.696) and the largest Mahalanobis (D^2) (3.423) among other variables. After X_{10} was entered into the model, the remaining variables are evaluated on the basis of their incremental discriminating ability and the group mean is also differences after the variance associated with X_{10} was removed. In addition, the variables with significance levels greater than .05 are removed from consideration for entry at the next step.

Next, in Table 5.9, cooperation (X_4) has the highest Mahalanobis (D^2) (6.965) and the largest F to enter value (35.604). So it becomes the second variable which had the most significant differences for using in the model.

Table 5.9 Result from step 1 of stepwise

Over all Model Fit					
	Value	F Value	Degree of Freedom 1	Degree of Freedom 2	Significance
Wilks' Lambda	0.547	63.696	1	77	0.000

Variable Entered/Removed at step 1

		F			
		Minimum D2	Value	Significance	Between Groups
X_{10}	Trust	3.423	63.696	0.000	1 and 2

Variable in the analysis after step 1

	Variable	Tolerance	F to remove	Between Groups
X_{10}	Trust	1.000	63.696	1 and 2

Variable in the analysis after step 1

Variable		Tolerance	Minimum Tolerance	F to Enter	Minimum D2	Between Groups
X_1	Work quality	0.994	0.994	20.310	5.444	1 and 2
X_2	Time control in planning	0.995	0.995	10.672	4.485	1 and 2
X_3	Experience	0.995	0.995	11.392	4.556	1 and 2
X_4	Cooperation	0.992	0.992	35.604	6.965	1 and 2
X_5	Honesty	0.973	0.973	9.234	4.342	1 and 2
X_6	Commitment	0.988	0.988	15.789	4.994	1 and 2
X_7	Resources	0.912	0.912	1.409	3.563	1 and 2
X_8	Coordination	0.952	0.952	4.764	3.897	1 and 2
X_9	Monitoring	0.983	0.983	9.417	4.360	1 and 2

Significance testing of group difference after step 1

		long-term relationship
Short-term relationship	F	63.696
	sig	0.000

In the second step, X_4 was entered into the model. The overall model is significant (F = 63.963) and improves in the discrimination between groups as evidenced by the decrease in Wilks' lambda from 0.547 to 0.373. Moreover, the discriminating power of both variables included at this point is also statistically significant (F values of 63.696 for X_{10} and 63.963 for X_4). Then, the examined will move to find the next variable which has high discriminant power between groups.

Table 5.10 Result from step 2 of stepwise

Over all Model fit

	Value	F Value	Degree of Freedom 1	Degree of Freedom 2	Signif icance
Wilks' Lambda	0.373	63.963	1	77	0.000

Variable Entered/Removed at step 2

			F		
		Minimum D^2	Value	Significance	Between Groups
X_4	Cooperation	6.965	63.963	0.000	1 and 2

Variable in the analysis after step 2

	Variable	Tolerance	F to remove	D^2	Between Groups
X_{10}	Trust	0.992	43.704	2.911	1 and 2
X_4	Cooperation	0.992	35.604	3.423	1 and 2

Variable in the analysis after step 2

Variable		Tolerance	Minimum Tolerance	F to Enter	Minimum D^2	Between Groups
X_1	Work quality	0.980	0.978	18.54	9.711	1 and 2
X_2	Time control in planning	0.995	0.987	7.098	8.016	1 and 2
X_3	Experience	0.970	0.966	4.041	7.564	1 and 2
X_5	Honesty	0.816	0.816	0.330	7.014	1 and 2
X_6	Commitment	0.722	0.722	0.714	7.071	1 and 2
X_7	Resources	0.912	0.904	.803	7.084	1 and 2
X_8	Coordination	0.945	0.941	1.929	7.251	1 and 2
X_9	Monitoring	0.558	0.558	0.865	7.093	1 and 2

Significance testing of group difference after step 2

		long-term relationship
Short-term relationship	F	63.963
	0.000	0.000

In the third step, X_1 was entered into the model. The overall model is significant (F = 58.666) and improves in the discrimination between groups as evidenced by the decrease in Wilks' lambda from 0.373 to 0.299. Moreover, the discriminating power of these variables is also statistically significant (F values of 63.696 for X_{10}, 63.963 for X_4 and 58.666 for X_1). Then, the examined will move to find the next variable which has high discriminant power between groups.

Table 5.11 Result from step 3 of stepwise

Over all Model fit					
	Value	F Value	Degree of Freedom 1	Degree of Freedom 2	Signif icance
Wilks' Lambda	0.299	58.666	1	77	0.000

Variable Entered/Removed at step 2

			F		
		Minimum D^2	Value	Significance	Between Groups
X_1	Work quality	9.711	58.666	0.000	1 and 2

Variable in the analysis after step 2

	Variable	Tolerance	F to remove	D2	Between Groups
X_{10}	Trust	0.984	37.515	5.093	1 and 2
X_4	Cooperation	0.978	33.398	5.444	1 and 2
X_1	Work quality	0.980	18.543	6.965	1 and 2

Variable in the analysis after step 2

	Variable	Tolerance	Minimum Tolerance	F to Enter	Minimum D^2	Between Groups
X_2	Time control in planning	0.987	0.972	4.118	10.481	1 and 2
X_3	Experience	0.945	0.945	1.431	9.978	1 and 2
X_5	Honesty	0.784	0.784	0.066	9.723	1 and 2
X_6	Commitment	0.722	0.720	0.782	9.857	1 and 2
X_7	Resources	0.911	0.897	0.517	9.807	1 and 2
X_8	Coordination	0.944	0.936	1.966	10.079	1 and 2
X_9	Monitoring	0.558	0.558	0.528	9.809	1 and 2

Significance testing of group difference after step 2

		long-term relationship
Short-term relationship	F	58.666
	0.000	0.000

In fourth step, X_2 is the next variable that was added in discrimination function. The overall results are still statistically significant and continue to improve in discrimination, as evidenced by the increase in the Wilks' lambda value (from 0.299 to 0.283). When third variable (X_1) was added to the discriminant function, the value of Wilks' lambda was much smaller than the previous one. Next, the procedure moves to identifying any remaining candidates for inclusion.

As seen in the Table 5.12, after X_2 was entered in the equation, X_8 which is considered as not significant variable in this calculation process has the higher D^2 among other variables. Thus, the estimation process stops with four variables (X_{10}, X_4, $X_1$and X_2) in the discriminant function. Moreover, the remaining variables also have relatively little additional discriminatory power too.

Table 5.12 Result from step 4 of stepwise

Over all Model Fit

	Value	F Value	Degree of Freedom 1	Degree of Freedom 2	Signifi cance
Wilks' Lambda	0.283	46.858	1	77	0.000

Variable Entered/Removed at step 3

		F			
		Minimum D^2	Value	Significance	Between Groups
X_2	Time control in planning	10.481	46.858	0.000	1 and 2

Variable in the analysis after step 3

	Variable	Tolerance	F to remove	D^2	Between Groups
X_{10}	Trust	.978	30.767	6.188	1 and 2
X_4	Cooperation	.978	29.994	6.265	1 and 2
X_1	Work quality	.972	15.009	8.016	1 and 2
X_2	Time control in planning	.987	4.118	9.711	1 and 2

Variable in the analysis after step 3

	Variable	Tolerance	Minimum Tolerance	F to Enter	Minimum D^2	Between Groups
X_3	Experience	0.940	0.940	1.024	10.686	1 and 2
X_5	Honesty	0.783	0.783	0.033	10.488	1 and 2
X_6	Commitment	0.695	0.695	1.573	10.796	1 and 2
X_7	Resources	0.911	0.893	0.415	10.564	1 and 2
X_8	Coordination	0.927	0.925	2.649	11.012	1 and 2
X_9	Monitoring	0.557	0.557	0.597	10.601	1 and 2

Significance testing of group difference after step 3

		long-term relationship
Short-term relationship	F	46.858
	sig	0.000

Finally, Table 5.13 presents the overall stepwise discriminant analysis results after all the significant variables are included in the estimation of the discriminant function. This summary table describes the four variables (X_{10}, X_4, X_1 and X_2) that were significant discriminators based on their Wilks' lambda and minimum Mahalanobis D^2values. Moreover, the overall model fit was reported under the heading Canonical Discriminant Functions and it showed that the discriminant function is highly significant (0.000) with a canonical correlation of 0.847. We interpret this correlation by squaring it $(0.847)^2 = 0.717$. Thus, 71.7 percent of the variance in the dependent variable can be accounted for this model, which includes only four independent variables.

Moreover, The unstandardized discriminant coefficients are used to calculate the discriminant Z scores that can be used in classification and the discriminant loadings which were under the heading Structure Matrix are ordered from highest to lowest by the size of the loading. Thus, this loading was discussed later under the interpretation stage. Last, group centroids result were determined and represented as the mean of the individual discriminant function scores for each group. From this Table 5.13, it also shows that the group centroid for short-term relationship (group 1) is -2.008 whereas the group centroid for long-term relationship (group 2) is 1.229.

Table 5.13 Summary of the Stepwise Estimation Process

Overall Model Fit: Canonical Discriminant Functions

		Percent of Variance		
Function	Eigenvalue	Function %	Cumulative %	Canonical Correlation
	2.533	100.0	100.0	0.847

Wilks' Lambda	Chi-Square	Df	Significance
0.283	94.658	4	0.000

Discriminant Function

Independent Variables		Discriminant Function	
		Unstandardized	Standardized
X_1	Work quality	0.773	0.492
X_2	Time control in planning	0.346	0.273

	Independent Variables	Unstandardized	Standardized
X_4	Cooperation	0.882	0.642
X_{10}	Trust	0.896	0.647
	Constant	-10.263	

Structure Matrix

	Independent Variable	Function 1
X_{10}	Trust	0.571
X_4	Cooperation	0.527
X_9	Monitoring	0.451
X_5	Honesty	0.408
X_1	Work quality	0.395
X_2	Time control in planning	0.359
X_6	Commitment	0.304
X_3	Experience	0.232
X_7	Resources	0.195
X_8	Coordination	0.116

Group Means (Centroids) of Discriminant Functions

Category	Functions
Short-term relationship	-2.008
long-term relationship	1.229

Before we could interpretation of the result, the research need to assess the classification accuracy and it consists of three main tasks such as calculating the cutting score, developing the classification matrices for both the analysis and the holdout samples, and assessing the levels of predictive accuracy from the classification matrices. Each task was defined as in the following.

First is the determination of the cutting score, we need to know about the prior probabilities of classification. As our sample is randomly selected, we can be reasonably sure that this sample does reflect the population proportions. So this discriminant analysis uses the sample proportions to specify the prior probabilities for classification purposes. Then the cutting score was become a weighted average of the

two group centroids score and was calculated in the following formula. The result of cutting score is obtained around -0.3895.

$$Z_{CS} = \frac{Z_B + Z_A}{2} = \frac{(1.229) + (-2.008)}{2} = -0.3895 \qquad (5.1)$$

Next after understand about the value of cutting score, we could develop the classification of samples into two cases. The first group is classified a subcontractor into short-term relationship (group 1) when if its discriminant score is less than -0.3895. Then, the second group is classified a subcontractor into long-term relationship (group 2) when if its discriminant score is greater than -0.3895. Moreover, we also compare the classification between actual and predicted group membership value of estimation and validation sample. From the result of Table 5.14, we get 82.62 percents are predictive accuracy which is similar to the 82.62 percents accuracy of the cross-validated sample.

Table 5.14 Classification Results

		Category	Predicted Group		
			1 Short term relationship	2 long term relationship	Total
Original	Count	1 Short term relationship	30	0	30
		2 long term relationship	1	48	49
	%	1 Short term relationship	100	0	100.0
		2 long term relationship	2.0	98.0	100.0
Cross-validated	Count	1 Short term relationship	30	0	30
		2 long term relationship	1	48	49
	%	1 Short term relationship	100	0	100.0
		2 long term relationship	2.0	98.0	100.0
Holdout Sample	Count	1 Short term relationship	8	1	8
		2 long term relationship	1	5	6
	%	1 Short term relationship	87.5	12.5	100.0
		2 long term relationship	20	80	100.0

a. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.
b. 98.7% of original grouped and cross-validated grouped cases correctly classified.
c. 83.75% for handout grouped cases correctly classified

Table 5.15 Predictions cases in the Two-Group Discriminant Analysis

ID	Actual Group	Discriminant Z Score	Predicted Group	ID	Actual Group	Discriminant Z Score	Predicted Group
Analysis Sample							
1	2	0.429	2	21	2	3.449	2
5	2	1.216	2	22	2	1.671	2
13	2	0.979	2	25	1	-0.799	1
19	2	0.443	2	26	1	-1.695	1
33	2	0.552	2	24	2	0.979	2
34	2	1.434	2	28	1	-0.69	1
62	2	2.676	2	27	2	1.325	2
84	2	3.876	2	30	2	0.552	2
91	1	-1.695	1	31	2	-0.263	2
2	1	-1.226	1	32	2	2.221	2
3	1	-1.226	1	36	2	1.311	2
4	2	2.567	2	38	1	-3.241	1
6	2	0.761	2	39	1	-1.226	1
7	2	0.633	2	37	2	1.671	2
8	2	0.443	2	40	2	0.415	2
9	2	1.202	2	42	1	-2.814	1
10	2	2.098	2	43	1	-3.696	1
12	2	0.32	2	45	1	-3.35	1
15	2	0.566	2	41	2	2.553	2
16	2	1.875	2	46	2	0.443	2
18	2	3.103	2	47	2	0.789	2
20	2	2.567	2	48	2	2.98	2
50	1	-0.799	1	74	1	-1.226	1
51	1	-2.454	1	75	1	-0.989	1
49	2	-0.107	2	72	2	2.084	2
52	2	0.789	2	77	2	-0.121	2
55	1	-0.799	1	78	2	1.216	2
53	2	0.083	2	80	1	-2.8	1
58	1	-2.245	1	81	1	-2.013	1
60	1	-2.454	1	82	1	-1.681	1
61	1	-3.241	1	83	1	-1.586	1
57	2	1.671	2	79	2	-0.093	2
66	2	-0.567	1	85	1	-0.813	1
67	1	-3.004	1	87	1	-3.004	1
68	1	-2.8	1	88	1	-2.345	1
63	2	0.979	2	86	2	2.553	2
69	2	0.192	2	89	2	1.434	2
70	2	0.083	2	92	1	-1.572	1
71	2	1.325	2	90	2	0.775	2
73	1	-2.814	1				

Hold out samples							
14	1	-1.022	1	56	2	0.083	2
11	2	1.434	2	76	2	2.098	2
17	2	2.33	2	93	2	3.876	2
23	2	-0.453	1	29	1	-2.122	1
35	2	0.552	2	44	1	-1.226	1
59	1	0.552	2	54	1	-0.799	1
65	1	-1.885	1	64	2	2.098	2

Although all of the measures of classification accuracy are seem to be high, the evaluation still process requires a comparison to the classification by chance. This classification by chance does not need discriminant function and uses to understand the improvement of the discriminant model. Because the overall sample is still small around 93 for estimation and hold out samples, we will use the overall sample to establish the comparison standards. With 36 and 57 of the group size 1 and 2 in the whole sample size, we can see the proportional chance value is 0.509 ($(0.57)^2$+(1-0.57)^2=0.509). Because group 2 (long-term relationship) is the largest group at 57 percent of the sample, our model would be accurate classification if the value is greater that 57 percent and it was be acceptable too, so we choose the maximum chance criterion as the standard of evaluation. Therefore, we could see that all of the classification accuracies were exceed 98.7 percent, which were higher than the proportional chance criterion of 50.9 percent and the maximum chance criterion of 57 percent.

All three hit ratios also exceed the suggested threshold of these values (comparison standard plus 25 percent), which in this case is 63.625 percent (50.9% x 1.25 = 63.625 %) for the proportional chance and 57 percent (57% x 1.25 = 71.25%) for the maximum chance. Then, all classification including analysis sample, holdout sample, and cross-validation were indicated an acceptable and accuracy. In addition, the hit ratio for individual groups is deemed adequate as well. Last, we need to measure the classification accuracy of Press's Q which is depended on a random process. From the result, we could get the both value of Press's Q were exceed the critical value of 6.63. Therefore, the classification accuracy for the analysis and holdout sample exceeds at a statistically significant level the classification accuracy expected by chance.

For the estimation sample, we could calculate Press's Q is

$$\text{Press}'\text{sQ}_{\text{estimatoin sample}} = \frac{[79-(78\text{x}2)]^2}{79(2-1)} = 75.05 \qquad (5.2)$$

For the validation sample, we could calculate Press's Q is

$$\text{Z}_{\text{CS}} = \frac{[14-(2\text{x}2)]^2}{14(2-1)} = 7.143 \qquad (5.3)$$

Finally, after we have identified the predictive accuracy of the model, we will exam the misclassified cases. We could find the specific cases misclassified for each group on both analysis and holdout samples by using t-test method. The objective of method is to identify specific differences on the independent variables that might identify the new variables to be added for consideration in discrimination function. From the result in the Appendix E, it shows the significant differences of all independent variables both inside and outside discrimination function. Moreover, the remaining variable that does not use in the discriminant function for two groups classification should be examined in the future for better understanding the characteristics of influencing the group classification.

5.5.3 Interpretation the result of discriminant function

This stage will interpret the result by determining the relative importance of each independent variable in discriminating between the groups. There are two steps for interpreting the discriminant function namely discriminant loadings, and profiling each group on the pattern of mean values.

First, the discriminant loading is reported under the heading of Structure Matrix, these loading values were considered the more appropriate measurement of discriminatory power and it is calculated in every independent variable even the variables which are not included in discrimination function. From Table 5.12, it has included unstandardized and standardized discriminant weights, loadings for the discriminant function, Wilks' lambda, and the univariate F ratio. Moreover, after 10 independent variables were screened by the stepwise procedure. Four variables (X_{10},

X_4, X_1 and X_2) are significant enough to be included in the function. For interpretation purposes, we rank the independent variables in terms of their loadings and univariate F values both indicators of the variable's discriminating power. Signs of the weights or loadings do not affect the rankings; they simply indicate a positive or negative relationship with the dependent variable. Moreover, The loading values of the four variables used in the discriminant function are also greater than ± 0.40, so it means they are suitable to be the important discriminating variables.

Next, profiling the discriminating variables is used to understand what the differing group means on each variable. From Table 5.16, we see varied profiles between the two groups. For example, Group 1 has higher perceptions on two variables: X_1 (Time control in planning) and X_2 (Work quality). Group 2 has higher perceptions on three variables: X_2 (Work quality), X_4 (Experience) and X_1(Time control in planning). Based on these results, we could understand that the time controls in planning and work quality are more likely to help in determine short and long-term relationship for main contractor.

Table 5.16 Summary of Interpretive Measures for Two-Group Discriminant Analysis

	Discriminant coefficients		Discriminant Loadings		Wilks Lambda	Univariate F ratio		
Independent Variables	Unstandardized	Standardized	Loading	Rank	Value	F value	Sig	Rank
Trust	.773	.492	0.395	5	.717	30.400	.000	4
Cooperation	.346	.273	0.359	6	.754	25.073	.000	8
Monitoring	NI	NI	0.232	8	.745	26.320	.000	7
Honesty	.882	.642	0.527	2	.587	54.176	.000	2
Work uality	NI	NI	0.408	4	.726	29.028	.000	5
Time control in planning	NI	NI	0.304	7	.663	39.225	.000	3
Independent Variables	Unstandardized	Standardized	Loading	Rank	Value	F value	Sig	Rank
Commitment	NI	NI	0.195	9	.834	15.290	.000	10
Experience	NI	NI	0.116	10	.781	21.604	.000	9
Resources	NI	NI	0.451	3	.741	26.876	.000	6
Coordination	.896	.647	0.571	1	.547	63.696	.000	1

Note: NI = Not included in estimated discriminant function.

5.5.4 Validation of discrimination result

Finally, although this research does not include the addition sample besides original samples because of time constrain and possibility to access with main contractor, the classification accuracy of holdout sample and the cross-validated sample in earlier analysis were above all the measures of predictive accuracy and this analysis was known internal validity. To improve for applying this model into the other situations, this research is encouraged to add another sample or relevant population for checking classification accuracy and it is known as external validity. So it will test the externality of the model too.

5.6 Discussion result of factors from main contractor opinion and current practice

To sum up of both analysis finding, we could get the result of influencing factor in actual practice. First, the sensitivity analysis of neural network presents the influencing factors of subcontractor relationship such as trust, cooperation, work quality and time control in planning. In addition, the result of discriminant analysis shows the influencing factors namely work quality, time control in planning, cooperation and trust. Therefore, the analysis found top four factors which have high degree of influencing in actual practice of main contractor evaluation.

Although we know about the important factor of subcontractor relationship from main contractor opinion, it would be useful if we could understand about the influencing of these factors in the real practice of main contractor evaluation. From the result of chapter 4, we found top four important factor including time control in planning, work quality, cooperation and experience. For the influencing factors of subcontractor relationship, we found four factors which mentioned on above paragraph. Thus, it could be concluded that there is not much difference between main contractor opinion and real practice of main contractor evaluation in some of subcontractor relationship factors like time control in planning, work quality, and

cooperation. However, it still has a few factors such experience and trust that have given the differences between main contractor opinion and actual practice. So a further discussion should be conducted for understanding about this problem.

First, the meaning of trust is defined as a willingness of making friend with subcontractor who main contractor has confidence with. This factor has become one of the most influencing factors in the real practice of main contractor evaluation on selecting subcontractor relationship while the opinion of main contractors do not concern much about this factor. So this factor could be influenced by other factors which make the difference between main contactor opinion and real practice. Regarding to the explanation of main contractor opinion on the important factors of subcontractor relationship, we could see that the trust factor seems unlikely become one of the most important factor. Main contractor would choose not to trust their subcontractor 100% in construction project because they were afraid of subcontractor irresponsibility or escaping from work sometimes. Then main contractor has to check the progressive work of subcontractor and understand about subcontractor situation which could lead to the project success or not. Based on main contractor opinions, this factor is like the nature of human that they have to think carefully before trusting someone. In real practice of using trust factor, main contractor may be impacted by the time of working with subcontractor that the more time they work together, the better understanding between main contractor and subcontractor would be obtained. Main contractor has to trust their own subcontractor before giving the work. Moreover, previous study by Patrick and Benson in 2006 found trusting behavior factor as a key successful element that influencing in a long-run working with subcontractor.

Next, Experience is one of factors that have influenced on the difference between main contactor opinion and actual practice. From main contractor perceptions, experience found as a prequalification factor that they have to firstly consider when partnering with subcontractor. Moreover, some main contractors may require the high experience of subcontractor work which is related to the construction project. On the other hand, in reality of working with subcontractor, main contractor

may not concern much with the experience factor because they have seen the performance of subcontractor which has played an important in current situation. Thus, main contractor would develop a long-term relationship with subcontractor, when they do not care much about the experience of subcontractor and just need subcontractor to perform well in the construction work and produce a good productivity for them.

In conclusion, we could gain three important factors that have influenced on selecting subcontractor relationship both opinion and practice. Moreover, it is interested to understand about trust and experience factors which have made the differences between main contractor opinion and actual practice in construction work.

5.7 Discussion of model

Based on the result neural network and discriminant analysis, we could see compare the level of accuracy of each method. From training and testing data set in neural network, we get the percentages of error are 0.02 and 0.04 respectively. It means that the accuracies of training and testing are 98% and 96%. Next, the percentages of accuracy in estimation of discrimination analysis are 98.7 % whereas the percentages of accuracy in validation are 83.75 %. Thus both analyses have given a good result of low error. In conclusion, our research selects the neural network as an optimal method for developing a model because this method has high level of accuracy in both training and testing samples.

5.8 Summary

This chapter objectively develops a model that could help main contractor in decision making on selecting subcontractor relationship in construction project. Moreover, this model is constructed by using Artificial Neural Network (ANN) and discriminant analysis. Then we select the effective method which could provide higher accuracy among them. Next we also discuss the result between important factors of subcontractor relationship from main contractor opinion and influencing

factors from current practice in main contractor decision. So we could see the differences or similarity of subcontractor relationship factors in different circumstance and also could point out the factor that has priority to use in determine the subcontractor relationship. In conclusion, these findings is really useful for us to have a better understanding of subcontractor relationship issue especially the finding factors that we have found from main contractor opinion and actual practice. In addition, we could get an optimal method as neural network that has lower error in training and testing process comparing to discriminant analysis.

CHAPTER VI

RESEARCH CONCLUSIONS

6.1 Research finding

In construction project, subcontractor is a good partner who could handle some parts of main contractor work. Possessing a good subcontractor was a great success for main contractor in the future. This research is interested to find out how to select a good subcontractor for a long-term relationship whereas a poor performance of subcontractor will be used in the short-term. So developing a model for selecting subcontractor relationship is really an important issue to help main contractor in decision making and it will likely give main contractor more confidence in developing relationship with subcontractor.

To achieve in the goal of this study, it consisted of two important stages namely important factor identification and model development. First, 10 of 22 factors were identified as the important factors for selecting subcontractor relationship including (1) time control in planning (mean=4.514), (2) work quality (mean=4.457), (3) cooperation (mean=4.257), (4) experience (mean=4.171), (5) resources (mean=4.143), (6) honesty (mean=4.114), (7) commitment (mean=4.114), (8) monitoring (mean=4.114), (9) trust (mean=4.057) and (10) coordination (mean=4.029). Next, these ten factors were used to develop a model by using discriminant analysis and neural network.

After analysis the data by using discriminant analysis, the result shows that the accuracy percentage in estimation is around 98.7 % whereas the accuracy percentage in validation sample is 83.75 %. In addition, we also could get four influencing factors by using this method namely time control in planning, work quality, experience and coordination. In another analysis method, we use artificial neural network for comparing the level of accuracy with discriminant analysis method, the shows the percentage of error around 0.02 for training data and 0.04 for testing data set. Moreover, the correlation of these data in training and testing was around 99%.

Next, we use sensitivity analysis in neural network for determining inputs that has influenced to the output node by using the contributive percentages. From the result, we could get top five influencing factors including trust, cooperation, work quality, time control in planning and monitoring. Regarding to neural network and discriminant analysis results, we could make some discussion of these results. Based on the level of accuracy in estimating and testing the data set, these results show that neural network has a high performance of accuracy on selecting the subcontractor relationship comparing with discriminant analysis. In addition, both methods have given the similar influencing factors such as trust, cooperation, time control planning and work quality.

After we get the influencing factors from both analyses, this study would like to compare these factors with the important factor from main contractor opinion. Then, the result illustrates that there is not much difference between main contractor opinion and real practice in main contractor evaluation because they have the same factors like time control in planning, work quality, and cooperation. Moreover, it still has a few difference factors that are interested to understand in this problem such as trust and experience. Finally, we could get an optimal model which could classification subcontractor into short or long-term relationship by using the weight of neural network that we get qnet2000 analysis. This research would be useful for main contractor who would to identify a subcontractor for developing a long-term relationship.

6.2 Research contribution

After developing this model, I hope it would be fruitful for any user especially main contractor who wishes to have a good subcontractor for working for them in a long-term. So this finding will be significant change in the previous practice of main contractor who uses only their personal judgment in selecting subcontractor for relationship development. Moreover, this model can help main contractor to easily

select the subcontractor by evaluating based on these 10 factors and ran the model to see the result finding whether it is short or long-term relationship.

To ease the user in the model utility, I also have taken the weight that I got for the model to develop a user interface in Microsoft Excel. The purpose of using this model in excel because it will be suitable for any users who do not need much knowledge in ANN. Thus, they need to input the data and see the result at the end. The process of this model development in excel was followed by many steps. First, we begin with the architecture of model by constructing in the layer including input, hidden and output layer. Then we add the column weight of each connection node between input layer and hidden layer and between hidden layer and output layer. In addition, we also add another column for bias value for hidden and output layer. Last, in hidden and output column, we use sigmod function formula. Appendix G illustrates the process of model development by Microsoft Excel.

In conclusion, the finding of this model development on selecting subcontractor relationship has answered to the problem in this study and contributed to the main contractions that plan to develop the long-term relationship with subcontractor in contraction project. Finally, this model would be easy to use by user interface in Microsoft Excel and provide more accuracy in selecting subcontractor for relationship development.

6.3 Limitation and Future Study

Although this model was developed successfully, it still has some limitations that encourage many scholars who are interested in this problem to study more in the future. First, it is about increasing the sample size. Although the model was developed and tested with a small number of data set around 93 samples, the result that we get seems to be good with less percentage of error. Moreover, the important of an optimal model in decision making of main contractor in the future would suggest the next researcher to expend their samples size to be bigger. So the model will be shaped or improved more efficiency in various situation. Therefore, it would not be worst if we

could increase the sample size for developing another model next time. Then we can compare the level of accuracy with this research finding.

Next, the model for selecting subcontractor relationship was developed successfully, it was suggested to implement this model into some real case studies of construction project. Moreover, we can apply this model in the particular case with subcontractor, it would allow us to perceive the efficiency of the model and also understand about the problems of mismatching in the model. Last, this model focus on Cambodia construction project, it is also interested issue if we could apply it with other countries because we would like to see the level of accuracy in this model in the other countries especially neighboring counties where we have similar religious and culture.

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APPENDICES

APPENDIX A
Questionnaire for Data Collection Part I

จุฬาลงกรณ์มหาวิทยาลัย
Chulalongkorn University
Pillar of the Kingdom

Faculty of Engineering
Department of Civil Engineering
Construction Management

No……..……

Date: …….……

SURVEY OF SUBCONTRACTOR RELATIONSHIPS IN CONSTRUCITON PROJECT

This research is a part of Master Degree program in Civil Engineering and Management at Chulalongkorn University. It is a pilot study in a topic of **Decision making model for selecting subcontractor relationship in Cambodia construction project.** Structured questions have been formulated to achieve in this goal. The participant is asked in this questionnaire based on the experience and knowledge of the subcontractor relationship development mode. Therefore, the result will be analyzed after this data collection. Finally, I strongly believe that your participation will be valuable to increase our understanding in the relationship development aspect of building construction. Your response to this questionnaire is highly appreciated and will be treated with the strictest confidence. It will be used for academic purposes only.

Brief explanation: Regarding to this research study, I would like to give a precise explanation about the meaning in subcontractor relationships which are consisted of no relationship, short-term relationship and long-term relationship.

No relationship is understood when main contractors have worked with subcontractor at the first time so they will evaluate subcontractor based on the performance, price, and quality. Then if they have seen the poor performance of subcontractor, it will lead to dissatisfy for giving the work in the future.

Long-term relationship (LTR) is defined as a consistency of organization interaction between main contractor and subcontractors. It is not only considers in term of duration but it also consists of collaborative activity which has long-term orientation. Moreover, this LTR could be understood when main contractor commits or maintains this relationship with subcontractor regularly in order to achieve the expected result as an outcome.

Short-term relationship (STR) is explained when main contractor is not concern much about the subcontractor relationship and they use subcontractor in an essential occasion or no choice at that time. In conclusion, the short term relationship is defined by inconsistency of work between main-contractor and subcontractor.

Part [1]: General Information of Respondent

Background Information		
1.1	Company name	
1.2	Name of respondent	
	Position	
	Experience in Building Construction Work (Years)	
	Tel.	
	E-mail	
	Website	

Part [2]: Short and long term relationship criteria identification

1. Does your company have used subcontractors in construction project?

   ☐ Yes ☐ No

2. What types of subcontractor do you mostly use?

   ☐ Labor ☐ Labor and material ☐ Both

3. Among of those subcontractors, what types of relationship do you with subcontractor?

☐ Long-term relationship ☐ Short-term relationship ☐ Both

4. Why do you need to determine short and long term relationship with subcontractor?

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5. How do you evaluate in selecting short or long-term relationship with subcontractor ? (Ex. Experience, knowledge, or other methods)

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6. Have you ever selected wrong subcontractor for long-term relationship development? What are the problems?

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7. If you have chosen a good subcontractor for long-term relationship development, what are the benefits?

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8. Please ✓ in the column that will answer the types of works related to types of subcontractor and types of relationship development.

Note: STR=short term relationship, LTR=long term relationship

BOTH= short and long term relationship

N	Labor	Labor+ material	Both	Task Name	STR	LTR	BOTH
1				1- Earth Works			
2				Excavation			
3				Backfill			
4				Gravel Compaction			
5				Lean Concrete			
6				Polyethylene Sheet			
7				Soil Treatment (Anti Termite)			
8				2- Structural Works			
9				Concrete			
10				Formwork			
11				Reinforcing Bar			
12				Brick			
13				Steel Structure			
14				3- Exterior & Interior Finishing Works			
15				Masonry work			
16				Floor Finishing			
17				Gypsum Board			
18				Ceiling			
19				Color Paint			
20				4- Miscellaneous Works			
21				Hand rail			
22				Insect net			
23				Door and Window			
24				Toilet Partition			
25				Electricity			
26				Water system			

a. If any type of work is not included, please put in the space provided.

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……..…..

b. Explanation the reason of type of works that uses short-term relationship for above table

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……..……...……

……..…….

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c. Explanation the reason of works that uses long-term relationship for above table

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d. Explanation the reason of works that uses short and long-term relationship for above table

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……..……...……

……..…….

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9. Please ✓ in the box that you prefer or think that are important in developing subcontractor relationship in construction project.

1. Do you think **trust** is the important criterion in developing subcontractor relationship?					
Trust: a willingness of making friend with main-contractor who subcontractor has confidence with.	Very Disagree	Dis agree	Neutral	Agree	Very Agree
2. Do you think **honesty** is the important criterion in developing subcontractor relationship?					
Honesty: refers to a facet of moral character and denotes positive, virtuous attributes that subcontractor does not lie, cheat, or theft the main contractor.	Very Disagree	Dis agree	Neutral	Agree	Very Agree
3. Do you think **commitment** is the important criterion in developing subcontractor relationship?					
Commitment: is willingness for the subcontractor company to exert force in	Very Disagree	Dis	Neutral	Agree	Very

carrying out a task.		agree			Agree
4. Do you think **experience** is the important criterion in developing subcontractor relationship?					
Experience: knowledge or practical wisdom of subcontractor who gained from what one has observed, encountered, or undergone.	Very Disagree	Dis agree	Neutral	Agree	Very Agree
5. Do you think **flexibility to change** is the important criterion in developing subcontractor relationship?					
Flexibility to change: is ability that subcontractor could handle both the unexpected threats and opportunities posed by an uncertain future and unstable environment.	Very Disagree	Dis agree	Neutral	Agree	Very Agree
6. Do you think **clear understanding** is the important criterion in developing subcontractor relationship?					
Clear understanding: means the level of subcontractor understand accurately while working with main-contractor.	Very Disagree	Dis agree	Neutral	Agree	Very Agree
7. Do you think **innovation** is the important criterion in developing subcontractor relationship?					
Innovation: subcontractor has a process of development, or management which can improve their work such as technical or safety management.	Very Disagree	Dis agree	Neutral	Agree	Very Agree
8. Do you think **communication** is the important criterion in developing subcontractor relationship?					
Communication: Subcontractor has the capability to exchange information, ideas, knowledge, skill and technology with main	Very Disagree	Dis	Neutral	Agree	Very

contractor through difference effective channels.		agree			Agree

Coordination: Subcontractor organizes of the different activity in a construction project so as to enable the employee to work together effectively.	Very Disagree	Dis agree	Neutral	Agree	Very Agree
10. Do you think **joint problem solving** is the important criterion in developing subcontractor relationship?					
Joint problem solving: Subcontractor presents commitment and engages to solve the problem with main contractor.	Very Disagree	Dis agree	Neutral	Agree	Very Agree
11. Do you think **cooperation** is the important criterion in developing subcontractor relationship?					
Cooperation: Subcontractor works with main contractor well to achieve the construction objective.	Very Disagree	Dis agree	Neutral	Agree	Very Agree
12. Do you think **Monitoring** is the important criterion in developing subcontractor relationship?					
Monitoring: Subcontractor observes and checks the progress or quality of construction work over a period of time; keep under systematic review.	Very Disagree	Dis agree	Neutral	Agree	Very Agree
13. Do you think **time control in planning** is the important criterion in developing subcontractor relationship?					
Time control in planning: Subcontractor	Very	Dis	Neutral	Agree	Very

helps to manage time to avoid the delay in construction process.	Disagree	agree			Agree

14. Do you think **safety training for employees** is the important criterion in developing subcontractor relationship?					
Safety training for employees: Subcontractor has trained their employees about safety before entering the construction site.	Very Disagree	Dis agree	Neutral	Agree	Very Agree
15. Do you think **work quality** is the important criterion in developing subcontractor relationship?					
Work quality: Subcontractor produces the good quality of work.	Very Disagree	Dis agree	Neutral	Agree	Very Agree
16. Do you think **safety control system** is the important criterion in developing subcontractor relationship?					
Safety control system: Subcontractor follows safety system around construction site and during working time.	Very Disagree	Dis agree	Neutral	Agree	Very Agree
17. Do you think **wastage disposal control** is the important criterion in developing subcontractor relationship?					
Wastage disposal control: Subcontractor supports the management of material waste disposal; waste storing and delivering to the outside of construction area.	Very Disagree	Dis agree	Neutral	Agree	Very Agree

18. Do you think **employee skill training** is the important criterion in developing subcontractor relationship?					
Employee skill training: Subcontractor has provided skill training for new worker before working in construction site.	Very Disagree	Dis agree	Neutral	Agree	Very Agree

19. Do you think **financial status** is the important criterion in developing subcontractor relationship?					
Financial Status: The company budget which is shown by bank account and the detail information of subcontractor in case main contractor would like to contact for verifying the account.	Very Disagree	Dis agree	Neutral	Agree	Very Agree

20. Do you think **price adjustment** is the important criterion in developing subcontractor relationship?					
Price adjustment: Main contractor perception of high cost from subcontractor.	Very Disagree	Dis agree	Neutral	Agree	Very Agree

21. Do you think **Resources** is the important criterion in developing subcontractor relationship?					
Resources: refers to number of staff or labours and equipments that subcontractor process.	Very Disagree	Dis agree	Neutral	Agree	Very Agree

22. Do you think **Knowledge** is the important criterion in developing subcontractor relationship?					
Knowledge: refers to level of education of	Very	Dis	Neutral	Agree	Very

subcontractor.	Disagree	agree			Agree

10. If any criteria are not included, please put in the space provided.

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11. Do you have any problem about Subcontractor Company in Cambodia that would like to suggest for improving?

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ଌThank youଌ

APPENDIX B
Questionnaire for Data Collection Part II

จุฬาลงกรณ์มหาวิทยาลัย
Chulalongkorn University
Pillar of the Kingdom

Faculty of Engineering
Department of Civil Engineering
Construction Management

No……..……

Date: ……..…….

SURVEY OF SUBCONTRACTOR RELATIONSHIPS IN CONSTRUCITON PROJECT

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Part [1]: General Information of Respondent

Background Information		
1.1	Company name	
1.2	Name of respondent	
	Position	
	Experience in Building	

	Construction Work (Years)	
	Tel.	
	E-mail	
	Website	

Part [2]: Subcontractor Information

Please put the subcontractor name, type of sub-work and choose one of subcontractor types that you are possessing.

Note: There are two types of subcontractor such as C: company , G: Group people or team

I. Short-term relationship

N	Code	Subcontractor Name	Type of sub-work	Type of subcontractor
1	S_1	……		☐ C ☐ G
2	S_2	……		☐ C ☐ G
3	S_3	……		☐ C ☐ G
4	S_4	……		☐ C ☐ G
5	S_5	……		☐ C ☐ G
6	S_6	……		☐ C ☐ G
7	S_7	……		☐ C ☐ G
8	S_8	……		☐ C ☐ G
9	S_9	……		☐ C ☐ G

II. Long-term relationship

N	Code	Subcontractor Name	Type of sub-work	Type of subcontractor
1	S_1	……		☐ C ☐ G
2	S_2	……		☐ C ☐ G
3	S_3	……		☐ C ☐ G
4	S_4	……		☐ C ☐ G
5	S_5	……		☐ C ☐ G
6	S_6	……		☐ C ☐ G
7	S_7	……		☐ C ☐ G
8	S_8	……		☐ C ☐ G
9	S_9	……		☐ C ☐ G

Part [3]: Subcontractor Evaluation

Please evaluates subcontractor with these factors by given the number of likert scale below.

1=Very disagree 2=Disagree 3=Neutral 4=Agree 5=Very agree

N	Subcontractor / Factors									
1	Work quality									
2	Time control in planning									
3	Work experience									
4	Cooperation									
5	Honesty									
6	Commitment									
7	Profit base									

8	Resources									
9	Coordination									
10	Monitoring									
11	Trust									
12	Joint problem solving									
13	Clear understanding									
14	Safety training for employees									
15	Communication									
16	Flexibility to change									
17	Employee skill training									
18	Safety control system									
19	Financial status									
20	Knowledge									
21	Innovation									
22	Wastage disposal control									

ꕥThank youꕥ

Question Design for Part II

This question is developed in each factor to ask main contractor for evaluation their own subcontractors

1. Do you agree that this S_1 has done a good quality of work when S_1 worked with you?
2. Do you agree that S_1 has practiced the time control in planning when S_1worked with you?
3. Do you agree that S_1 has enough experience of work to be a partner in the future?
4. Do you agree that S_1 has presented the cooperative activity with you in the operating of construction work?
5. Do you agree that S_1 is honest in handling the subcontracted work?
6. Do you agree that S_1 has committed to work successfully?
7. Do you agree that the price of S1 in every bidding for work is acceptable?
8. Do you agree that S_1 has coordinated the work effectively for you?
9. Do you agree that S_1 has enough resources to work with you for long run?
10. Do you agree that S_1 has monitored the sublet work effectively?
11. Do you agree that S_1 is a trusted person for given the work?
12. Do you agree that S_1 has come to discuss and try to solve problem with you?
13. Do you agree that S_1 has clear understanding work after you have explained him?
14. Do you agree that this S_1 has cooperated with safety regulation to their staff before sending to the construction site?
15. Do you agree that S_1 has a good communication with you in construction work?
16. Do you agree that S_1 is a flexible person on construction work?
17. Do you agree that S_1 has trained some skills to their employee before sending to construction site?
18. Do you agree that S_1 has provided safe equipment to their employees in construction work?
19. Do you agree that S_1 has enough cash flow while working with you?
20. Do you agree that S_1 has enough education level that you prefer to be a partner in the suture?
21. Do you agree that S_1 has an innovative idea that can help you to save cost?
22. Do you agree that this S_1 has controlled and managed the waste disposal properly?

APPENDIX C

Data Collection of Part II

and Result of Discriminant Analysis by Using SPSS

Table C.1 Data collection for main contractor evaluation on each subcontractor

N	Subcontractor Code	Type	Work quality	Time control in planning	Experience	Cooperation	Honesty	Commitment	Resources	Coordination	Monitoring	Trust	Group	Remark
1	S1	G	4	4	4	4	2	3	4	4	4	3	L	2
2	S5	G	5	4	4	3	4	3	5	3	3	4	L	2
3	S13	G	4	3	4	4	3	5	5	5	4	4	L	2
4	S19	G	4	4	5	3	5	3	4	4	4	4	L	2
5	S33	C	3	4	4	4	4	3	4	3	3	4	L	2
6	S34	G	3	4	4	5	4	4	3	3	4	4	L	2
7	S62	C	3	5	3	5	3	5	4	4	5	5	L	2
8	S84	C	5	4	5	5	4	5	3	2	5	5	L	2
9	S91	G	4	3	4	3	3	3	3	2	3	2	S	1
10	S2	G	3	4	4	3	2	2	4	4	3	3	S	1
11	S3	G	3	4	2	3	3	2	2	3	2	3	S	1
12	S4	C	4	5	4	4	3	4	3	4	4	5	L	2
13	S6	G	4	5	5	5	4	3	5	3	4	2	L	2
14	S7	G	4	2	3	4	4	5	4	5	4	4	L	2
15	S8	G	4	4	4	3	4	4	5	5	4	4	L	2
16	S9	G	5	4	2	4	4	4	4	2	3	3	L	2
17	S10	G	5	4	4	4	5	5	4	3	4	4	L	2
18	S12	G	5	4	4	3	4	2	4	3	3	3	L	2
19	S15	G	3	4	4	3	3	5	4	5	3	5	L	2
20	S16	G	4	3	5	4	4	5	5	5	5	5	L	2

N	Subcontractor Code	Type	Work quality	Time control in planning	Experience	Cooperation	Honesty	Commitment	Resources	Coordination	Monitoring	Trust	Group	Remark
21	S18	G	4	4	5	5	5	4	5	5	5	5	L	2
22	S20	G	4	5	5	4	4	5	5	4	5	5	L	2
23	S21	G	4	5	4	5	5	4	3	5	4	5	L	2
24	S22	G	4	5	3	4	4	4	5	4	5	4	L	2
25	S25	C	4	3	4	3	3	4	3	3	4	3	S	1
26	S26	C	4	3	3	3	3	3	3	3	3	2	S	1
27	S24	C	4	3	4	4	3	4	3	3	2	4	L	2
28	S28	G	3	3	4	4	3	2	3	3	4	3	S	1
29	S27	C	4	4	4	4	3	3	4	4	3	4	L	2
30	S30	C	3	4	4	4	4	4	4	4	4	4	L	2
31	S31	C	4	2	3	4	3	4	2	4	3	3	L	2
32	S32	C	4	4	4	4	3	4	5	4	4	5	L	2
33	S36	G	4	4	4	5	4	3	4	2	4	3	L	2
34	S38	G	2	3	3	3	2	3	5	3	4	2	S	1
35	S39	G	3	4	4	3	3	3	3	3	4	3	S	1
36	S37	G	4	5	3	4	3	3	3	3	3	4	L	2
37	S40	C	4	4	4	5	4	4	2	5	3	2	L	2
38	S42	G	3	2	2	3	2	2	2	4	3	2	S	1
39	S43	C	3	2	3	2	2	4	4	3	3	2	S	1
40	S45	G	3	3	3	2	2	2	2	2	2	2	S	1
41	S41	C	4	5	5	5	4	4	5	5	4	4	L	2
42	S46	G	4	4	3	3	2	2	3	3	3	4	L	2

N	Subcontractor Code	Type	Work quality	Time control in planning	Experience	Cooperation	Honesty	Commitment	Resources	Coordination	Monitoring	Trust	Group	Remark
43	S47	C	4	5	4	3	4	4	4	4	3	4	L	2
44	S48	G	5	4	4	5	5	4	3	5	4	4	L	2
45	S50	G	4	3	3	3	2	3	2	3	4	3	S	1
46	S51	G	3	3	4	2	3	3	3	3	3	3	S	1
47	S49	G	4	5	4	3	4	4	3	4	3	3	L	2
48	S52	C	4	5	4	3	2	3	3	3	4	4	L	2
49	S55	G	4	3	3	3	3	3	3	3	3	3	S	1
50	S53	G	4	3	4	4	4	4	3	3	4	3	L	2
51	S58	G	4	4	2	3	2	3	2	1	3	1	S	1
52	S60	G	3	3	2	2	2	2	3	2	2	3	S	1
53	S61	G	2	3	1	3	2	3	3	3	3	2	S	1
54	S57	G	4	5	3	4	5	5	4	3	4	4	L	2
55	S66	C	2	3	3	4	4	4	2	3	4	4	L	2
56	S67	G	3	4	4	2	1	2	1	2	2	2	S	1
57	S68	G	3	2	2	2	2	2	3	3	2	3	S	1
58	S63	G	4	3	4	4	3	4	3	4	4	4	L	2
59	S69	C	3	3	4	5	4	5	3	3	5	3	L	2
60	S70	G	4	3	5	4	4	4	3	2	4	3	L	2
61	S71	G	4	4	3	4	3	4	3	2	4	4	L	2
62	S73	C	3	2	3	3	3	3	3	3	3	2	S	1
63	S74	C	3	4	3	3	4	3	4	3	3	3	S	1
64	S75	G	4	5	2	2	3	2	3	2	2	3	S	1

N	Subcontractor Code	Type	Work quality	Time control in planning	Experience	Cooperation	Honesty	Commitment	Resources	Coordination	Monitoring	Trust	Group	Remark
65	S72	G	5	4	4	5	3	5	3	4	5	3	L	2
66	S77	C	4	5	4	4	1	4	2	5	4	2	L	2
67	S78	G	5	4	4	3	2	3	1	4	3	4	L	2
68	S80	G	3	2	2	2	2	2	3	3	2	3	S	1
69	S81	C	2	4	3	4	3	4	2	2	4	2	S	1
70	S82	G	4	3	3	2	3	2	3	2	2	3	S	1
71	S83	G	3	3	4	4	3	4	2	3	4	2	S	1
72	S79	G	4	5	4	2	2	2	4	3	3	4	L	2
73	S85	G	4	3	4	4	4	4	3	3	4	2	S	1
74	S87	G	3	4	4	2	1	2	1	3	2	2	S	1
75	S88	G	2	3	3	3	3	3	3	2	3	3	S	1
76	S86	C	4	5	3	5	4	5	4	3	5	4	L	2
77	S89	C	3	4	4	5	3	5	3	3	5	4	L	2
78	S92	G	3	3	3	3	2	3	2	2	3	3	S	1
79	S90	C	4	5	4	4	4	4	3	2	4	3	L	2
80	S14	G	3	2	3	3	3	3	4	3	4	4	S	1
81	S11	G	3	4	4	5	4	4	4	4	4	3	L	2
82	S17	C	3	4	5	5	5	4	5	5	5	5	L	2
83	S23	C	4	4	3	3	3	4	4	3	3	4	L	2
84	S35	C	3	4	4	4	4	4	4	3	4	4	L	2
85	S59	C	3	4	4	4	3	5	3	3	4	2	S	1
86	S65	G	4	5	3	2	2	2	1	4	2	3	S	1

N	Subcontractor Code	Type	Work quality	Time control in planning	Experience	Cooperation	Honesty	Commitment	Resources	Coordination	Monitoring	Trust	Group	Remark
87	S56	G	4	3	4	4	4	4	5	4	3	5	L	2
88	S76	G	5	4	4	4	3	4	3	3	4	3	L	2
89	S93	C	5	4	3	5	4	5	4	3	5	3	L	2
90	S29	C	3	4	3	3	3	3	4	3	2	3	S	1
91	S44	G	3	4	3	3	3	3	3	4	3	3	S	1
92	S54	G	4	3	4	3	2	4	2	3	3	3	S	1
93	S64	G	5	4	4	4	3	4	4	3	4	4	L	2

Table C.2 Result of discriminant analysis by using SPSS

Group Statistics

Category		Mean	Std. Deviation
1 Short term relationship	Work quality	3.17	.648
	Time control in planning	3.17	.747
	Experience	3.03	.850
	Cooperation	2.80	.664
	Honesty	2.53	.730
	Commitment	2.77	.728
	Resources	2.77	.858
	Coordination	2.70	.651
	Monitoring	2.97	.765
	Trust	2.50	.572
2 long term relationship	Work quality	3.98	.629
	Time control in planning	4.08	.812
	Experience	3.92	.672
	Coorperation	4.04	.763
	Honesty	3.59	.911
	Commitment	3.94	.852
	Resources	3.61	.975
	Coordination	3.63	.972
	Monitoring	3.88	.754
	Trust	3.84	.800

Category		Mean	Std. Deviation
Total	Work quality	3.67	.746
	Time control in planning	3.73	.902
	Experience	3.58	.856
	Cooperation	3.57	.943
	Honesty	3.19	.988
	Commitment	3.49	.985
	Resources	3.29	1.015
	Coordination	3.28	.973
	Monitoring	3.53	.875
	Trust	3.33	.970

Group Statistics

Category		Valid N (listwise)	
		Unweighted	Weighted
1 Short term relationship	Work quality	30	30.000
	Time control in planning	30	30.000
	Experience	30	30.000
	Cooperation	30	30.000
	Honesty	30	30.000
	Commitment	30	30.000
	Resources	30	30.000
	Coordination	30	30.000
	Monitoring	30	30.000
	Trust	30	30.000

Category		Unweighted	Weighted
2 long term relationship	Work quality	49	49.000
	Time control in planning	49	49.000
	Experience	49	49.000
	Cooperation	49	49.000
	Honesty	49	49.000
	Commitment	49	49.000
	Resources	49	49.000
	Coordination	49	49.000
	Monitoring	49	49.000
	Trust	49	49.000
Total	Work quality	79	79.000
	Time control in planning	79	79.000
	Experience	79	79.000
	Cooperation	79	79.000
	Honesty	79	79.000
	Commitment	79	79.000
	Resources	79	79.000
	Coordination	79	79.000
	Monitoring	79	79.000
	Trust	79	79.000

Analysis 1

Box's Test of Equality of Covariance Matrices

Log Determinants

Category	Rank	Log Determinant
1 Short term relationship	4	-3.443
2 long term relationship	4	-2.390
Pooled within-groups	4	-2.710

The ranks and natural logarithms of determinants printed are those of the group covariance matrices.

Test Results

Box's M		5.883
F	Approx.	.552
	df1	10
	df2	17589.505
	Sig.	.854

Tests null hypothesis of equal population covariance matrices.

Stepwise Statistics

Variables Entered/Removed[a,b,c,d]

Step	Entered	Min. D Squared					
		Statistic	Between Groups	Exact F			
				Statistic	df1	df2	Sig.
1	Trust	3.423	1 Short term relationship and 2 long term relationship	63.696	1	77.000	1.107E-11
2	Cooperation	6.965	1 Short term relationship and 2 long term relationship	63.963	2	76.000	5.141E-17
3	Work quality	9.711	1 Short term relationship and 2 long term relationship	58.666	3	75.000	1.248E-19
4	Time control in planning	10.481	1 Short term relationship and 2 long term relationship	46.858	4	74.000	1.442E-19

At each step, the variable that maximizes the Mahalanobis distance between the two closest groups is entered.
a. Maximum number of steps is 20.
b. Minimum partial F to enter is 3.84.
c. Maximum partial F to remove is 2.71.
d. F level, tolerance, or VIN insufficient for further computation.

Variables in the Analysis

Step		Tolerance	F to Remove	Min. D Squared	Between Groups
1	Trust	1.000	63.696		
2	Trust	.992	43.704	2.911	1 Short term relationship and 2 long term relationship
	Cooperation	.992	35.604	3.423	1 Short term relationship and 2 long term relationship
3	Trust	.984	37.515	5.093	1 Short term relationship and 2 long term relationship
	Cooperation	.978	33.398	5.444	1 Short term relationship and 2 long term relationship
	Work quality	.980	18.543	6.965	1 Short term relationship and 2 long term relationship
4	Trust	.978	30.767	6.188	1 Short term relationship and 2 long term relationship
	Cooperation	.978	29.994	6.265	1 Short term relationship and 2 long term relationship
	Work quality	.972	15.009	8.016	1 Short term relationship and 2 long term relationship
	Time control in planning	.987	4.118	9.711	1 Short term relationship and 2 long term relationship

Variables Not in the Analysis

	Step	Tolerance	Min. Tolerance	F to Enter	Min. D Squared	Between Groups
0	Work quality	1.000	1.000	30.400	1.634	1 Short term relationship and 2 long term relationship
	Time control in planning	1.000	1.000	25.073	1.347	1 Short term relationship and 2 long term relationship
	Experience	1.000	1.000	26.320	1.414	1 Short term relationship and 2 long term relationship
	Cooperation	1.000	1.000	54.176	2.911	1 Short term relationship and 2 long term relationship
	Honesty	1.000	1.000	29.028	1.560	1 Short term relationship and 2 long term relationship
	Commitment	1.000	1.000	39.225	2.108	1 Short term relationship and 2 long term relationship
	Resources	1.000	1.000	15.290	.822	1 Short term relationship and 2 long term relationship
	Coordination	1.000	1.000	21.604	1.161	1 Short term relationship and 2 long term relationship
	Monitoring	1.000	1.000	26.876	1.444	1 Short term relationship and 2 long term relationship
	Trust	1.000	1.000	63.696	3.423	1 Short term relationship and 2 long term relationship
1	Work quality	.994	.994	20.310	5.444	1 Short term relationship and 2 long term relationship
	Time control in planning	.995	.995	10.672	4.485	1 Short term relationship and 2 long term relationship
	Experience	.995	.995	11.392	4.556	1 Short term relationship and 2 long term relationship
	Cooperation	.992	.992	35.604	6.965	1 Short term relationship and 2 long term relationship
	Honesty	.973	.973	9.234	4.342	1 Short term relationship and 2 long term relationship
	Commitment	.988	.988	15.789	4.994	1 Short term relationship and 2 long term relationship
	Resources	.912	.912	1.409	3.563	1 Short term relationship and 2 long term relationship
	Coordination	.952	.952	4.764	3.897	1 Short term relationship and 2 long term relationship
	Monitoring	.983	.983	9.417	4.360	1 Short term relationship and 2 long term relationship

	Step	Tolerance	Min. Tolerance	F to Enter	Min. D Squared	Between Groups
2	Work quality	.980	.978	18.543	9.711	1 Short term relationship and 2 long term relationship
	Time control in planning	.995	.987	7.098	8.016	1 Short term relationship and 2 long term relationship
	Experience	.970	.966	4.041	7.564	1 Short term relationship and 2 long term relationship
	Honesty	.816	.816	.330	7.014	1 Short term relationship and 2 long term relationship
	Commitment	.722	.722	.714	7.071	1 Short term relationship and 2 long term relationship
	Resources	.912	.904	.803	7.084	1 Short term relationship and 2 long term relationship
	Coordination	.945	.941	1.929	7.251	1 Short term relationship and 2 long term relationship
	Monitoring	.558	.558	.865	7.093	1 Short term relationship and 2 long term relationship
3	Time control in planning	.987	.972	4.118	10.481	1 Short term relationship and 2 long term relationship
	Experience	.945	.945	1.431	9.978	1 Short term relationship and 2 long term relationship
	Honesty	.784	.784	.066	9.723	1 Short term relationship and 2 long term relationship
	Commitment	.722	.720	.782	9.857	1 Short term relationship and 2 long term relationship
	Resources	.911	.897	.517	9.807	1 Short term relationship and 2 long term relationship
	Coordination	.944	.936	1.966	10.079	1 Short term relationship and 2 long term relationship
	Monitoring	.558	.558	.528	9.809	1 Short term relationship and 2 long term relationship
4	Experience	.940	.940	1.024	10.686	1 Short term relationship and 2 long term relationship
	Honesty	.783	.783	.033	10.488	1 Short term relationship and 2 long term relationship
	Commitment	.695	.695	1.573	10.796	1 Short term relationship and 2 long term relationship
	Resources	.911	.893	.415	10.564	1 Short term relationship and 2 long term relationship
	Coordination	.927	.925	2.649	11.012	1 Short term relationship and 2 long term relationship
	Monitoring	.557	.557	.597	10.601	1 Short term relationship and 2 long term relationship

Wilks' Lambda

Step	Number of Variables	Lambda	df1	df2	df3
1	1	.547	1	1	77
2	2	.373	2	1	77
3	3	.299	3	1	77
4	4	.283	4	1	77

Wilks' Lambda

Step	Exact F			
	Statistic	df1	df2	Sig.
1	63.696	1	77.000	.000
2	63.963	2	76.000	.000
3	58.666	3	75.000	.000
4	46.858	4	74.000	.000

Summary of Canonical Discriminant Functions

Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	2.533[a]	100.0	100.0	.847

a. First 1 canonical discriminant functions were used in the analysis.

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1	.283	94.658	4	.000

Standardized Canonical Discriminant Function Coefficients

	Function
	1
Work quality	.492
Time control in planning	.273
Cooperation	.642
Trust	.647

Structure Matrix

	Function
	1
Trust	.571
Coorperation	.527
Monitoring[a]	.451
Honesty[a]	.408
Work quality	.395
Time control in planning	.359
Commitment[a]	.304
Experience[a]	.232
Resources[a]	.195
Coordination[a]	.116

Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	2.533[a]	100.0	100.0	.847

a. This variable not used in the analysis.

Canonical Discriminant Function Coefficients

	Function
	1
Work quality	.773
Time control in planning	.346
Cooperation	.882
Trust	.896
(Constant)	-10.263

Unstandardized coefficients

Functions at Group Centroids

Category	Function
	1
1 Short term relationship	-2.008
2 long term relationship	1.229

Canonical Discriminant Function Coefficients

	Function
	1
Work quality	.773
Time control in planning	.346
Cooperation	.882
Trust	.896
(Constant)	-10.263

Unstandardized canonical discriminant functions evaluated at group means

Classification Statistics

Classification Processing Summary

Processed	79
Excl Missing or out-of-range group codes	0
uded At least one missing discriminating variable	0
Used in Output	79

Prior Probabilities for Groups

Category		Cases Used in Analysis	
	Prior	Unweighted	Weighted
1 Short term relationship	.380	30	30.000
2 long term relationship	.620	49	49.000
Total	1.000	79	79.000

Classification Results[b,c]

		Category	Predicted Group Membership		
			1 Short term relationship	2 long term relationship	Total
Original	Count	1 Short term relationship	30	0	30
		2 long term relationship	1	48	49
	%	1 Short term relationship	100.0	.0	100.0
		2 long term relationship	2.0	98.0	100.0
Cross-validated[a]	Count	1 Short term relationship	30	0	30
		2 long term relationship	1	48	49
	%	1 Short term relationship	100.0	.0	100.0
		2 long term relationship	2.0	98.0	100.0

a. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.
b. 98.7% of original grouped cases correctly classified.
c. 98.7% of cross-validated grouped cases correctly classified.

APPENDIX D

Independent sample t-test of 22 factors

Table D.1 Group Statistics

	category	N	Mean	Std. Deviation	Std. Error Mean
Trust	1 Direct	13	4.23	.927	.257
	2 Project manager	22	3.95	.575	.123
Honesty	1 Direct	13	4.08	.641	.178
	2 Project manager	22	4.14	.468	.100
Commitment	1 Direct	13	4.23	.599	.166
	2 Project manager	22	4.05	.486	.104
Experience	1 Direct	13	4.15	.801	.222
	2 Project manager	22	4.18	.733	.156
Flexibility to change	1 Direct	13	4.15	.376	.104
	2 Project manager	22	3.77	.685	.146
Clear understanding	1 Direct	13	3.92	.641	.178
	2 Project manager	22	4.05	.486	.104
Innovation	1 Direct	13	4.08	.277	.077
	2 Project manager	22	3.86	.710	.151
Communication	1 Direct	13	3.92	.954	.265
	2 Project manager	22	3.95	.375	.080
Coordination	1 Direct	13	4.15	.689	.191
	2 Project manager	22	3.95	.575	.123
Joint problem solving	1 Direct	13	4.15	.689	.191
	2 Project manager	22	3.86	.640	.136
Cooperation	1 Direct	13	4.31	.630	.175
	2 Project manager	22	4.23	.528	.113

	category	N	Mean	Std. Deviation	Std. Error Mean
Monitoring	1 Direct	13	4.00	.408	.113
	2 Project manager	22	4.18	.501	.107
Time control in planning	1 Direct	13	4.54	.660	.183
	2 Project manager	22	4.50	.598	.127
Safety training for employees	1 Direct	13	3.85	.801	.222
	2 Project manager	22	3.95	.899	.192
Work quality	1 Direct	13	4.62	.506	.140
	2 Project manager	22	4.36	.581	.124
Safety control system	1 Direct	13	3.92	.494	.137
	2 Project manager	22	3.68	.780	.166
Wastage disposal control	1 Direct	13	3.77	.725	.201
	2 Project manager	22	3.59	.590	.126
Employee skill training	1 Direct	13	4.00	.577	.160
	2 Project manager	22	3.86	.560	.119
Financial Status	1 Direct	13	3.31	.947	.263
	2 Project manager	22	3.73	.631	.135
Price adjustment	1 Direct	13	3.92	.760	.211
	2 Project manager	22	3.95	.575	.123
Resources	1 Direct	13	4.08	.641	.178
	2 Project manager	22	4.18	.588	.125
Knowledge	1 Direct	13	3.69	.630	.175
	2 Project manager	22	3.73	.550	.117

Table D.2 Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Trust	Equal variances assumed	10.9	.002	1.092	33	.283	.276	.253	-.239	.791
	Equal variances not assumed			.970	17.569	.345	.276	.285	-.323	.876
Honesty	Equal variances assumed	.67	.416	-.316	33	.754	-.059	.188	-.442	.323
	Equal variances not assumed			-.292	19.634	.774	-.059	.204	-.485	.366
Commitment	Equal variances assumed	2.51	.122	1.000	33	.325	.185	.185	-.192	.562
	Equal variances not assumed			.946	21.295	.355	.185	.196	-.222	.592
Experience	Equal variances assumed	.14	.703	-.105	33	.917	-.028	.265	-.568	.512
	Equal variances not assumed			-.103	23.523	.919	-.028	.271	-.589	.533
Flexibility to change	Equal variances assumed	3.49	.070	1.841	33	.075	.381	.207	-.040	.802
	Equal variances not assumed			2.124	32.899	.041	.381	.179	.016	.746
Clear understanding	Equal variances assumed	1.22	.276	-.639	33	.527	-.122	.191	-.512	.267
	Equal variances not assumed			-.595	20.208	.558	-.122	.206	-.551	.306
Innovation	Equal variances assumed	5.14	.030	1.032	33	.309	.213	.207	-.207	.634
	Equal variances not assumed			1.256	29.769	.219	.213	.170	-.134	.560

		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Communication	Equal variances assumed	5.44	.026	-.139	33	.891	-.031	.227	-.493	.430
	Equal variances not assumed			-.114	14.224	.911	-.031	.276	-.623	.561
Coordination	Equal variances assumed	1.25	.271	.920	33	.364	.199	.217	-.241	.640
	Equal variances not assumed			.878	21.821	.390	.199	.227	-.272	.670
Joint problem solving	Equal variances assumed	.113	.739	1.261	33	.216	.290	.230	-.178	.758
	Equal variances not assumed			1.237	23.813	.228	.290	.235	-.194	.775
Cooperation	Equal variances assumed	1.09	.303	.405	33	.688	.080	.199	-.324	.484
	Equal variances not assumed			.387	21.877	.703	.080	.208	-.351	.512
Monitoring	Equal variances assumed	3.26	.080	-1.107	33	.276	-.182	.164	-.516	.152
	Equal variances not assumed			-1.168	29.511	.252	-.182	.156	-.500	.136
Time control in planning	Equal variances assumed	.069	.794	.177	33	.861	.038	.217	-.404	.481
	Equal variances not assumed			.172	23.310	.865	.038	.223	-.423	.500
Safety training for employees	Equal variances assumed	2.04	.162	-.359	33	.722	-.108	.302	-.723	.507
	Equal variances not assumed			-.370	27.731	.714	-.108	.293	-.709	.493
Work quality	Equal variances assumed	.467	.499	1.296	33	.204	.252	.194	-.143	.647
	Equal variances not assumed			1.344	28.188	.190	.252	.187	-.132	.635
Safety control system	Equal variances assumed	6.65	.015	1.000	33	.325	.241	.241	-.250	.732
	Equal variances not assumed			1.120	32.770	.271	.241	.215	-.197	.680
Wastage disposal control	Equal variances assumed	.294	.591	.793	33	.433	.178	.225	-.279	.636
	Equal variances not assumed			.752	21.370	.460	.178	.237	-.314	.671

		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Employee skill training	Equal variances assumed	.325	.572	.688	33	.496	.136	.198	-.267	.540
	Equal variances not assumed			.683	24.699	.501	.136	.200	-.275	.548
Financial Status	Equal variances assumed	3.91	.056	-1.575	33	.125	-.420	.266	-.962	.122
	Equal variances not assumed			-1.421	18.396	.172	-.420	.295	-1.039	.200
Price adjustment	Equal variances assumed	1.87	.181	-.139	33	.891	-.031	.227	-.493	.430
	Equal variances not assumed			-.129	20.194	.899	-.031	.244	-.540	.477
Resources	Equal variances assumed	.020	.888	-.493	33	.625	-.105	.213	-.538	.328
	Equal variances not assumed			-.482	23.602	.634	-.105	.217	-.554	.344
Knowledge	Equal variances assumed	.480	.493	-.172	33	.864	-.035	.203	-.448	.378
	Equal variances not assumed			-.166	22.625	.870	-.035	.211	-.471	.401

APPENDIX E
Independent samples t-test of 10 factors

Table E.1 Group Statistics

	category	N	Mean	Std. Deviation	Std. Error Mean
Work quality	1 short-term relationship	37	3.24	.683	.112
	2 long-term relationship	56	3.96	.660	.088
Time control in planning	1 short-term relationship	37	3.27	.804	.132
	2 long-term relationship	56	4.05	.773	.103
Experience	1 short-term relationship	37	3.11	.809	.133
	2 long-term relationship	56	3.91	.668	.089
Cooperation	1 short-term relationship	37	2.86	.673	.111
	2 long-term relationship	56	4.07	.759	.101
Honesty	1 short-term relationship	37	2.57	.689	.113
	2 long-term relationship	56	3.63	.885	.118
Commitment	1 short-term relationship	37	2.89	.809	.133
	2 long-term relationship	56	3.96	.808	.108
Resources	1 short-term relationship	37	2.81	.908	.149
	2 long-term relationship	56	3.68	.956	.128
Coordination	1 short-term relationship	37	2.81	.660	.108
	2 long-term relationship	56	3.63	.945	.126
Monitoring	1 short-term relationship	37	3.00	.782	.129
	2 long-term relationship	56	3.89	.755	.101
Trust	1 short-term relationship	37	2.62	.639	.105
	2 long-term relationship	56	3.84	.804	.107

Table E.2 Independent Samples Test

		Levene's Test		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Work quality	Equal variances assumed	1.712	.194	-5.087	91	.000	-.721	.142	-1.003	-.439
	Equal variances not assumed			-5.050	75.289	.000	-.721	.143	-1.005	-.437
Time control in planning	Equal variances assumed	1.226	.271	-4.707	91	.000	-.783	.166	-1.114	-.453
	Equal variances not assumed			-4.668	75.021	.000	-.783	.168	-1.118	-.449
Experience	Equal variances assumed	2.629	.108	-5.210	91	.000	-.803	.154	-1.109	-.497
	Equal variances not assumed			-5.010	66.864	.000	-.803	.160	-1.122	-.483
Cooperation	Equal variances assumed	.243	.623	-7.838	91	.000	-1.207	.154	-1.512	-.901
	Equal variances not assumed			-8.034	83.380	.000	-1.207	.150	-1.505	-.908
Honesty	Equal variances assumed	1.616	.207	-6.136	91	.000	-1.057	.172	-1.400	-.715
	Equal variances not assumed			-6.456	88.485	.000	-1.057	.164	-1.383	-.732
Commitment	Equal variances assumed	.378	.540	-6.260	91	.000	-1.072	.171	-1.413	-.732
	Equal variances not assumed			-6.259	77.163	.000	-1.072	.171	-1.414	-.731
Resources	Equal variances assumed	.876	.352	-4.371	91	.000	-.868	.199	-1.262	-.473
	Equal variances not assumed			-4.418	79.945	.000	-.868	.196	-1.259	-.477
Coordination	Equal variances assumed	11.577	.001	-4.554	91	.000	-.814	.179	-1.169	-.459
	Equal variances not assumed			-4.890	90.682	.000	-.814	.166	-1.145	-.483
Monitoring	Equal variances assumed	.026	.871	-5.504	91	.000	-.893	.162	-1.215	-.571
	Equal variances not assumed			-5.464	75.326	.000	-.893	.163	-1.218	-.567
Trust	Equal variances assumed	.400	.529	-7.734	91	.000	-1.218	.157	-1.530	-.905
	Equal variances not assumed			-8.103	87.810	.000	-1.218	.150	-1.516	-.919

APPENDIX F
Result from Qnet analysis

Targets and Network Outputs
Network Name: subcontractor
Iterations: 20000
(Note: * = Test Pattern)
1*=> Category target,output= 1.00000, 0.96991
2*=> Category target,output= 1.00000, 0.91585
3*=> Category target,output= 1.00000, 1.09744
4*=> Category target,output= 1.00000, 0.97116
5*=> Category target,output= 1.00000, 0.99125
6*=> Category target,output= 1.00000, 1.02245
7*=> Category target,output= 1.00000, 0.98868
8*=> Category target,output= 1.00000, 0.87283
9*=> Category target,output= 0.00000, 0.00409
10 => Category target,output= 0.00000, -0.04432
11 => Category target,output= 1.00000, 1.00963
12 => Category target,output= 1.00000, 1.00801
13 => Category target,output= 1.00000, 0.99807
14 => Category target,output= 1.00000, 1.01151
15 => Category target,output= 0.00000, 0.01044
16 => Category target,output= 0.00000, 0.01820
17 => Category target,output= 1.00000, 0.97879
18 => Category target,output= 1.00000, 1.02799
19 => Category target,output= 0.00000, 0.03334
20 => Category target,output= 0.00000, -0.03393
21 => Category target,output= 1.00000, 0.98555
22 => Category target,output= 1.00000, 1.00604
23 => Category target,output= 1.00000, 1.01672
24 => Category target,output= 1.00000, 0.96096
25 => Category target,output= 1.00000, 1.01109
26 => Category target,output= 1.00000, 0.98349
27 => Category target,output= 1.00000, 0.98456
28 => Category target,output= 1.00000, 1.01186
29 => Category target,output= 1.00000, 1.01357
30 => Category target,output= 1.00000, 1.00204
31 => Category target,output= 1.00000, 0.98787
32 => Category target,output= 1.00000, 0.96913
33 => Category target,output= 1.00000, 1.03345
34 => Category target,output= 0.00000, 0.02584
35 => Category target,output= 0.00000, -0.05584
36 => Category target,output= 1.00000, 1.00647
37 => Category target,output= 0.00000, 0.02086
38 => Category target,output= 1.00000, 1.00341
39 => Category target,output= 1.00000, 1.01503
40 => Category target,output= 1.00000, 0.96335
41 => Category target,output= 1.00000, 0.98772
42 => Category target,output= 1.00000, 1.00380
43 => Category target,output= 0.00000, 0.00811

44 => Category target,output= 0.00000, -0.04837
45 => Category target,output= 1.00000, 0.98724
46 => Category target,output= 1.00000, 1.03595
47 => Category target,output= 0.00000, -0.00643
48 => Category target,output= 0.00000, -0.01533
49 => Category target,output= 0.00000, 0.06111
50 => Category target,output= 1.00000, 0.98311
51 => Category target,output= 1.00000, 0.97403
52 => Category target,output= 1.00000, 1.03761
53 => Category target,output= 1.00000, 1.00831
54 => Category target,output= 0.00000, -0.00712
55 => Category target,output= 0.00000, 0.01349
56 => Category target,output= 1.00000, 1.00012
57 => Category target,output= 1.00000, 1.04002
58 => Category target,output= 0.00000, 0.07926
59 => Category target,output= 1.00000, 0.91123
60 => Category target,output= 0.00000, -0.00241
61 => Category target,output= 0.00000, -0.01046
62 => Category target,output= 0.00000, 0.00282
63 => Category target,output= 1.00000, 0.99584
64 => Category target,output= 1.00000, 1.03128
65 => Category target,output= 0.00000, -0.00032
66 => Category target,output= 0.00000, 0.00182
67 => Category target,output= 1.00000, 1.04832
68 => Category target,output= 1.00000, 0.99828
69 => Category target,output= 1.00000, 0.96318
70 => Category target,output= 1.00000, 1.03271
71 => Category target,output= 0.00000, 0.01137
72 => Category target,output= 0.00000, -0.01601
73 => Category target,output= 0.00000, 0.00441
74 => Category target,output= 1.00000, 0.98734
75 => Category target,output= 1.00000, 0.95741
76 => Category target,output= 1.00000, 1.02184
77 => Category target,output= 0.00000, 0.00182
78 => Category target,output= 0.00000, -0.03522
79 => Category target,output= 0.00000, -0.03783
80 => Category target,output= 0.00000, 0.00183
81 => Category target,output= 1.00000, 0.99599
82 => Category target,output= 0.00000, 0.06626
83 => Category target,output= 0.00000, -0.07041
84 => Category target,output= 0.00000, -0.01791
85 => Category target,output= 1.00000, 0.97903
86 => Category target,output= 1.00000, 1.02576
87 => Category target,output= 0.00000, 0.01407
88 => Category target,output= 1.00000, 1.01838

Network Weights and Current Adjustment Deltas
Network Name: Subcontractor Relationship
Iterations: 20000

Layer	Node	Connection	Weight	Weight Delta
2	1	1	-0.09556	-0.000043
2	1	2	0.14953	-0.000076
2	1	3	0.30379	0.000042
2	1	4	1.38795	-0.000022
2	1	5	-0.32469	0.000037
2	1	6	-0.56017	-0.000032
2	1	7	0.09176	-0.00004
2	1	8	-1.09234	-0.000068
2	1	9	-1.6328	-0.000016
2	1	10	1.57774	0.000003
2	1	11	0.4616	0.000219
2	2	1	0.73354	-0.000025
2	2	2	0.29325	0.000018
2	2	3	1.31915	-0.000019
2	2	4	1.42038	0.000011
2	2	5	0.2867	-0.000029
2	2	6	0.78987	-0.000002
2	2	7	0.52532	-0.000024
2	2	8	0.66666	0.000012
2	2	9	0.87874	0
2	2	10	1.6035	-0.000009
2	2	11	0.22743	-0.000046
2	3	1	1.03315	-0.000048
2	3	2	1.02059	-0.000024
2	3	3	1.49479	-0.000062
2	3	4	2.72645	-0.000003
2	3	5	0.38114	-0.000059
2	3	6	0.38102	0.000021
2	3	7	-0.11697	-0.000043
2	3	8	1.3215	-0.000007
2	3	9	0.18232	0.000005
2	3	10	3.88679	-0.000036
2	2	11	-0.71942	-0.000146

Layer	Node	Connection	Weight	Weight Delta
2	4	1	-1.16994	-0.000075
2	4	2	-0.54054	-0.000036
2	4	3	0.09205	0.000125
2	4	4	4.48772	0.0001
2	4	5	0.61465	-0.000082
2	4	6	2.95482	0.000136
2	4	7	-1.93522	-0.000017
2	4	8	0.55642	-0.000043
2	4	9	0.78928	0.000131
2	4	10	3.54966	0.000037
2	4	11	-2.17856	-0.000056
2	5	1	2.00358	-0.000055
2	5	2	3.06725	0.000078
2	5	3	0.34543	-0.000084
2	5	4	1.6263	0.000015
2	5	5	-0.56016	-0.000016
2	5	6	-0.87717	0.000043
2	5	7	1.60959	-0.000025
2	5	8	1.97686	0.000101
2	5	9	-0.91836	0.000001
2	5	10	1.86658	-0.000002
2	5	11	-3.56735	-0.000054
2	6	1	1.01915	-0.000001
2	6	2	2.26364	-0.000011
2	6	3	1.23444	-0.000005
2	6	4	4.35048	0
2	6	5	0.87716	-0.000006
2	6	6	-0.91737	0.000027
2	6	7	-0.70593	0.000011
2	6	8	2.39651	0.000008
2	6	9	-1.24609	0.000012
2	6	10	6.49285	-0.000003
2	6	11	-0.05197	-0.000011
2	7	1	0.95517	0.000026
2	7	2	0.3612	-0.000068
2	7	3	0.56839	0.000011
2	7	4	1.11529	0.000001

Layer	Node	Connection	Weight	Weight Delta
2	7	5	0.75875	0.000103
2	7	6	-0.06078	-0.00002
2	7	7	0.40881	0.000065
2	7	8	-0.11209	-0.000057
2	7	9	-0.70026	-0.000013
2	7	10	1.63336	0.00006
2	7	11	-0.4436	0.000013
2	8	1	-4.99421	-0.000107
2	8	2	-4.75534	-0.000123
2	8	3	-1.86739	0.000024
2	8	4	-10.01898	-0.000271
2	8	5	-0.08927	-0.000025
2	8	6	-2.54138	-0.000076
2	8	7	1.4832	0.00004
2	8	8	-0.58293	-0.000041
2	8	9	4.26681	0.000081
2	8	10	-12.01206	-0.000304
2	8	11	15.58895	0.000419
2	9	1	-0.14613	-0.000008
2	9	2	-1.77531	-0.000056
2	9	3	0.12371	-0.000001
2	9	4	-2.46589	0.000083
2	9	5	-0.74335	0.000078
2	9	6	5.8695	-0.000009
2	9	7	1.43812	-0.000005
2	9	8	-1.98417	0.000075
2	9	9	2.43465	0.000041
2	9	10	-4.43255	-0.00007
2	9	11	-2.53002	-0.00008
2	10	1	1.12206	0.000092
2	10	2	-0.1303	-0.00014
2	10	3	-2.41562	-0.00007
2	10	4	-5.10342	-0.000227
2	10	5	1.8879	0.000108
2	10	6	-2.17555	0.000149
2	10	7	-2.73018	-0.000084
2	10	8	0.78845	-0.000108

Layer	Node	Connection	Weight	Weight Delta
2	10	9	-1.96488	0.000025
2	10	10	-2.34513	-0.000014
2	10	11	2.30931	0.00013
3	1	1	-2.17414	-0.000004
3	1	2	2.46323	0.000009
3	1	3	4.50272	0.000023
3	1	4	-4.63683	-0.000007
3	1	5	-4.85811	0.000081
3	1	6	5.99617	-0.000011
3	1	7	-1.12544	-0.000037
3	1	8	-6.21136	0.000133
3	1	9	-4.41905	0.000048
3	1	10	-5.75032	-0.000233
3	1	11	0.61789	-0.000013

Network Statistics
Network Name: Subcontractor Relationship
Iterations: 20000

TRAINING DATA:

Node	Std Dev	Bias	Max Error	Correlation
Category	0.02901	-0.00017	0.08877	0.99826

TEST DATA:

Node	Std Dev	Bias	Max Error	Correlation
Category	0.06255	-0.01848	0.12717	0.98182

Validation samples:

Targets and Network Outputs
Network Name: NO NAME

1 => Category target,output= 1.00000, 0.92950
2 => Category target,output= 0.00000, 0.26418
3 => Category target,output= 0.00000, 0.01593
4 => Category target,output= 0.00000, 0.54390
5 => Category target,output= 1.00000, 1.00827

APPENDIX G

Decision making on selecting subcontractor relationship by using Microsoft Excel

Table G.1 Evaluation form of subcontractor

จุฬาลงกรณ์มหาวิทยาลัย
CHULALONGKORN UNIVERSITY
ภาควิชาวิศวกรรมโยธา คณะวิศวกรรมศาสตร์ ถนนพญาไท ปทุมวัน กรุงเทพฯ 10330
Department of Civil Engineering, Faculty of Engineering
Phayathai Rd., Pathumwan, Bangkok 10330 Tel : (662) 218-6460 to 62, Fax : (662) 251-7304

Evaluation Form: Decision Making Model on selecting subcontractor relationship

Date:
Subcontractor Name:

	Factors	Very Agree	Agree	Neutral	Disagree	Very Disagree
1	Do you agree that this subcontractor has practiced the time control in planning when he worked with you?	○	○	○	○	◉
2	Do you agree that this this subcontractor has done a good quality of work when he worked with you?	○	○	○	◉	○
3	Do you agree that this subcontractor has presented the cooperative activity with you in the operating of construction work?	○	○	○	◉	○
4	Do you agree that this subcontractor has enough experience of work to be a partner in the future?	○	◉	○	○	○
5	Do you agree that this subcontractor has enough resources to work with you for long run?	○	◉	○	○	○
6	Do you agree that this subcontractor is honest in handling the subcontracted work?	○	○	○	◉	○
7	Do you agree that this subcontractor has committed to work successfully?	○	○	○	◉	○
8	Do you agree that this subcontractor has monitored the sublet work effectively?	○	○	○	◉	○
9	Do you agree that this subcontractor is a trusted person for given the work?	○	○	○	○	◉
10	Do you agree that this subcontractor has coordinated the work effectively for you?	○	○	○	○	◉
	Subcontractor Relationship			0		

Table G.2 Decision making on selecting subcontractor relationship by using Microsoft Excel

Model of selecting subcontractor relationship															
Input Layer		Connection weight		$\sum_{i=0}^{n} x_i w_{ji}$	Bias Node	$\sum_{i=0}^{n} x_i w_{ji} + b$	Hidden Layer		Connection weight		$\sum_{i=0}^{n} x_i w_{ji}$	Bias Node	Output Layer		Remark
Time control in planningX1=	0	Weight X_1-X_1	-0.096		0.461819		Function 1		Weight 1	-2.174144		0.617877	Result=		
Work quality	0.25	Weight X_2-X_1	0.149454												
Cooperation X3=	0.25	Weight X_3-X_1	0.303832												
Experience X4=	0.75	Weight X_4-X_1	1.387928												
Resources X5=	0.75	Weight X_5-X_1	-0.324653												
Honesty X6=	0.25	Weight X_6-X_1	-0.560202												
Commitment X7=	0.25	Weight X_7-X_1	0.09172												
Monitoring X8=	0.25	Weight X_8-X_1	-1.092408												
TrustX9=	0	Weight X_9-X_1	-1.632816												
Coordination X10=	0	Weight X_{10}-X_1	1.577743												
			Sum=												
Time control in planningX1=	0	Weight X_1-X_2	0.734		0.227384		Function 2		Weight 2	2.463239					
Work quality	0.25	Weight X_2-X_2	0.293268												
Cooperation X3=	0.25	Weight X_3-X_2	1.319131												
Experience X4=	0.75	Weight X_4-X_2	1.420391												
Resources X5=	0.75	Weight X_5-X_2	0.286671												
Honesty X6=	0.25	Weight X_6-X_2	0.789868												
Commitment X7=	0.25	Weight X_7-X_2	0.525296												
Monitoring X8=	0.25	Weight X_8-X_2	0.666672												
TrustX9=	0	Weight X_9-X_2	0.87874												
Coordination X10=	0	Weight X_{10}-X_2	1.603491												

Time control in planningX1=	0	Weight X_1-X_3	1.033		-0.71957		Function 3		Weight 3	4.502743					
Work quality	0.25	Weight X_2-X_3	1.020566												
Cooperation X3=	0.25	Weight X_3-X_3	1.494728												
Experience X4=	0.75	Weight X_4-X_3	2.726447												
Resources X5=	0.75	Weight X_5-X_3	0.381081												
Honesty X6=	0.25	Weight X_6-X_3	0.381041												
Commitment X7=	0.25	Weight X_7-X_3	-0.117013												
Monitoring X8=	0.25	Weight X_8-X_3	1.321493												
TrustX9=	0	Weight X_9-X_3	0.182325												
Coordination X10=	0	Weight X_{10}-X_3	3.886754												
			Sum=												
Time control in planningX1=	0	Weight X_1-X_4	-1.170		-2.17862		Function 4		Weight 4	-4.636837					
Work quality	0.25	Weight X_2-X_4	-0.540576												
Cooperation X3=	0.25	Weight X_3-X_4	0.092175												
Experience X4=	0.75	Weight X_4-X_4	4.48782												
Resources X5=	0.75	Weight X_5-X_4	0.614568												
Honesty X6=	0.25	Weight X_6-X_4	2.954956												
Commitment X7=	0.25	Weight X_7-X_4	-1.935237												
Monitoring X8=	0.25	Weight X_8-X_4	0.556377												
TrustX9=	0	Weight X_9-X_4	0.789411												
Coordination X10=	0	Weight X_{10}-X_4	3.549697												
			Sum=												

Time control in planningX1=	0	Weight X_1-X_5	2.004		-3.5674		Function 5		Weight 5	-4.858029					
Work quality	0.25	Weight X_2-X_5	3.067328												
Cooperation X3=	0.25	Weight X_3-X_5	0.345346												
Experience X4=	0.75	Weight X_4-X_5	1.626315												
Resources X5=	0.75	Weight X_5-X_5	-0.560176												
Honesty X6=	0.25	Weight X_6-X_5	-0.877127												
Commitment X7=	0.25	Weight X_7-X_5	1.609565												
Monitoring X8=	0.25	Weight X_8-X_5	1.976961												
TrustX9=	0	Weight X_9-X_5	-0.918359												
Coordination X10=	0	Weight X_{10}-X_5	1.866578												
			Sum=												
Time control in planningX1=	0	Weight X_1-X_6	1.019		-0.05198		Function 6		Weight 6	5.996159					
Work quality	0.25	Weight X_2-X_6	2.263629												
Cooperation X3=	0.25	Weight X_3-X_6	1.234435												
Experience X4=	0.75	Weight X_4-X_6	4.35048												
Resources X5=	0.75	Weight X_5-X_6	0.877154												
Honesty X6=	0.25	Weight X_6-X_6	-0.917343												
Commitment X7=	0.25	Weight X_7-X_6	-0.705919												
Monitoring X8=	0.25	Weight X_8-X_6	2.396518												
TrustX9=	0	Weight X_9-X_6	-1.246078												
Coordination X10=	0	Weight X_{10}-X_6	6.492847												
			Sum=												

Time control in planningX1=	0	Weight X_1-X_7	0.955		-0.44359		Function 7		Weight 7	-1.125477					
Work quality	0.25	Weight X_2-X_7	0.361132												
Cooperation X3=	0.25	Weight X_3-X_7	0.568401												
Experience X4=	0.75	Weight X_4-X_7	1.115291												
Resources X5=	0.75	Weight X_5-X_7	0.758853												
Honesty X6=	0.25	Weight X_6-X_7	-0.0608												
Commitment X7=	0.25	Weight X_7-X_7	0.408875												
Monitoring X8=	0.25	Weight X_8-X_7	-0.112147												
TrustX9=	0	Weight X_9-X_7	-0.700273												
Coordination X10=	0	Weight X_{10}-X_7	1.63342												
			Sum=												
Time control in planningX1=	0	Weight X_1-X_8	-4.994		15.58937		Function 8		Weight 8	-6.211227					
Work quality	0.25	Weight X_2-X_8	-4.755463												
Cooperation X3=	0.25	Weight X_3-X_8	-1.867366												
Experience X4=	0.75	Weight X_4-X_8	-10.019251												
Resources X5=	0.75	Weight X_5-X_8	-0.089295												
Honesty X6=	0.25	Weight X_6-X_8	-2.541456												
Commitment X7=	0.25	Weight X_7-X_8	1.48324												
Monitoring X8=	0.25	Weight X_8-X_8	-0.582971												
TrustX9=	0	Weight X_9-X_8	4.266891												
Coordination X10=	0	Weight X_{10}-X_8	-12.012364												
			Sum=												

Time control in planningX1=	0	Weight X_1-X_9	-0.146		-2.5301		Function 9		Weight 9	-4.419002					
Work quality	0.25	Weight X_2-X_9	-1.775366												
Cooperation X3=	0.25	Weight X_3-X_9	0.123709												
Experience X4=	0.75	Weight X_4-X_9	-2.465807												
Resources X5=	0.75	Weight X_5-X_9	-0.743272												
Honesty X6=	0.25	Weight X_6-X_9	5.869491												
Commitment X7=	0.25	Weight X_7-X_9	1.438115												
Monitoring X8=	0.25	Weight X_8-X_9	-1.984095												
TrustX9=	0	Weight X_9-X_9	2.434691												
Coordination X10=	0	Weight X_{10}-X_9	-4.43262												
			Sum=												
Time control in planningX1=	0	Weight X_1-X_{10}	1.122		2.30944		Function 8		Weight 8	-5.750553					
Work quality	0.25	Weight X_2-X_{10}	-0.13044												
Cooperation X3=	0.25	Weight X_3-X_{10}	-2.41569												
Experience X4=	0.75	Weight X_4-X_{10}	-5.103647												
Resources X5=	0.75	Weight X_5-X_{10}	1.888008												
Honesty X6=	0.25	Weight X_6-X_{10}	-2.175401												
Commitment X7=	0.25	Weight X_7-X_{10}	-2.730264												
Monitoring X8=	0.25	Weight X_8-X_{10}	0.788342												
TrustX9=	0	Weight X_9-X_{10}	-1.964855												
Coordination X10=	0	Weight X_{10}-X_{10}	-2.345144												
			Sum=												

BIOGRAPHY

Nov Pisal was born in October 27, 1987 in Phnom Penh, Cambodia. He finished high school at Sorn Thor Mok high school in 2005 and then he has continued Bachelor Degree in two Universities. One university, he graduated Bachelor Degree of Civil Engineering at Norton University in 2010 and another university, he graduated Bachelor Degree of Professional Communication (PC) in English at Institute of Foreign Languages (IFL) in 2010. Since studying at the universities, Pisal has took some short training courses such as Management and Leadership Course at Youth Mentality Development Program (YMDP) in 2007 and trained in soil mechanic at Building and Public Works Laboratory (LTBP) in 2008. Moreover, during his working at Sithen Construction Company as a site engineer for half of a year, he was awarded by neighboring country scholarship to continue his Master's study in field of construction engineering and management, Department of Civil Engineering, Faculty of Engineering, Chulalongkorn University, Thailand in 2011. The future plan after this studying, he would like to improve Cambodia construction management which each party like main contractor and subcontractor could work efficiency in construction project and be a good partner for a long run too.